SUGGESTED GUIDE FOR WEED CONTROL 1967

Agriculture Handbook No. 332

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

USDA POLICY ON PESTICIDES

One of the most important responsibilities of the Department of Agriculture is to develop and facilitate the use of methods and materials for the control of pests. The Department's research, education, and regulatory programs are expected to make continuing progress in the never-ending struggle to protect man, his food and fiber supplies, and his forests from the ravages of pests. Such protection is essential if the American people are to continue to enjoy their present high standard of living, and if this abundance of quality food and relative freedom from the hazards of pests are to be enjoyed by all mankind.

In protecting man, animals, plants, farm and forest products, communities, and households against depredation of pests, the Department has vital concern for (1) the health and well-being of people who use pesticides and those who use products protected by their use; and (2) for the protection of fish, wildlife, soil, air, and water from pesticide pollution.

In keeping with this concern, it is the policy of the Department of Agriculture to practice and to encourage the use of those means of effective pest control which provide the least potential hazard to man and animals. When residual pesticides must be used to control or eliminate pests, they shall be used in minimal effective amounts, applied precisely to the infested area and at minimal effective frequency. Biological, ecological, or cultural methods or nonpersistent and low-toxicity pesticides will be used whenever such means are feasible and will safely and effectively control or eliminate target pests.

In carrying out these objectives, the Department will cooperate in the fullest with the other agencies and departments of government, and will seek to develop broad areas of collaboration in establishing the criteria to guide the use and development of pest-control materials.

Further, the USDA will urge that all users of pesticides exercise constant vigilance to assure the protection of human health by avoiding unnecessary exposure of crops, livestock, fish, and wildlife.

The Department commends this policy to States and local authorities as a guide in their respective jurisdictions.

Orville L. Freeman

Secretary's Memorandum 1565,
issued December 23, 1964.

SUGGESTED GUIDE FOR WEED CONTROL 1967

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PREFACE

Research in weed control is conducted by the U.S. Department of Agriculture and certain other Federal agencies, State agricultural experiment stations, and industrial organizations. Many of the most effective weed-control practices resulting from this research are summarized in this handbook as a guide for farm advisory personnel in the various States.

Correct identification of a weed species is helpful in selecting and using weed-control suggestions. Providing information on weed identification is outside the scope of this handbook. Descriptive and illustrative guides to the identification of weeds have been published and are available from the State agricultural experiment stations in nearly all States.

The successful and safe use of weed-control methods depends on strict adherence to the appropriate treatment procedures. These details may vary between localities because of differences in soil, climate, crop varieties, cultural methods, and weed species. The weed-control methods described here may be considered as a general guide. Specific information may be obtained from State agricultural experiment station and extension service personnel and other local agricultural authorities.

All suggested uses of herbicides were registered prior to January 1, 1967, under the provisions of the Federal Insecticide, Fungicide, and Rodenticide Act. The registration of herbicides changes frequently as new information on uses and residues becomes available. New uses are frequently added to labels and old uses are sometimes cancelled. In order to use herbicides effectively and safely, up-to-date labels and instructions must be followed.

Because new herbicides and new uses for older ones are being developed constantly, it is important to obtain the latest information from the U.S. Department of Agriculture, State agricultural experiment stations and extension services, and manufacturers of specific products.

If herbicides are handled or applied improperly, or if unused portions are not disposed of safely, they may be injurious to humans, domestic animals, desirable plants, and fish or other wildlife, and may contaminate water supplies. Use herbicides only when needed and handle them with care. Follow the directions and heed all precautions on the container label.

CONTENTS

LIST OF TABLES

SUGGESTED GUIDE FOR WEED CONTROL 1967

Prepared by CROPS RESEARCH DIVISION, *Agricultural Research Service* [1]

BASIC PRINCIPLES AND METHODS OF WEED CONTROL

Weed control is an integral part of the overall management program for crop production, grazing land, lawns, gardens, irrigation and drainage systems, and other crop and noncrop areas. For greatest effectiveness and economy, weed-control methods must be based on the basic principles of plant ecology and physiology, soil fertility, soil-water relations, and plant growth. Effective weed-control methods and materials include crop rotation, grazing, cultivation, mowing, flame, and the use of herbicides, surfactants, and biological agents. The effects of chemicals and biological agents on human beings, livestock, fish, and wildlife must be considered. All these principles and phases of vegetation control are considered in the preparation of this handbook.

GROWTH CYCLES AND PROPAGATION OF WEEDS

A weed is any plant that grows where it is not desired. Weeds, like other plants, are classified by growth cycle as annuals, biennials, and perennials. Algae and some other aquatic plants have a shorter life cycle. Annuals mature in one season and are nearly always propagated by seeds. Examples are pigweed, crabgrass, and common ragweed. A variation of the true annual is the winter annual that germinates in the fall and matures seed the next season. Examples are cheat, pennycress, shepherds-purse, and wild barley. Most annuals are prolific seed producers, and seeds of many remain viable in the soil for many years. Even though most annual weeds are easily killed by mechanical or chemical means, the enormous accumulation of seeds in the soil makes their control difficult.

Biennials require two growing seasons to complete the reproduction cycle and are propagated by seeds only. Common examples are burdock, wild carrot, and mullein. They often can be controlled by cultivation or timely mowing.

Perennials live more than 2 years. Many have several methods of reproduction in addition to seeds. These include bulbs, tubers, corms, lateral roots, rhizomes, and stolons. Most of these organs have buds and store food for overwintering and reproduction. Several provide means of vegetative spread. Many perennial weeds are difficult to control and require intensive and persistent effort. Common examples are Canada thistle, cattail, field bindweed, johnsongrass, and nutsedge. Unlike most annual plants, killing the top growth of a perennial once does not usually prevent it from surviving and producing a new top growth from food in the storage or reproductive organs. To prevent this vegetative reproduction, the supply of stored food must be greatly depleted by repeatedly destroying the top growth, roots, and reproductive organs or greatly altering the physiological processes with herbicides.

PLANT COMPETITION

Competition of desirable crops or plants with undesirable plants frequently provides effective and economical weed control. Careful selection of adapted and desirable species or varieties and maintenance of optimum soil fertility and cultural conditions for their maximum growth are important. Mowing, pasturing with livestock, spraying with selective herbicides, liming, fertilizing, or other means of altering the environment to favor the desired species over weeds may be necessary for the most satisfactory results. Usually the desired competitive crop must be planted.

Occasionally a mixture of desirable and undesirable vegetation already established on native ranges, ditchbanks, fence rows, or other noncultivated areas can be favorably altered by repeated applications of selective herbicides. Under such treatment the resistant desirable species become dominant and the susceptible undesirable species are gradually eliminated. The elimination of deep-rooted perennial weeds or other aggressive species often necessitates the use of drastic and frequently expensive chemical or mechanical

[1] The technical information in this publication was compiled and reviewed by F. L. Timmons, L. L. Danielson, J. T. Holstun, Jr., D. L. Klingman, H. L. Morton, W. C. Shaw, W. B. Ennis, Jr., and associated personnel of the Crops Protection Research Branch, Crops Research Division. Helpful suggestions were made by reviewers in the Pesticides Regulation Division and the Federal Extension Service of the U.S. Department of Agriculture.

methods. Thereafter, desirable species can be planted and suitable conditions provided for their effective competition with surviving or reinvading weeds.

HAND AND MECHANICAL METHODS

Numerous effective herbicides and improved methods of application have replaced many less effective hand and mechanical methods of weed control. However, hand and mechanical methods are still necessary or advantageous in many situations. Hand weeding of flowerbeds, small vegetable gardens, and other small-area plantings sensitive to herbicides is often the safest and most satisfactory method. Improvements in tools used for cultivating, mowing, burning, and ditch cleaning and in other machinery needed for vegetation control have coincided with improvements in chemical methods. Judicious use of such equipment in seedbed preparation, cultivation of crops, and mowing in noncultivated areas may cause weed seeds to germinate, destroys successive crops of weeds, and prevents weeds from producing mature seeds. Even the most effective chemical methods frequently must be supplemented by hand or mechanical weeding to remove surviving weeds and to prevent future spread by seed or other plant parts.

FLAME

Flame is used effectively for weed control in some situations. Several types of burners are available. Those used for nonselective control of weeds as on ditchbanks produce a relatively large, varying flame pattern. Those used for selective control of weeds as in cotton and corn produce a relatively small constant flame pattern that can be confined to definite areas in or between the rows. Some specialized burners are designed to trap and retain the generated heat momentarily in the weed area.

Fuels most commonly used are propane, butane, and mixtures of these two petroleum gases. Either a vaporizer or self-energizing design of the burner usually increases the efficiency of the combustion. Fuel oil, kerosene, and other petroleum liquids are also used.

HERBICIDES

Since 1950 thousands of chemicals have been evaluated for effectiveness as herbicides and more than 100 of these have been recommended for controlling one or more weeds. The effectiveness of herbicides on susceptible species is affected by stage of growth, soil organic matter and pH, fertility, and texture; rainfall and irrigation; water pH and chemical content; temperature of air and water; light intensity; and other soil, water, and climatic factors. Crop and weed plants vary widely in their responses to different herbicides.

Some herbicides may kill fish, some may injure livestock and wildlife, and a few may affect humans. However, safe and effective herbicides are available for controlling many weeds growing in various environments, including cropland, rangeland, gardens, lawns, ditchbanks and other noncrop areas, and in irrigation, drainage, navigable, and potable waters. Because of the many factors and principles involved and the dynamic nature of research on herbicides, information about chemical weed control is rapidly increasing and new recommendations are continually replacing old ones.

Suggestions for application rates of herbicides are based on the active ingredient or acid equivalent contained, and not on the total weight of the product.

BIOLOGICAL AGENTS

Only limited attention has been given to controlling undesirable plants by using insects, plant disease organisms, and other natural enemies. Research is now underway to discover and develop effective and safe biological agents to control such weedy species as alligatorweed, waterhyacinth, submersed aquatic weeds, Scotch-broom, halogeton, cactus, tansy-ragwort, puncturevine, gorse, and St. Johnswort. One noticeably successful biological control agent in the Northwestern States is the beetle *Chrysolina* spp. This insect is native to Europe but was introduced from Australia to the United States to control St. Johnswort. Research on biological control of weeds is being increased and probably will be emphasized considerably in the future.

IMPACT OF WEED CONTROL ON CROP PRODUCTION

Weed-control principles, methods, and practices have an important impact on all phases of crop production. New chemical, cultural, mechanical, biological, and combination methods of weed control affect crop choice; the variety to use; seedbed preparation; method of seeding; seeding rates; row spacing; plant spacing in the row; plant populations; fertilizer practices including type, time of application, and placement; cultivation; irrigation practices; harvesting; seed-cleaning operations; erosion control; fallow practices for weed control; disease- and insect-control practices; pasture renovation; pasture and range management; clearing new lands for crops or pasture; forest management; the utilization of farm water resources for irrigation and recreation; and the maintenance of drainage ditches, ditchbanks, irrigation canals, and farm roadsides. Equally important are the significant effects crop management and production practices have on the choice and effectiveness of weed-control methods.

PRECAUTIONS FOR SAFE USE OF HERBICIDES

All chemicals described in this handbook, especially when used on raw agricultural crops as defined under Public Law 518, should be applied in accordance with the directions on the manufacturer's label, as registered under the Federal Insecticide, Fungicide, and Rodenticide Act. Specifications with respect to crop, amount of chemical, and time of application should be strictly observed.

Many herbicides are irritating or potentially dangerous, but they are not hazardous if used properly and if recommended precautions are heeded. Most herbicides have a low acute oral toxicity, but a few are highly toxic to humans, livestock, and wildlife, and some are toxic to fish. The relative degree of acute toxicity to warmblooded animals is given for most herbicides listed for weed control in table 1. In the following data the LD_{50} ratings (lethal dosage that kills 50 percent of the experimental animals) are classified as to acute oral toxicity:

Class	*Acute oral toxicity LD_{50}, mg. per kg.*	*Lethal dosage for 150-pound man*
Highly toxic	50 and below	Few drops to 1 teaspoon.
Moderately toxic	50–500	1 teaspoon to 1 ounce.
Mildly toxic	500–5,000	1 ounce to 1 pint or 1 pound.
Nontoxic	Above 5,000	1 pint to over 1 quart.

All LD_{50} values in table 1 are based on a single dose of material orally administered to animals, followed by observation of the treated animals for a definite period. However, these findings do not indicate the possible hazards that may arise from skin contact or inhalation of the substances. Likewise, these data do not accurately predict the toxicity of a formulation that may differ according to the solvent or diluent used.

The following general precautions should be observed in applying herbicides:

For humans—

1. Read the label on each container before using the contents. Follow instructions; heed all cautions and warnings. Store in original labeled containers.
2. Avoid inhaling vapors, dusts, or spray mists. Use a mask when specified on the container label.
3. Avoid repeated or prolonged contact of herbicides by the skin. Some individuals are hypersensitive to certain chemicals and must be especially careful to avoid allergic reactions.
4. Wash hands and face thoroughly with soap and water after each use of an herbicide. Do not eat, drink, or smoke until you have washed your hands and face. Wear synthetic rubber gloves and wear goggles where label instructions specify.
5. Avoid spilling herbicide concentrate on your skin and keep it out of your eyes, nose, and mouth. If you spill any on your skin, wash it off immediately with soap and water. If you spill it on your clothing, launder the clothing before wearing it again.
6. Handle flammable chemicals with care to avoid ignition from friction, sparks, or contact with combustible materials.
7. Avoid contaminating potable water supplies with herbicides.
8. Dispose of empty containers and surplus herbicide solutions by burial at least 18 inches deep in a level, isolated area where they will not contaminate water supplies.

For livestock—

1. Prevent livestock from grazing in areas where herbicide sprays may have increased the palatibility of poisonous plants or increased the amounts of nitrate or other chemicals of certain plants to a toxic level.
2. Prevent livestock from drinking water that has been treated with an herbicide during the time after treatment prescribed on the label.

For wildlife and fish—

1. Avoid overdoses and spillage of herbicides in or near streams, ponds, and lakes or in areas frequented by wildlife.
2. A few herbicides are toxic to fish and wildlife. Do not apply herbicides that do not have an approved label for such use to canals, lakes, ponds, or streams.
3. Consult Federal or State game and fish departments for advice if a proposed herbicide application might endanger wildlife or fish.

For desirable plants—

1. Avoid spraying when and where drift of fine spray or volatilized fumes is likely to contact nearby sensitive crop or ornamental plants. Use spot treatment control of weeds in lawns if they are not too numerous.
2. Reduce drift hazards by using low drift formulations, amine or low-volatile esters of phenoxy herbicides, low spraying pressures, and large volumes of coarse sprays and by spraying when wind is low in velocity and blowing away from nearby sensitive plants. Do not spray when temperatures exceed 90° F.
3. Avoid applying a soil sterilant herbicide over the root zone of a tree, shrub, or other desirable plant where leaching the chemical into the soil may result in death or injury of the plant.
4. Avoid applying herbicides or cleaning out application equipment on sloping bare ground,

pavement, or other areas where the herbicide may be carried by surface runoff to valuable plants downslope.

5. Avoid using herbicide sprayers for other purposes on crop or ornamental plants that are sensitive to herbicides until the equipment is thoroughly cleaned. Clean the equipment with warm water and detergent, followed by 12 to 24 hours of soaking with a solution of 1 part of household ammonia in 100 parts of water, or rinse the sprayer for 2 minutes with a 0.25 percent suspension of activated charcoal (one-fourth pound of activated charcoal in 10 gallons of water containing household detergent), followed by a rinse of clean water.

No matter how well it has been cleaned, a sprayer that previously has been used for applying phenoxy herbicides should not be used to spray cotton, tomatoes, grapes, and many ornamentals highly sensitive to 2,4-D and other phenoxy or similar growth-regulator herbicides.

6. Do not store herbicides near seeds, bulbs, fertilizers, insecticides, fungicides, or other farm chemicals and supplies.

PROPERTIES OF HERBICIDES

Descriptions of the chemical, physical, and biological properties of herbicides mentioned in this handbook are given in table 1. The herbicides are designated by their common and chemical names. Their acute oral toxicity to warmblooded animals is indicated by the LD_{50} rating, or lethal dosage that kills 50 percent of the experimental animals, and is given in terms of milligrams of herbicide per kilogram of body weight of rats, except where other animals are specifically named. The basic chemical reference material used to calculate application rates is shown for each herbicide. The kinds of commercial formulations are given as a convenience in determining the kinds of application equipment needed in using the herbicides. Brief reference is made to certain important weeds controlled by each herbicide, some of the practical uses in crops, specialized methods of application, and specific toxic or persistence characteristics. Specialized, accepted uses of the herbicides in various crops and in noncrop weed situations are described in detail under the appropriate headings on pages 18–59.

GENERAL CONSIDERATIONS IN USE OF HERBICIDES

PURCHASING HERBICIDES

Formulations

Most herbicides are usually purchased as a commercial formulation that contains the herbicide and can be (1) dissolved, emulsified, or suspended in a liquid carrier, (2) distributed dry by a spreader or by hand, or (3) injected into soil for vaporization and fumigation. Often an emulsifier, spreader, sticker, or other surfactant is added to facilitate dilution and adhering capacity or to increase wetting of plants. Many formulations contain inactive fillers that serve as diluents only. For example, there may be 2, 3, 4, or 6 pounds of active herbicide in a gallon of liquid formulation weighing as much as 10 pounds or 4, 10, 20, 50, or 80 percent of active chemical in a granule, pellet, or powder formulation.

Active Chemical Content

Although the carrier components contained in herbicides, such as emulsifiers, solvents, and other adjuvants, often affect problems encountered in mixing and spraying and on weed-control results, the economic value of an herbicide is largely dependent on the relative amount of phytotoxic chemical that is contained per gallon or pound. One of the best guides to use in purchasing a commercial herbicide is the price per pound of active chemical. The containers for all commercial herbicides have labels that state the amount of active chemicals contained in the particular product. This is expressed in percentage of active ingredient, acid equivalent, or phenol equivalent for solids and in pounds per gallon for liquids. Where a formulation contains a mixture of herbicides, the amount of each herbicide is given on the label and should be considered in determining the relative value of the mixture.

Acid equivalent is commonly used to express the active chemical in dalapon and the phenoxy, benzoic, and picolinic acid herbicides, such as 2,4-D, silvex, 2,3,6-TBA, and picloram. Phenol equivalent is used to express the active chemical in dinitrophenol and pentachlorophenol derivatives. For most other compounds the active chemical content is expressed as active ingredient.

Usually the concentrated formulations are more economical to use than diluted concentrations when the herbicide is applied in a spray. For example, 2,4-D formulations that contain 4 pounds of acid equivalent per gallon nearly always cost less per pound of 2,4-D than formulations containing only 1 or 2 pounds of 2,4-D acid equivalent per gallon. On the other hand, herbicides to be broadcast dry in granules or pellets may require diluted concentrations as low as 4, 10, or 20 percent to permit precise and uniform application.

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TABLE 1.—*Chemical, physical, and biological properties of herbicides*

Common name	Chemical name	Acute oral toxicity (LD_{50})	Basic chemical used to calculate application rate	Commercial formulation [2]	Remarks
		Mg. per kg.[1]			
Acrolein	acrylaldehyde	46	100 percent acrolein	WML	Controls submerged aquatic weeds and algae; highly volatile, flammable vapor; very irritating to eyes and respiratory passages; toxic to mammals and aquatic life; must be applied from special containers under nitrogen gas pressure.
Allyl alcohol		7.1 (rabbits)	100 percent allyl alcohol.	WML	For seedbeds, coldframes, soils for golf greens; liquid and vapors highly toxic.
Ametryne	2-ethylamino-4-isopropylamino-6-methylmercapto-*s*-triazine.	1,110	100 percent ametryne.	EC, WP	Controls most annual broadleaved weeds and grasses when used as preemergence treatment; also effective as postemergence herbicide and has considerable activity through foliage contact.
Amiben	3-amino-2,5-dichlorobenzoic acid.	3,500	100 percent amiben	G or WSC	Controls germinating barnyardgrass, crabgrass, curly dock, lambsquarters, pigweed, ragweed, smartweed.
Amitrole	3-amino-1,2,4-triazole	5,000 (mice)	100 percent amitrole	WSP	Controls bermudagrass, Canada thistle, cattails, hoarycress, horsetail rush, leafy spurge, poison-ivy, poison-oak, prickly-ash, quackgrass, Russian knapweed, sedges, tules, white ash; apply in spray to foliage in spring; re-treat as needed.
Amitrole-T	3-amino-1,2,4-triazole plus ammonium thiocyanate.		100 percent basic chemical.	WML	Controls quackgrass, reed canarygrass, water-hyacinth; formulation more effective than amitrole alone.
AMS	ammonium sulfamate	3,900	100 percent AMS	WML, WSP	Controls broadleaved weeds and woody plants adjacent to sensitive crop plants; controls weeds after emergence; prevents stumps from sprouting when applied to cut surface; crystals or concentrated solution will kill large trees by filling ax chips made around base of tree.
Aspirin	acetylsalicylic acid	1,240	100 percent aspirin	WSS	Aspirin is medicinal product; included here only so reader may use LD_{50} value of this material for comparative purposes.
Atrazine	2-chloro-4-ethylamino-6-isopropylamino-*s*-triazine.	3,080	100 percent atrazine	WP	Controls germinating weed grasses and broadleaved weeds; use as preplanting soil-incorporated treatment to control quackgrass; chemical residues in soil may injure susceptible crops year after treatment.
Barban	4-chloro-2-butynyl *m*-chlorocarbanilate.	1,350	100 percent barban	EC	Controls wild oats and wildrye when treated in 2-leaf stage.

See footnotes at end of table.

TABLE 1.—*Chemical, physical, and biological properties of herbicides*—Continued

Common name	Chemical name	Acute oral toxicity (LD_{50})	Basic chemical used to calculate application rate	Commercial formulation [2]	Remarks
		Mg. per kg.[1]			
Benefin	*N*-butyl-*N*-ethyl-*alpha,alpha,alpha*-trifluoro-2,6-dinitro-*p*-toluidine.	10,000	100 percent benefin	EC	Controls germinating broadleaved weeds and weed grasses.
Bensulide	*N*-(2-mercaptoethyl) benzenesulfonamide *S*-(*O,O*-diisopropyl phosphorodithioate).	892	100 percent bensulide.	EC, G	Controls germinating annual broadleaved weeds and weed grasses; herbicide persists in soil for extended period.
Boron compounds (borax, sodium pentaborate, boron trioxide, anhydrous sodium biborate, and mixtures).			100 percent basic chemical.	G or WSP	For soil sterilization to control deep-rooted perennial weeds and growth of all vegetation; addition of 2,4-D, sodium chlorate, benzoic acid, or substituted phenylurea herbicide to compounds will greatly reduce application rate needed for effective control.
Bromacil	5-bromo-3-*sec*-butyl-6-methyluracil.	5,200	100 percent bromacil.	WP	For control of germinating weed grasses and most herbaceous broadleaved weeds; especially effective on daisies and goldenrod; gives long-term control; persists in soils.
Cacodylic acid	dimethylarsinic acid	1,350 (mice)	Acid equivalent	WSS	Quickly kills most vegetation; used mainly to renovate turf.
Calcium arsenate	calcium arsenate	35	100 percent calcium arsenate.	G, WP	Controls bluegrass, chickweed, crabgrass, other weeds; should be applied to dry foliage; will cause burning of wet foliage; excess calcium arsenate may restrict turf growth but can be offset with application of 400–500 lbs. of superphosphate fertilizer per acre; keep children and pets away from treated area until rain or irrigation occurs.
Calcium cyanamide		1,400 (rabbits)	100 percent of product.	G, WSS	Kills germinating weed seed in soil; use in tobacco plant beds; often used as combination herbicide and crop fertilizer.
CDAA	2-chloro-*N,N*-diallylacetamide.	700	100 percent CDAA	EC, G	Controls germinating weed grasses; causes temporary stunting of broadleaved weeds; may cause serious irritation to eyes; wear goggles and rubber gloves during application.
CDEC	2-chloroallyl diethyldithiocarbamate.	3,000–5,000	100 percent CDEC	EC, G	Controls germinating weed grasses; excellent for henbit; moderate control of chickweed; prolonged contact with skin will cause irritation.
Chloro-substituted phenols (PCP and sodium PCP).	pentachlorophenol, sodium pentachlorophenate.	50–500	PCP equivalent	Oil soluble, WS.	Controls germinating weed seed and young growing weeds.

CIPC	isopropyl *N*-(3-chlorophenyl)carbamate.	3,000–5,000	100 percent CIPC	EC, G	Controls germinating weed grasses, carpetweed, chickweed, knotweed, lambsquarters, morning-glory, pigweed, purslane, smartweed; use in combination with other herbicides for multiple weed control.
Copper sulfate (blue vitriol, bluestone).			100 percent copper sulfate.	WSa	Controls algae in ponds, lakes, other aquatic sites; corrosive to metals; at 50 p.p.m. hazardous to warm-blooded animals; below 2.5 p.p.m.w. U.S. Public Health Service considers concentrations harmless in potable water supplies; toxic to fish at 1 p.p.m.w.
Dalapon	2,2-dichloropropionic acid	6,590–8,120	Acid equivalent	WS	Use as spray to control growing annual weeds, bermudagrass, johnsongrass, quackgrass, other perennial weeds, cattails, Phragmites; most effective in crops when applied in combination with tillage and cultural practices.
DCPA	dimethyl 2,3,5,6-tetrachloroterephthalate.	3,160	100 percent DCPA	WP	Controls germinating annual weeds and weed grasses; highly selective on many crop and ornamental plants.
Diallate	*S*-2,3-dichloroallyl *N*,*N*-diisopropylthiolcarbamate.	395	100 percent diallate	EC	Controls germinating wild oats; highly selective herbicide with very little herbicidal activity on any other weed.
Dicamba	2-methoxy-3,6-dichlorobenzoic acid.	3,500	Acid equivalent	WSa	Controls emerged Canada thistle, chickweed, corncockle, dogfennel, field bindweed, red sorrel, Russian knapweed, other deep-rooted perennial weeds.
Dichlobenil	2,6-dichlorobenzonitrile	2,710	100 percent dichlobenil.	G, WS	Controls germinating broadleaved annual weeds, annual weed grasses, brackenfern, nutsedge, wild strawberry, certain submersed aquatic weeds.
Dichlone	2,3-dichloro-1,4-naphthoquinone.	1,500	100 percent dichlone.	WS	Controls algae in lakes and ponds; remains active in water having pH up to 10.
Diphenamid	*N*,*N*-dimethyl-2-2-diphenylacetamide.	1,000	100 percent diphenamid.	WP	Controls many germinating weed grasses and certain broadleaved weeds.
Diquat	6,7-dihydrodipyrido(1,2-*a*:2′,1′-*c*)pyrazidiinium salt.	400–500	Cation equivalent	WS, WSa	Controls certain aquatic weeds; is general contact herbicide for control of many established weeds; desiccant in harvesting certain crops; deactivated on contact with soil.
Diuron	3-(3,4-dichlorophenyl)-1,1-dimethylurea.	3,400–7,500	100 percent diuron	G, WML, WP	Controls perennial grasses and annual broadleaved weeds.
DMPA	*O*-(2,4-dichlorophenyl) *O*-methyl isopropylphosphoramidothioate.	1,000	100 percent DMPA	EC, G	Controls germinating annual grasses, chickweed, henbit, knotweed, nimblewill, speedwell.
DMTT	3,5-dimethyltetrahydro-1,-3,5,2*H*-thiadiazine-2-thione.		100 percent DMTT	WP	Use as soil fumigant to control weeds, soil fungi, nematodes.

See footnotes at end of table.

TABLE 1.—*Chemical, physical, and biological properties of herbicides*—Continued

Common name	Chemical name	Acute oral toxicity (LD_{50})	Basic chemical used to calculate application rate	Commercial formulation [2]	Remarks
		Mg. per kg.[1]			
DNBP	4,6-dinitro-*o*-*sec*-butylphenol.	26–45	DNBP equivalent	EC	Controls many germinating and established broadleaved and weed grasses; imparts yellow coloring to clothes and skin; avoid inhaling or coming in contact with sprays; crop may be injured if extremely high temperatures occur in 2-week period after preemergence spray.
DSMA	disodium methanearsonate	800–2, 800	100 percent DSMA	G, WP, WS	General contact herbicide used as spot treatment to control many weeds in early stages of growth.
EGT	ethylene glycol bis (trichloroacetate).	7, 000	100 percent active chemical.	OS	Nonselective herbicide for general weed control in noncrop areas or spot treatments on cropland.
Endothall	7-oxabicyclo[2.2.1]heptane-2,3-dicarboxylic acid.	35–120	100 percent salt of endothall.	EC, G, WS, WSa.	Controls germinating weeds in certain crops and some submersed aquatic weeds; fish are tolerant to relatively high concentrations of disodium salts, but dimethylalkanolamine salts are toxic at concentrations of 0.5 p.p.m.w.
EPTC	ethyl *N*,*N*-dipropylthiocarbamate.	3, 000–5, 000	100 percent EPTC	EC, G	Controls germinating broadleaved weeds and annual grasses; high rate controls quackgrass; herbicide sometimes incorporated in soil in early spring before planting.
Erbon	2-(2,4,5-trichlorophenoxy)-ethyl-2,2-dichloropropionate.	1, 000–3, 500 (chickens, guinea pigs, rabbits).	100 percent erbon	EC	Controls established morning-glory, perennial rye, bermudagrass in noncrop areas.
Fenac	2,3,6-trichlorophenylacetic acid.	2,500–3,000	Acid equivalent	G, WS, WSa, WSP.	Controls bindweed, puncturevine, Russian-thistle, seedling johnsongrass, other seedling annual broadleaved weeds, weed grasses; persists in soil for long periods when used as soil sterilant.
Fenuron	3-phenyl-1,1-dimethylurea	3,400–7,500	100 percent fenuron	G, WP	Controls many species of brush; nonselective for control on noncultivated land.
FW–925	2,4-dichlorophenyl-4-nitrophenyl ether.	2,630	100 percent basic chemical.	EC	Controls many germinating annual broadleaved weeds and weed grasses.
IPC	isopropyl *N*-phenylcarbamate.	3,000–5,000	100 percent IPC	EC, G, WP	Controls germinating annual grasses, chickweed, some broadleaved weeds.
Isocil	5-bromo-3-isopropyl-6-methyluracil.	3,400	100 percent isocil	WP	Controls growing herbaceous weeds, weed grasses, woody vines, brambles.
KOCN	potassium cyanate	780	100 percent KOCN	WSP	Controls young seedlings of broadleaved weeds and weed grasses.
Linuron	3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea.	1,500	100 percent linuron	WP	Controls broadleaved weeds and weed grasses when used as preemergence or postemergence treatment; incorporated in soil for preemergence

					control; contact for postemergence of seedling weeds in corn.
MCPA	2-methyl-4-chlorophenoxyacetic acid.	375–1,200	Acid equivalent	EC, WS, WSa	Controls growing broadleaved annual weeds, perennial weeds including Canada thistle; salt formulations recommended near susceptible plants such as cotton, flowers, grapes, ornamentals, tomatoes.
MCPB	4-(2-methyl-4-chlorophenoxy)butyric acid.	375–1,200	do		Do.
Methyl bromide			100 percent methyl bromide.	Compressed gas.	Soil fumigant; controls many weeds, weed seed, rootstocks; apply under gasproof cover after thorough tillage; *methyl bromide is very dangerous to man and warmblooded animals;* absorbed through skin as well as by inhalation.
MH	1,2-dihydropyridazine-3,6-dione (maleic hydrazide).	5,800	100 percent MH	WP, WSa	Controls growth of quackgrass, annual and perennial grasses.
Molinate	*S*-ethyl hexahydro-1 *H*-azepine-1-carbothioate.	680	100 percent molinate	EC or G	Controls many germinating annual broadleaved weeds and weed grasses including wild oats.
Monuron	3-(*p*-chlorophenyl)-1,1-dimethylurea.	3,400–7,500	100 percent monuron	G, WML, WP	Controls many germinating broadleaved weeds and weed grasses; use in certain row crops and as soil sterilant in noncrop areas.
MPMT	2,4-bis(3-methoxypropylamino)-6-methylthio-*s*-triazine.		100 percent MPMT	EC	Controls lambsquarters in safflower; apply when weeds are small.
MSMA	monosodium acid methanearsonate.	700	100 percent MSMA	EC, WSa	Always use with surfactant since thorough coverage is extremely important; very useful for postemergence control of young crabgrass in turf and for control of dallisgrass.
Neburon	1-butyl-3-(3,4-dichlorophenyl)-1-methylurea.	3,400–7,500	100 percent neburon	WP	Controls many germinating broadleaved weeds and weed grasses.
Nitrogen solutions	ammonium nitrate, sodium nitrate.		100 percent nitrogen.	WS	Controls young growing weeds in emerged corn.
Norea	3-(hexahydro-4,7-methanoindan-5-yl)-1,1-dimethylurea.	2,000	100 percent norea	WP	Controls germinating broadleaved weeds and weed grasses.
NPA	*N*-1-naphthylphthalamic acid.	8,200	Acid equivalent	EC, G, WP	Do.
Oils, aromatic	aromatic solvent, naphtha, solvent naphtha, petroleum naphtha, Stoddard solvent.	2,000	100 percent oil	Oil	Controls young broadleaved weeds and weed grasses including johnsongrass; also submersed aquatic weeds in irrigation canals and drains; toxic to fish.
Paraquat	1,1′-dimethyl-4,4′-bipyridinium salt.	157	Cation equivalent	WML, WS	Use as general contact weedkiller or directed sprays on young weeds.
PBA	polychlorobenzoic acid		Acid equivalent	WML	Controls bindweed, quackgrass, wild garlic, other broadleaved weeds, some species of brush.

See footnotes at end of table.

TABLE 1.—*Chemical, physical, and biological properties of herbicides*—Continued

Common name	Chemical name	Acute oral toxicity (LD_{50})	Basic chemical used to calculate application rate	Commercial formulation [2]	Remarks
		Mg. per kg.[1]			
PCP	pentachlorophenol	78–210	100 percent PCP	EC, flakes, pellets, WP.	Controls bermudagrass, crabgrass, foxtails, johnsongrass, lambsquarters, pigweed, many other seedling grasses and broadleaved weeds; irritating to skin, nose, eyes; absorbed through skin.
Pebulate	*S*-propyl butylethylthiocarbamate.	1,120	100 percent pebulate.	EC, G	Controls some germinating broadleaved weeds and several weed grasses.
Petroleum naphtha	refined petroleum liquid consisting mostly of paraffins, naphthenes, and aromatics.	High	100 percent petroleum naphtha.	Straight oil	Some petroleum naphthas specially refined for weed control in various crops such as carrots, cotton, soybeans.
Picloram	4-amino-3,5,6-trichloropicolinic acid.	8,200	Acid equivalent	G, WSC	Controls several brush species; use on noncropland including utility rights-of-way and industrial storage areas.
Prometone	2-methoxy-4,6-bis(isopropylamino)-*s*-triazine.	2,980	100 percent prometone.	EC	Controls many germinating broadleaved weeds and weed grasses in noncropland.
Prometryne	2,4-bis(isopropylamino)-6-methylmercapto-*s*-triazine.	3,750	100 percent prometryne.	WP	Do.
Propanil	3′,4′-dichloropropionanilide.	1,400	100 percent propanil	EC	Controls germinating barnyardgrass in rice.
Propazine	2-chloro-4,6-bis(isopropylamino)-*s*-triazine.	5,000	100 percent propazine.	WP	Controls germinating broadleaved weeds and weed grasses.
Pyrazon	5-amino-4-chloro-2-phenyl-3(2*H*)-pyridazinone.	3,600	100 percent pyrazon	WP	Controls germinating broadleaved weeds including lambsquarters.
Sesone	sodium 2,4-dichlorophenoxyethyl sulfate.	730–1,400	Acid equivalent	G, WS, WSa	Controls germinating broadleaved weeds and weed grasses; incorporate in soil for preemergence properties similar to 2,4-D; no phytotoxicity to most established plants; not effective as postemergence spray.
Siduron	1-(2-methylcyclohexyl)-3-phenylurea.	5,000	100 percent siduron	WP	Controls hairy and smooth crabgrass, downy brome in turf and in some crops, foxtails, Kentucky bluegrass, red fescue; several bentgrasses exceptionally tolerant of this material.
Silvex	2-(2,4,5-trichlorophenoxy) propionic acid.	375–1,200	Acid equivalent	EC, G, WSa	Controls young broadleaved weeds including chickweed, curly dock, henbit, lambsquarters.
Simazine	2-chloro-4,6-bis(ethylamino)-*s*-triazine.	5,000	100 percent simazine.	WP	Controls germinating annual broadleaved weeds and weed grasses; controls vegetation on noncropland; long residual action.
SMDC	sodium *N*-methyldithiocarbamate.	3,000–5,000	100 percent SMDC	WML	Soil fumigant; controls many annual weeds; drench onto soil with water

					or mix in surface 6-inch layer of soil, then thoroughly wet; 7–14 days' waiting period required before planting crop.
Sodium arsenite		10–50	100 percent sodium arsenite.	WML, WP, WSC.	Controls submersed aquatic weeds; also use as soil sterilant to control all vegetation; fish not injured at concentrations up to 10 p.p.m.w.; as soil sterilant, soil unproductive for 1–4 years; do not treat areas frequented by livestock with this herbicide.
Sodium chlorate		7,000	100 percent basic chemical.	WSP, WSS	Use as soil sterilant to control all vegetation; leaves soil unproductive 1–4 years depending on precipitation, temperature, soil type; sandy soils of humid areas require higher applications than heavy soils of arid regions; toxicity persists longer in arid regions.
Stoddard solvent	aromatic oils	2,000	100 percent solvent	Oil	Controls young growing annual broadleaved weeds and weed grasses; selective on carrots and related crops.
Surfactants	soaps or synthetic detergents and emulsifiers.				Increase wetting, spreading, and sticking properties of herbicidal sprays; at 0.1 percent or greater may change activity of herbicide on various species.
Table salt	sodium chloride	3,320	100 percent sodium chloride.	WSS	Salt sometimes used as herbicide and commonly used as food seasoning and preservative; included here so reader may use LD_{50} value of this material for comparative purposes.
TBP	2,3,6-trichlorobenzyloxypropanol.	3,160	100 percent active chemical.	WML	Controls deep-rooted perennial broadleaved weeds; use only on noncropland.
TCA	trichloroacetic acid	5,000	Acid equivalent	WS, WSa, WSP.	Controls many germinating and established perennial grasses, broadleaved weeds including johnsongrass, quackgrass; residual toxicity may persist year or longer at high rates.
TCBC	trichlorobenzylchloride		100 percent basic chemical.	EC or G	Controls germinating weed grasses; use only in combination with CDAA in nonirrigated corn.
TCBP	2,3,6-trichlorobenzyloxypropanol.	3,160	100 percent TCBP	EC or G	Use to control many deep-rooted perennial weeds on noncropland.
Triallate	*S*-2,3,3,-trichloroallyl *N*,*N*-diisopropylthiolcarbamate.	1,675–2,165	100 percent triallate	EC	Controls germinating wild oats in various crops.
Trifluralin	*alpha,alpha,alpha*-trifluoro-2,6-dinitro-*N*,*N*-dipropyl-*p*-toluidine.	10,000	100 percent trifluralin.	EC, G	Controls many germinating annual broadleaved weeds and weed grasses.
Urea					For tobacco plant beds.
Vernolate	*S*-propyl dipropylthiocarbamate.	1,780	100 percent vernolate.	EC, G	Broadleaved weeds and weed grasses; preemergence.

See footnotes at end of table.

TABLE 1.—*Chemical, physical, and biological properties of herbicides*—Continued

Common name	Chemical name	Acute oral toxicity (LD_{50})	Basic chemical used to calculate application rate	Commercial formulation [2]	Remarks
		Mg. per kg.[1]			
2,3,6-TBA	2,3,6-trichlorobenzoic acid	1,644	Acid equivalent	EC, G, OS, WML, WSa.	Preemergence and postemergence treatments for control of bindweed, quackgrass, wild garlic, some perennial broadleaved herbaceous weeds; brush treatment may prevent crop production for 1–3 years.
2,4-D	2,4-dichlorophenoxyacetic acid.	375–1,200	do	EC, WML, WS, WSa.	Controls many germinating and established annual broadleaved weeds including lambsquarters, mustard, pigweed; do not use volatile esters near susceptible plants such as cotton, flowers, grapes, ornamentals, tomatoes.
2,4-DB	4-(2,4-dichlorophenoxy)-butyric acid.	375–1,200	do	EC, WML, WS, WSa.	Controls many broadleaved weeds and weed grasses.
2,4-DEP	tris(2,4-dichlorophenoxy-ethyl)phosphite.	850	do	EC, G, WS	Controls many germinating annual broadleaved weeds and weed grasses.
2,4,5-T	2,4,5-trichlorophenoxy-acetic acid.	375–1,200	do	EC, WML, WS, WSa.	Broadleaved weeds; do not use volatile esters near such susceptible plants as cotton, flowers, grapes, ornamentals, tomatoes.

[1] Milligrams of herbicide per kilogram of body weight of rats or other specified animal.

[2] EC, emulsifiable concentrate; G, granular base; oil, oil soluble; OS, soluble in organic solvents; WML, water-miscible liquid; WP, wettable powder; WS, water soluble; WSa, water-soluble salt; WSC, water-soluble concentrate; WSP, water-soluble powder; WSS, water-soluble solid.

Volatility

Another important consideration in purchasing 2,4-D, 2,4,5-T, or other phenoxy herbicides for certain weeds and special situations is the type of herbicide formulation—amine or high-volatile or low-volatile ester. When vapors from the herbicide are likely to injure adjacent crops or plants, an emulsifiable acid, amine salt formulation, or a low-volatile ester should be used. Esters of 2,4-D and 2,4,5-T are classified as high or low volatile according to the degree of vaporization that occurs. In general, methyl, ethyl, isopropyl, butyl, and amyl esters are considered highly volatile. The butoxyethyl, butoxyethoxypropyl, ethoxyethoxypropyl, propyleneglycolbutylether, isooctyl, and other high molecular weight esters are low volatile.

Granular Herbicides

Granular herbicides are formulated for application as dry granules. They are applied with specialized granular pesticide spreading equipment or modified fertilizer spreaders.

Granules are prepared in several ways. Some herbicides are impregnated on granules of clay, vermiculite, or crop residues such as corncobs, by spraying, dipping, or exposing the granules to herbicide vapors. Granules are also prepared by mixing an herbicide with finely ground clay or fertilizer salts, and particles are formed by extrusion or prilling.

One of the most important properties of granular herbicides is physical selectivity or the tendency for particles to bounce off foliage and other plant parts to the soil or to settle to the bottom of ponds, lakes, and other bodies of water. This physical selectivity enhances the chemical selectivity of herbicides used on growing crops or on submersed aquatic weeds. Sprays are often intercepted by crop foliage and their effectiveness in killing germinating weed seeds in the soil is reduced. Granules tend to bounce off and sift down through the foliage to the soil where they are needed.

Granular herbicides are of special interest in the growing of horticultural crops, because their physical selectivity helps to broaden the use of a few effective herbicides to cover a relatively large number of crops. They have therefore been used rather extensively in horticultural crops after clean cultivation. Granules also fill a specific need in transplanted crops, where preemergence herbicide treatments cannot be used. As a matter of convenience, granular herbicides have also been extensively used in preplant soil-incorporated and preemergence treatments of horticultural crops.

Because of the scarcity in many areas of clean water supplies for spraying and the need for extra labor and equipment for water hauling, granular herbicides have been used in several field row crops and in ranges and pastures. Granular forms of some herbicides are also useful in controlling aquatic weeds and weeds in noncropland areas, including ditchbanks, rights-of-way, and industrial sites.

Numerous experiments have shown that granules and sprays of many herbicides are equally effective in controlling germinating weed seed in the soil. Each herbicide, whether used in spray or granular form, requires certain specific conditions of climate, soil, and application technique for best results. Recommendations prepared by weed research specialists in State agricultural experiment stations and by the individual manufacturers of granular herbicides outline these necessary conditions.

CALCULATIONS FOR HERBICIDE APPLICATIONS

Recommended rates of herbicide applications are stated in ounces or pounds per square rod, 1,000 square feet, or acre where the area to be treated can be measured. Where spot spraying of individual or small clumps of plants is necessary or where dense foliage of certain aquatic plants, brush, or trees is to be thoroughly wet, the concentration of spray is usually recommended in pounds of active chemical per 100 gallons of water or oil. To control submersed aquatic weeds, the rate is usually expressed as pounds of active chemical per acre-foot of water or as parts per million by weight of water (p.p.m.w.) in the area treated.

1. To determine the amount of herbicide required for submersed aquatic weeds, use the following data and calculations:

1 acre-foot of water weighs 2,722,500 pounds
1 p.p.m.w.=2.7 pounds of active herbicide in 1 acre-foot of water

(1) Pounds of herbicide = pounds per acre-foot (area in acres × average depth in feet)

Example:
Rate=4 pounds per acre-foot
Area=2.5 acres
Depth=3 feet (average), or 7.5 acre-feet
Then pounds of herbicide=4×7.5=30 pounds required

(2) Pounds of herbicide=p.p.m.w.×acre-feet ×2.7

Example:
Rate=1.5 p.p.m.w.
Volume=2 acres, 3 feet deep (average), or 6 acre-feet
Then pounds of herbicide=1.5×6×2.7=24.3 pounds required

2. To determine the amount of herbicide formulation required per acre, per acre-foot, per 100 gallons, or for a total area, use the following calculations:

(1) For liquid formulations—

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$$\frac{\text{Rate or amount required in pounds}}{\text{Pounds of herbicide per gallon}} = \text{gallons required}$$

Examples:

$$\frac{\text{Rate, 2 pounds per acre}}{\text{4 pounds per gallon}} = 0.5 \text{ gallon}$$

$$\frac{\text{Concentration, 4 pounds per 100 gallons}}{\text{4 pounds per gallon}} = 1 \text{ gallon}$$

$$\frac{\text{Amount required, 24.3 pounds}}{\text{2 pounds per gallon}} = 12.15 \text{ gallons}$$

(2) For granule, dust, or pellet formulations—

Use the same calculations as for liquid formulations, except use pounds of active herbicide per pound of formulation (percent÷100) instead of pounds per gallon.

Examples:

$$\frac{\text{Rate, 2 pounds per acre}}{\text{0.5 pound (50-percent material)}} = 4 \text{ pounds}$$

$$\frac{\text{Concentration, 4 pounds per 100 gallons}}{\text{0.5 pound (50-percent material)}} = 8 \text{ pounds}$$

$$\frac{\text{Amount required, 24.3 pounds}}{\text{0.20 pound (20-percent material)}} = 121.5 \text{ pounds}$$

The amounts of herbicide liquid formulation or dry product to use per acre in various concentrations and for various application rates are given in table 2.

MIXING SPRAY MATERIALS

When the capacity of a spray tank is not known or adequately marked to indicate the number of gallons at different levels of liquid in the tank, the best procedure is to set the sprayer or tank on a level base and gradually fill the tank with known quantities of water. As the water is added, the level of water should be marked in number of gallons or fractions of a gallon on the side of the tank or on a calibration rod or stick held perpendicularly in the center of the tank. Carefully measured markings are very useful in determining the volume in partially filled tanks.

To approximate quickly the capacity of a sprayer tank (all measurements in inches), use the following calculations:

Rectangular tanks: Capacity in gallons=length×width×depth×0.00439

Example:

60×36×30×0.00439=284.47 gallons

Cylindrical tanks: Capacity in gallons=length×square of diameter×0.0034

Example:

60×(36×36)×0.0034=264.38 gallons

Tanks with elliptical cross section: Capacity in gallons=length×square of (short diameter+long diameter)÷2×0.0034

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

Concentration of herbicide	Amount to use per acre to obtain rate of—							
	⅛ pound	¼ pound	½ pound	¾ pound	1 pound	2 pounds	3 pounds	4 pounds
Pounds of active ingredient per gallon:	*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 active ingredient in dry formulations:[1]	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
10	1.25	2.5	5	7	10	20	30	40
20	[2] 10	1.25	2.5	3.5	5	10	15	20
25	[2] 8.75	[2] 17.5	2	3	4.16	8.33	12.5	16.67
30	[2] 7.25	[2] 15	1.67	2.33	3.33	6.67	10	13.33
40	[2] 5	[2] 10	1.25	1.75	2.5	5	7.5	10
50	[2] 4	[2] 8	1	1.4	2	4	6	8
75	[2] 3	[2] 6	[2] 11	1	1.33	2.67	4	5.33
90	[2] 2.25	[2] 4.5	[2] 9	[2] 12.5	1.11	2.25	3.33	4.4

[1] To be added to water or other liquid to be sprayed on 1 acre. [2] Ounces.

Example:

$$60\times\left(\frac{24+36}{2}\right)^2\times 0.0034=183.6 \text{ gallons}$$

Never pour the liquid concentrate or dry herbicide formulation into an empty tank. Either fill the tank half full with water, add the herbicide, agitate, and complete the filling or start filling and add the herbicide gradually as the filling is continued. Agitate or stir until all solid material is dissolved. If a water-soluble powdered or crystalline form of herbicide is to be used with a liquid herbicide, dissolve the solid material in water first and then add and mix the liquid. If oil is to be used in an oil-water or invert emulsion, premix the emulsifier and the oil-soluble herbicide with the oil in a separate container and then add slowly to a partially filled tank of water with constant stirring or agitation. Circulate the mixture until it is uniformly white before using.

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

APPLICATION EQUIPMENT

Results from using herbicides depend largely on how well or how poorly they are applied. This, in turn, depends on the suitability of the equipment for the particular situation and the care and skill with which the operator utilizes the equipment. Suitable equipment has been devised for nearly every situation requiring herbicide applications.

Ground sprayers include (1) hand sprayers of various types suitable for treating small patches, inaccessible areas, fence rows, and spot spraying; (2) boomless power sprayers—nozzle-cluster type—adapted for spraying roadsides and ditchbanks, under utility lines, and along fence rows; (3) power sprayers with tractor or truck-mounted solid or sectional booms suitable for spraying field, pasture, range, and turf areas or for roadside and ditchbank spraying; (4) power row-crop sprayers with various single and multiple nozzle arrangements or other devices for placement spraying; (5) power sprayers equipped with hoses, hand booms, or adjustable spray guns for application of foliage, basal, and stump treatments for brush control, spot treatments, and spraying around structures; and (6) power-driven mist blowers, ranging from hand-carried to truck-mounted equipment, designed for dispersing concentrated sprays in finely atomized form at low volumes per acre and adapted for covering vegetation rapidly with a minimum of solution in inaccessible areas where wind drift can be utilized to advantage and where a hazard to desirable vegetation does not exist.

Aerial sprayers of many types have been developed on fixed-wing aircraft and helicopters. They have several advantages for application of herbicides at low volumes for many large field, rangeland, aquatic, and right-of-way areas when and where spray drift is not a hazard.

Suitable spreaders, ranging from hand-operated to power-driven and tractor-, truck-, or boat-mounted types, have been developed for most situations requiring application of granular or pellet herbicide formulations.

See U.S. Department of Agriculture Handbook 269, Herbicide Manual for Noncropland Weeds, or publications of the State agricultural experiment stations or extension service for more detailed information on herbicide application equipment, including tanks, pumps, booms, nozzles, hoses and fittings, power sources, pressure regulation, droplet size, specialized accessories, and other features of selection, adaptation, and use of application equipment.

For information on aerial equipment, see U.S. Department of Agriculture Handbook 287, Aerial Application of Agricultural Chemicals.

CALIBRATION OF APPLICATION EQUIPMENT

The type and operating condition of application equipment for herbicides are important for efficient chemical weed control. This is especially true of sprayers. Accurate application of the desired rate and uniform distribution of spray solution or dry material are essential requirements for good results. A sprayer must uniformly distribute any quantity from 5 to 100 gallons or more per acre, since various weeds and locations may require a wide range of dilution for proper plant coverage. Sprayer or spreader output should be determined for each particular treatment operation.

A good method of calibration is to make initial adjustments to suit the machine and job requirements, and then make a trial run to determine the actual output of the machine. The herbicide spray mixture then should be prepared accordingly. The calibration should be repeated frequently to check nozzle orifice wear and other factors affecting performance. This is especially important when wettable powders or abrasive sprays are used.

HOW TO DETERMINE PER-ACRE OUTPUT OF SPRAYERS

There are many methods of calibrating a sprayer. One method is given for calibrating each of the following types of ground and aerial sprayers.

Power Sprayers—Boom Type

1. Check to see whether all nozzles are discharging uniformly by spraying water through

them at a uniform pressure and catching the discharge from each nozzle in a separate container, such as a calibrated baby bottle. If the discharge varies widely, replace all worn nozzle tips that give a much larger discharge.

2. Place the sprayer on level ground and fill the spray tank completely with water. Adjust the spraying pressure as you will use it in the field.

3. Drive exactly one-eighth mile (660 feet) 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 spraying begins. Mark the notch in which the throttle is set and keep it there when spraying.

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

5. Calculate the output as follows:

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

Example:

Water used=6 quarts
Spray swath width=20 feet

Then $\frac{6 \times 16.5}{20} = 4.95$ gallons per acre

6. Divide the number of gallons the tank holds by the number of gallons your sprayer applies per acre (approximately 5). 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:

Tank capacity=55 gallons
Output=5 gallons per acre
Desired rate of herbicide=2 pints per acre

Then $\frac{55}{5} \times 2 = 22$ pints, or 2.75 gallons, of herbicide

In some row crops only narrow bands are sprayed, centered over each row, such as in preemergence treatments of cotton or soybeans. When treatments are made in this manner, the rate of treatment is in terms of the area treated and not per acre of actual crop. Thus in cotton with 36-inch row spacing, if a 12-inch band is treated at 1.5 pounds per acre (*based on the area actually treated*), the amount of chemical *per acre of cotton* is $\frac{12}{36} \times 1.5 = 0.5$ pound.

Hand-Type Boom Sprayers

1. Fill knapsack or other hand sprayer to a marked point with water and spray while walking at a steady pace, maintaining a constant tank pressure for a distance of 330 feet. Multiply 330 by the width of swath in feet and divide by 43,560 to obtain the fraction of an acre sprayed.

2. Refill to the marked point in the tank. Change the number of pints or quarts required to gallons by dividing by 8 or 4 and divide by the fraction of an acre sprayed.

Example:

Swath width=4 feet
Water required to refill=5.5 pints, or 0.69 gallon

$\frac{4 \times 330}{43{,}560} = 0.030$ acre sprayed

$\frac{0.69}{0.03} = 23$ gallons (approximately) per acre

3. If too much spray is applied, walk faster or use a lower spraying pressure until the desired volume is achieved. Use the reverse procedure to obtain more volume. For larger volumes, change the orifice size of the nozzle.

4. Determine the amount of herbicide for each tankful by dividing the capacity of the tank in gallons by the number of gallons applied per acre to obtain the fraction of an acre each tankful will spray. Multiply that fraction by the desired rate of application per acre.

Example:

Capacity of tank=3 gallons
Output per acre=23 gallons
Rate per acre=2 pints

Then $\frac{3}{23} = 0.13$ acre per tank

$2 \times 0.13 = 0.26$ pint per tank
1 pint=16 fluid ounces=2 cups=32 tablespoons
Then $0.26 \times 32 = 8.3$ tablespoons, or 0.5 cup, per tank, or 2.8 tablespoons per gallon

Single-Nozzle Hand Sprayers

1. Use the same procedure as for hand-type boom sprayers, except measure off an area 10×43.6 (436 square feet) to obtain the basic data for determining sprayer output and calculate as follows:

$\frac{436}{43{,}560} = 0.01$ acre sprayed

If 2 pints, or 0.25 gallon, is used, then

$\frac{0.25 \text{ gallon}}{0.01 \text{ acre}} = 25$ gallons per acre.

2. Determine the amount of herbicide for each tankful as follows:

Capacity of tank=3 gallons
Output of sprayer=25 gallons per acre
Desired rate per acre=2 pints

Then $\frac{3}{25} = 0.12$ acre per tankful

2 pints $\times 0.12$ acre=0.24 pint per tankful
0.24 pint $\times 32$ tablespoons=7.7 tablespoons, or about 0.5 cup

Aerial Sprayers

1. To determine the rate of flow per acre and per minute, put a measured amount of spray in the tank or fill the tank with water to a definite level. Instruct the pilot to turn on the spray for a timed interval, for example 60 seconds, while flying level and straight at the speed to be used for spraying. Subtract the velocity of headwind from the airspeed to obtain the groundspeed. 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 as follows:

S=groundspeed of plane per hour (assume 80 m.p.h. airspeed−5 m.p.h. headwind=75 m.p.h.)
W=width of effective swath (not total swath) in feet (assume 40 feet)
T=time sprayed in seconds (assume 60 seconds, or $\frac{1}{60}$, or 0.017 hour)
G=gallons used (assume 12.5)

Then $\frac{S\ (75\text{ m.p.h.}) \times 5{,}280\text{ feet per hour} \times W\ (40\text{ feet}) \times T\ (0.017\text{ hour})}{43{,}560\text{ square feet}} = 6.18\text{ acres}$

$$\text{Gallons per minute} = \frac{G}{T} = \frac{12.5}{1} = 12.5$$

$$\text{Gallons per acre} = \frac{12.5}{6.18} = 2.02$$

2. To determine the amount of herbicide required for each filling of the tank, divide the capacity of the tank by gallons per acre applied and multiply by the desired rate per acre.
Example:
If 120 gallons is the capacity of the tank and 2 pints per acre is the desired rate, then
$\frac{120}{2.0}$=60 acres sprayed per tank and
60×2 pints=120 pints (15 gallons) of herbicide required.

HOW TO DETERMINE OUTPUT OF SPREADERS

For acceptable accuracy, calibration of mechanical broadcasters or spreaders for applying dry herbicide formulations must be done with the actual material under the conditions to be encountered in the field. Where calibration pans are available for spreaders to catch the material during trial runs and retain it for weighing, calibration is a simple procedure. Determining and maintaining a desired rate of application by hand or mechanical blowers, broadcasters, and other devices not equipped for catching the material applied require a more complicated and wasteful procedure.

Mechanical Spreaders With Calibration Pans

1. Fill the spreader at least half full of the material to be applied. With the calibration pan in place, push or pull the spreader by hand or power-driven vehicle over terrain typical of that to be treated for a sufficient distance to cover 0.01 acre, or 435.6 square feet. For a spreader 3 feet wide, the distance should be $\frac{435.6}{3}$=145.2 feet. For a spreader 8 feet wide, the distance would be $\frac{435.6}{8}$=54.45 feet.

2. Weigh the material from the calibration pan and multiply by 100 to give the amount applied per acre.

3. Continue this procedure with adjustments of the feed mechanism until the desired rate is achieved.

Hand Broadcasting and Mechanical Devices Not Equipped To Catch Herbicide

Begin with a weighed amount of herbicide formulation. Apply the material to a measured area, preferably 435.6 square feet, or 0.01 acre. Weigh the remaining material and subtract from the initial weight to determine how much was applied. Continue the procedure with appropriate adjustments until the desired rate can be approximated in repeated trials. If the treatment period extends over several hours or days, occasionally check the rate being applied by weighing the amount applied to a measured area and make any necessary corrective adjustments.

EFFECT OF WEATHER CONDITIONS ON HERBICIDE APPLICATIONS

Wind

Winds cause improper distribution of herbicides and greatly increase the hazard of damage from drift to sensitive crops in nearby fields or gardens. Ground applications of herbicides seldom should be made during winds of more than 10 to 15 miles per hour. Applications by airplane should stop when winds become stronger than 6 to 8 miles per hour.

The herbicide 2,4-D and other phenoxy herbicides should never be applied when wind of any velocity is blowing across the area to be sprayed toward nearby valuable sensitive plants.

Humidity

High or moderate humidity increases the effectiveness of most herbicide applications to foliage, because it reduces losses of spray from evaporation and aids absorption of the chemicals by weed foliage. Low humidity, on the other hand, reduces the effectiveness of herbicide sprays by increasing the rate of evaporation. The disadvantages of low humidity can be overcome partially by using oil or oil-water emulsions instead of water as spray diluents.

Temperature

Moderate temperatures, ranging from 70° to 85° F., are favorable for spray applications of most herbicides. Low temperatures during the week before spraying often slow plant growth and retard herbicidal activity. High temperatures increase losses of herbicides that are volatile and increase the possibility of injury to crops from selective herbicides. The carbamates, dinitro compounds, and high-volatile esters of 2,4-D, 2,4,5-T, and other phenoxy compounds volatilize rapidly at temperatures above 80°. At temperatures above 90°, even the low-volatile esters of 2,4-D and other phenoxy compounds become significantly volatile. In general, do not use herbicidal sprays when the temperature is above 90°.

Rainfall

Rainfall immediately after postemergence foliage applications of herbicides may reduce the effectiveness of the amine salt formulations of 2,4-D, water-soluble dinitro compounds, and some other foliage toxicants. Usually effectiveness is not reduced if a moderate rain occurs several hours after postemergence application. The effectiveness of preemergence herbicide treatments may be increased by moderate rain occurring shortly after application. In low-rainfall areas sprinkler irrigation is often used with good results when the water is applied immediately after preemergence herbicide applications. However, if heavy rains occur soon after preemergence treatments, control of weeds may be reduced or crop damage increased.

WEED CONTROL IN FIELD CROPS

The treatments described for weed control in field crops (tables 3–5) are, in many cases, components of a program involving two or more treatments. Because problems and conditions vary widely, it would be impractical to attempt to list the hundreds of different combined practices that would be necessary to cover all localized problems. Local recommendations of State agricultural experiment stations and extension service weed specialists, herbicide labels provided by the manufacturer, and local conditions must be considered in developing programs that include several treatments.

TABLE 3.—*Weed control in field row crops*

[Numbers in parentheses = pounds of active ingredient per acre unless otherwise indicated]

Treatment	Time of application	Weeds controlled	Remarks
		CORN	
Rotary hoe in and between rows.	When corn is young enough to tolerate (after 2 inches tall but before stalks stiffen).	All seedling weeds that are uprooted.	Effective only on shallow-rooted seedling weeds.
Shallow cultivation (2 inches deep or less) between rows.	From emergence to lay-by.	All weeds	Use often enough to control weeds while young; this practice will control but seldom eradicates deep-rooted perennial weeds.
Flame	Before corn is 2 inches tall and after 12 inches tall.	Kills tops of most weeds up to 4 inches tall.	If less than 2 inches tall, corn will be burned to ground but will recover; if 12 inches tall, is tolerant; if 3–10 inches tall, may be severely injured if flamed; do not repeat flaming of 2-inch stage.
Atrazine (4)	In fall preceding year of corn production.	Quackgrass, most small-seeded annual weeds.	Incorporate 2–4 inches deep.
Atrazine (2–4)	After planting but before emergence.	Most small-seeded annual weeds.	Planting corn deeper than 1 inch will increase safety margin; works effectively with less soil moisture than simazine.

TABLE 3.—*Weed control in field row crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		CORN—continued	
CDAA (3.5) plus TCBC (7).	After planting but before emergence.	Most small-seeded annual weeds.	Planting corn deeper than 1 inch will increase safety margin.
Diuron (0.4–0.8)	do	do	May cause serious injury if corn is planted less than 1½ inches deep.
Simazine (2–4)	do	do	Planting corn deeper than 1 inch will increase safety margin; more effective on brachiaria than atrazine.
2,4-D (1–2)	do	do	Planting corn deeper than 1 inch increases safety margin; low-volatile esters are preferred formulations in most States; in some States amine formulations cause injury, particularly in sandy soils; use only amine or low-volatile esters where such susceptible crops as cotton, grapes, tobacco, or tomatoes are nearby; follow precautions to avoid drift of any formulation.
Atrazine (2–4)	Before weeds are more than 1 inch tall.	Most annual weeds less than 1 inch tall.	Apply as foliage spray to corn and weeds until corn is about 6 inches tall; thereafter use in basally directed spray to minimize contact with corn.
DNBP (1–2)	After corn emergence and before 2-leaf stage.	Most small-seeded annual weeds small enough to be covered by spray.	Apply as basally directed spray; limit use to inbred corn.
Linuron (1.5) plus 0.5-percent surfactant.	After corn is 15 inches tall and weeds are less than 4–6 inches tall.	Most annual weeds covered by spray.	Direct spray so as to cover only weeds, soil, and lower 3–6 inches of corn.
2,4-D (0.25–0.5) or dicamba (0.25).	When corn is 4–18 inches tall and weeds are smaller than corn.	Most broadleaved annual weeds; control or stunting of perennial broadleaved weeds.	Apply as foliage spray to corn and weeds until corn is 12 inches tall; thereafter use in basally directed spray to avoid spraying into corn whorl; inbred lines of corn may be injured if treated; low-volatile ester or amine formulations less likely to damage nearby susceptible crops; avoid applications when temperatures are high and corn is growing rapidly; seed set may be reduced if 2,4-D is applied 2 weeks before silking until after silks are dry; dicamba not registered for use after corn is 36 inches tall.
Nitrogen solution (80–120) N plus one of following additives: Atrazine (1), linuron (0.62), diuron (0.6), 2,4-D (0.30); add 0.5-percent surfactant to mixture.	When corn is 20–30 inches tall.	Most annual weeds less than 1 inch tall; some annual weeds up to 3–4 inches tall.	Apply as basally directed spray contacting only weeds, soil, and lower 3–4 inches of stalk; need spray equipment, such as stainless steel or fiberglass, not corroded by nitrogen; agitation required; clean field of weeds when corn is 12 inches tall.
2,4-D (0.5) in drill row and (1.5) between rows.	After last cultivation	Most small-seeded annual weeds from after last cultivation until harvest.	Apply with drop nozzles of 2 volume capacities (small nozzles for drill row, large nozzles for between rows); direct spray to contact only weeds, soil, and lower 3–4 inches of corn.

TABLE 3.—*Weed control in field row crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		COTTON	
Seedbed preparation and fungicide treatment of seed.	Before and at planting	Helpful in controlling all weeds.	Locally proper techniques of seedbed preparation and planting procedures, including use of fungicides, that lead to quick emergence of healthy, uniform stands on uniform seedbeds are essential to optimum results from weed-control practices.
Hand hoeing and spot spraying.	Usually when cotton is 6–18 inches tall where other control measures are used.	All weeds resistant to other control measures.	Apply as needed, normally on spot basis, to remove weeds escaping other control practices; spot removal, by hoeing or chemicals, of resistant weeds may be necessary to prevent their increase over several years.
Cultivate with tools such as sweeps set to cultivate 1–2 inches deep.	From cotton emergence to approximately 18 inches tall.	Generally all weeds growing between rows.	More effective if used before weeds are more than 2 inches tall; cultivation too close to row or too deep may damage cotton; select type of cultivation with regard to other operations that may precede or follow cultivation.
Cross-cultivate with tools such as shield-type sweeps, sweeps, or disk-hillers and sweeps set to cultivate 1–2 inches deep; distance between inside tools determines cotton stand left.	From cotton emergence to approximately 15 inches tall; cultivate first in direction of planting, then at right angles to direction of planting.	Generally all weeds growing between rows and most weeds in rows.	Used in check-planted or drilled cotton in lieu of check planting; cross-cultivation generally restricted to relatively level fields; one of most effective controls for chemical-resistant weeds such as johnsongrass, nutsedge, and perennial vines; effectively used in combination with other control measures.
Flame in rows and between rows.	Flame directed into row at base of cotton plants can be used after cotton is 10–12 inches high until it is so large it is damaged mechanically by equipment; flame between rows can be started any time.	Most small plants enveloped by flame will be topkilled; large grass plants can be slowly burned back by series of light flamings.	Best used on small weeds to keep clean field clean; may be of value in carefully planned salvage programs; greatest hazard arises from burning vegetation killed by previous flaming; this hazard can be avoided with several light flamings where weed growth is heavy; for in-row flaming, direct burners so as to keep high-heat zone in drill row near soil surface; use hooded burners for flaming between rows.
Incorporate trifluralin (0.5–1) in soil or DCPA (8–10.5).	From several weeks to immediately before planting.	Most grasses from seed; some small-seeded annual broadleaved weeds such as pigweed and purslane.	Incorporate immediately after application; mix uniformly ½–1 inch deep.
Apply EPTC (1–1.5) 1 inch subsurface in two 6-inch-wide bands centered 7 inches from drill row.	In conjunction with planting only.	Nutsedge, johnsongrass from seed, most annual weeds.	Use in combination with preplanting trifluralin or preemergence diuron; follow with postemergence naphtha, postemergence DSMA, and possibly other postemergence treatments; special instructions for triband weed control are essential to this practice.
CIPC (4–10), DCPA (8), diuron (0.4–1.6), monuron (1.6), norea (0.75–2.5), or prometryne (2–3).	After planting but before emergence.	Most small-seeded annual weeds.	Normally apply in conjunction with planting; usually restrict to band treatment; apply CIPC as spray or granules; incorporate granular CIPC ½ inch deep; in general, only use DCPA on very light soils and monuron on very heavy soils.

TABLE 3.—*Weed control in field row crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		COTTON—continued	
Naphtha, 20 gal. per acre of band actually treated (5 gal. per 13,068 row-feet of 10-inch band).	1–3 applications after smallest cotton is 2 inches tall and before bark cracks appear (about 1 week after emergence until 4 weeks after emergence).	Most annual weeds in seedling stage; perennial grasses and nutsedge will be topkilled if treated in early emergence stages; few perennial broadleaved weeds will be topkilled when small enough to be covered by spray.	Apply as laterally directed spray to drill area at less than 1 inch above soil; diseased or mechanically damaged cotton may be severely injured; naphthas not developed specifically for cotton may not be satisfactory.
DSMA (3)	1–2 applications after smallest cotton is 3 inches tall but before first bloom opens.	Most annual grasses, seedling cocklebur, few other broadleaved weeds; nutsedge and small johnsongrass will be topkilled.	Apply as basally directed spray; 2 applications are frequently necessary for good control; normally use 1 pt. surfactant for each 25 gal. spray mixture; DSMA appears more effective during hot, dry periods.
DSMA (3) plus diuron (0.2).	1–2 applications after smallest cotton is at least 6 inches tall but before first bloom opens.	Most annual weeds; nutsedge and small johnsongrass will be topkilled.	Apply as basally directed spray; normally use 1 pt. surfactant for each 25 gal. spray mixture; DSMA plus diuron is less dependent on weather conditions than DSMA or diuron used alone.
Diuron (0.2–0.4)	1–2 applications after cotton is 6 inches tall.	Most annual weeds if treated when less than 3 inches tall, young, and actively growing.	Apply as basally directed spray; add 1 pt. surfactant for each 25 gal. spray mixture.
For lay-by purposes, split application; diuron, 0.3–0.75 lb. per application.	Once when cotton is 12 inches tall; again when 15–24 inches.	Most small-seeded annual weeds germinating after treatment; young actively growing weeds less than 3 inches tall.	Apply as basally directed spray; add 1 pt. surfactant for each 25 gal. spray mix; normally use no cultivation after first application; for this reason split-application technique is not suggested where resistant weeds are present.
For lay-by purposes, single application; CIPC (8), diuron (0.5–1.5), linuron (0.5–1.6), monuron (0.5–1.6), or prometryne (1).	When cotton is 15–24 inches tall.	Most small-seeded annual weeds germinating after treatment; young, actively growing weeds less than 3 inches tall if surfactant is added.	Apply as basally directed spray; add 1 pt. surfactant for each 25 gal. spray mix if emerged weeds are present; in irrigated areas, water management is essential to insure thorough wetting of beds after application.
Trifluralin (0.75)	Before first irrigation after cotton emergence.	Most small-seeded annual weeds and johnsongrass from seed between rows.	For western irrigated Cotton Belt only; apply to soil between rows and incorporate immediately to depth of 1–2 inches; control of annual groundcherry is temporary.
		PEANUTS	
Seedbed preparation and cultivation; bury litter at least 3 inches deep with moldboard plow in preparing flat seedbed; shallow-running, nondirting, flat sweeps are most satisfactory for cultivation.	Before planting and after emergence.	Control of all weeds is affected by seedbed preparation; cultivation between rows controls all weeds.	Improper land preparation and cultivation often increase incidence of southern blight, which may drastically reduce peanut yields and quality; broken stands intensify weed problems; rough seedbeds complicate use of herbicides.
Incorporate preplanting vernolate (2.5) in soil.	From 2 weeks to immediately before planting.	Most annual weeds; suppression of nutsedge.	Incorporate vernolate about 3 inches deep; usually temporary stunting and leaf fusion of peanuts; do not use seed of poor vitality.

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TABLE 3.—*Weed control in field row crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		PEANUTS—continued	
Sesone (3), 2,4-DEP (3), NPA (2–4), or DNBP (9–12).	After planting but before emergence.	Most small-seeded annual weeds.	All these herbicides may cause injury, especially in cold, rainy periods during crop emergence; crop injury usually temporary; do not use seed of poor vitality.
DNBP (6) alone or DNBP (1.5) plus one of following additives: 2,4-DEP (2), sesone (2–2.7), diphenamid (2–3), or NPA (3).	When peanuts are cracking soil unless weeds become visible first; in this case apply herbicides before peanuts start to crack soil.	do	Mixtures usually perform better than single herbicides; timing is critical; emergent sprays are most effective if applied when weeds are first visible; treatment after oldest peanuts have more than 2 leaves is very hazardous; peanuts from seed of poor vitality are likely to be severely injured.
Postemergence DNBP (3).	Before peanuts are more than 1½–2 inches in diameter (3- to 5-leaf stage).	do	Less effective than emergent mixtures; peanut foliage will be injured, especially in hot weather or hot and wet weather.
Postemergence DNBP (1. 5).	Within 1 month after peanuts first crack soil; use 1–2 applications.	do	Can be used if needed as followup treatment after emergent mixtures; apply when weeds first become visible; protect peanuts from spray with shields or similar devices.
		SAFFLOWER	
EPTC (3–5)	Several weeks to immediately before planting.	Winter annual weeds including volunteer cereals.	Incorporate in top inch of soil immediately after application.
Barban (0.38)	When wild oats have 1–2 true leaves (approximately 4 inches high).	Wild oats	Apply as broadcast spray.
MPMT (0.5)	If safflower is at least 3 inches tall and weeds are less than 2 inches tall.	Lambsquarters	Do.
		SORGHUM	
Cultivation	Before planting to destroy several weed crops and after crop emergence until layby.	All weeds	Preplanting cultivation should generally be shallow to reduce moisture loss; postemergence cultivation should be often enough to control weeds in young stages of growth; set row widths to facilitate cultivation.
Rotary hoe in and between rows.	After sorghum is 2 inches tall until stalk begins to stiffen.	All seedling weeds young enough to be uprooted.	Effective only on shallow-rooted seedling weeds.
Preemergence atrazine (1–2).	After planting but before crop emergence.	Most small-seeded annual weeds.	Some injury to sorghum may occur; plant sorghum 1 inch deep or deeper to increase safety margin; do not use atrazine on sorghum grown in coarse-textured soil.
Preemergence CDAA (1–2).	do	do	Plant sorghum 1 inch deep or deeper to increase safety margin.
Preemergence propazine (1–2.5).	do	do	Do.
Postemergence atrazine (2–3).	After crop emergence	Most annual weeds less than 1 inch tall.	Apply as broadcast spray in sorghum; or if necessary to cover weeds, use directed basal spray.

TABLE 3.—*Weed control in field row crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		SORGHUM—continued	
Postemergence 2,4-D (0.25–0.5).	When crop is 4–12 inches tall.	Most broadleaved annual weeds.	Apply as foliage spray to crop and weeds while sorghum is 4–12 inches tall; basally directed spray in sorghum 6–12 inches tall presents less danger to crop and may be used if weeds are shorter than crop; some injury to sorghum by 2,4-D may occur regardless of growth stage at application.
Flame	After sorghum is 12 inches tall.	Topkill of most small weeds.	Direct flame basally; balance speed and pressure to kill tops of small weeds without causing more than slight damage to lower leaves of sorghum; flame few rows day before field is to be flamed; adjust equipment according to appearance of trial rows 1 day after flaming.
		SOYBEANS	
6–10 cultivations to depths of 2–4 inches.	6–8 weeks before planting.	Perennial grasses such as johnsongrass and quackgrass, most annual weeds.	Alternating disk with field cultivator is as effective and more economical than using 1 implement; 2 cultivations may be applied in 1 day if wet weather delays schedule; most effective in dry weather; may reduce soil moisture to critical levels, making it advisable to wait for rain before planting.
2–3 shallow cultivations at depths no greater than 2 inches.	2–4 weeks before planting.	Most annual weeds; some control of perennial grasses such as johnsongrass and nutsedge.	Less likely to reduce soil moisture to critical levels than intensive cultivations at greater depths; use only where weeds have emerged or are emerging.
Cultivate in row with rotary hoe at high speed.	When beans have 1–3 trifoliate leaves and weeds in emerging seedling stage.	Most shallow-rooted annual weeds.	Best results obtained when soil is loose or lightly crusted; safety to soybeans increases if rotary hoeing is done only when beans have lost some turgidity; chance of yield reductions increases markedly if soybeans are rotary hoed after full expansion of third trifoliate.
Cultivate between rows with tools such as sweeps.	As needed after emergence and until beans become too large.	All weeds	Cultivation is effective and usually most economical method of controlling weeds growing between rows.
Dalapon (3.7–7.5); use 0.5-percent surfactant in spray.	In spring when johnsongrass is approximately 1 foot high (at least 4 weeks before planting soybeans).	Johnsongrass	Disk treated fields 4–7 days after treatment; plant soybeans no sooner than 3 weeks after disking; fall plowing delays emergence of johnsongrass in northern areas; spring plowing after dalapon treatment is advisable so soybeans can be planted earlier; use amiben preemergence to control seedling johnsongrass not affected by dalapon treatment.
Amiben (2–3) or linuron (1–3).	After planting but before emergence.	Most small-seeded annual grasses.	Preemergence herbicides likely to cause injury on very light-textured sandy soils; soybeans may be injured severely by linuron on soils low in organic matter.
CDAA (4–5) or trifluralin (0.5–1).	do	do	Preemergence herbicides likely to cause injury on many very light-textured sandy soils; trifluralin is usually incorporated in soil.

TABLE 3.—*Weed control in field row crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		SOYBEANS—continued	
Nonfortified naphthas (same as for cotton) at approximately 20 gal. per acre of land actually treated.	1 application when beans are 12–19 days old; if needed, second application may be made no sooner than 5 days after first application.	Most small-seeded annual weeds in seedling stage; kills tops of most small perennial weeds.	Apply as laterally directed spray to 10-inch band centered over row at less than 1 inch above soil (5 gal. per 13,068 row-feet); do not treat beans more than 4 weeks old.
2,4-DB (0.2)	1 application 2 weeks before early bloom until midbloom when cocklebur plants are growing above soybeans.	Cocklebur	Apply as broadcast foliage spray; normally use amine formulation; treatment often injures soybeans but symptoms (stem curvature and drooping leaves) generally disappear within 1 week after treatment; injury is more severe if treatment is made when soil is very dry.
2,4-D wax bars (6 bars for 4 rows).	After most sesbania plants have grown above soybeans.	Sesbania	Wax bars are suspended from boom or rod attached to rear of tractor so as to travel 2–3 inches above soybean plants; sesbania stems rub 2,4-D wax formulation off bars; speed should not exceed 4 m.p.h. and should be slower in extremely heavy infestations; handle wax bars carefully and remove from tractor when not in actual weed-control operation.
		SUGARBEETS	
Cultivation	Postemergence (variable)	Small weeds in rows; all weeds between rows.	Weeds between rows easily controlled by cultivation; mechanical thinners provide some weed control in rows; various devices such as harrows with flexible tines used successfully for weed control in row if beets big enough to withstand operation and weeds small enough to be killed.
Incorporate preplanting diallate (1.5–2) in soil.	Immediately before planting.	Wild oats	
IPC (3–5)	do	Wild oats, volunteer cereals, some other annual grasses.	Incorporate in soil right after application; does not control foxtail.
Pebulate (4–5) or EPTC (2–2.5).	do	Most annual grasses, many annual broadleaved weeds.	Incorporate in soil immediately after application.
Incorporate preplanting pyrazon (4–4.8) in soil.	do	Many annual broadleaved weeds.	
Preemergence endothall (5.5).	After planting but before crop emergence.	Many annual weeds	
Preemergence pyrazon (3–4).	do	Many annual broadleaved weeds.	
Preemergence TCA (5–7).	do	Most annual grasses except wild oats and volunteer cereals.	
Postemergence barban (0.62–0.75).	When wild oats in 2-leaf stage.	Wild oats	Apply as broadcast foliage spray.
Postemergence dalapon (2–3).	When crop has emerged until it has 4 true leaves and grassy weeds are less than 3 inches tall.	Most small grassy weeds	Do.

TABLE 3.—*Weed control in field row crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		SUGARBEETS—continued	
Postemergence endothall (0.75–1.5).	When crop has emerged until it has 6 true leaves and weeds are less than 2½ inches tall.	Smartweed, wild buckwheat, some other broadleaved weeds.	Use lower rate when beets have less than 2 true leaves; when temperature is above 80° F., endothall may cause excessive injury, especially to very small sugarbeets.
Postemergence pyrazon (4).	When crop has emerged but before weeds have more than 2 true leaves.	Many annual broadleaved weeds.	
		SUGARCANE	
Fallow plowing	6–8 fallow plowings during spring and summer before sugarcane is replanted.	Johnsongrass from seed and rhizomes.	
Atrazine, simazine, diuron, or monuron (2–4); for organic soils of Florida: CDAA (8) plus 2,4-D (2); for Hawaii only: Ametryne (4–8).	Immediately after planting or ratooning; most may be repeated and/or supplemented with other herbicides during growing season.	Most annual grasses, many small-seeded broadleaved annual weeds.	Apply re-treatments in directed sprays.
Preemergence fenac (6–8); for Louisiana only: Repeat applications of TCA (8) plus silvex (3).	Fenac immediately after planting in Florida and in early spring to fall-planted cane in Louisiana; TCA-silvex after planting, in early spring, and 4–5 weeks later.	Johnsongrass from seed, most annual grasses, many broadleaved weeds.	Apply fenac broadcast in Florida; apply fenac and TCA-silvex on 24- to 30-inch band in Louisiana (⅓ of row width).
Dalapon (2–4) alone or combined with TCA (5–7) and 2,4-D (2); for Florida primarily: Atrazine (3.2); for Hawaii only: Diuron (2–3.2) plus surfactant, PCP (5) emulsified in naphtha, or ametryne (2–4).	Young succulent weeds at any time after crop emergence and before cane closes in; 1–3 applications may be necessary.	Most annual grasses, some small-seeded broadleaved weeds; in Hawaii many perennial grasses and broadleaved weeds.	Apply as directed spray, usually as supplement to preemergence treatment; apply atrazine when seedling weeds are approximately 1½ inches tall; dalapon or other chemicals control larger weeds.
2,4-D (approximately 2); for resistant weeds: 2,4,5-T or silvex (approximately 1).	Postemergence when needed to weeds growing vigorously.	2,4-D controls chickweed, henbit, morning-glory, pigweed; other chemicals control these weeds plus dogfennel, groundcherry, koa haole (*Leucaena leucocephala*), nightshade, wild lettuce.	Apply as broadcast foliage spray.
Mixture of TCA (8) plus dalapon (4.5) plus silvex (3); in Louisiana, ratoon crop only.	Early spring when cane and johnsongrass are approximately 10 inches tall.	Johnsongrass from rhizomes, most emerged annual weeds.	Apply as foliage spray on 24-inch band (⅓ of row width) when temperature is above 65° F.

TABLE 3.—*Weed control in field row crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		TOBACCO	
Commercial urea, 1 lb., plus calcium cyanamide, 0.5 lb., per sq. yd., or methyl bromide, 1 lb. per 100 sq. ft.	Urea-cyanamide or cyanamide in October in mid-Atlantic States.	All annual weeds in plant beds.	For plant beds only; thoroughly mix urea-cyanamide or calcium cyanamide with upper 3 inches of soil by disking or raking; apply methyl bromide to well-pulverized seedbed under gasproof cover; methyl bromide is very poisonous; many users employ specially trained personnel to apply it.
Diphenamid (4)-------	Immediately after transplanting and before any weed emergence.	Most annual grasses, some small-seeded broadleaved weeds.	Shallow cultivation may improve effectiveness.

TABLE 4.—*Weed control in close-drilled field crops*

[Numbers in parentheses=pounds of active ingredient per acre unless otherwise indicated]

Treatment	Time of application	Weeds controlled	Remarks
		ESTABLISHED ALFALFA	
Flaming----------	Twice at 3-day interval in stubble after harvest.	Dodder seedlings, dodder attached to stubble.	Spot flaming can be used also for isolated patches of dodder in seed crop.
Drying of soil in irrigated areas by increasing interval between irrigations.	Whenever feasible during growing and harvesting season.	Dodder----------	
Shading by crop------	----------	-----do----------	Alfalfa, through shading after it is 2 feet tall, provides important part of full-season control of dodder if dodder is controlled by other methods while alfalfa is less than 2 feet tall.
Frequent, shallow cultivation.	In early spring and in stubble after harvest.	Dodder seedlings--------	
CIPC (6) (granular formulation) or DCPA (10).	To moist soil before dodder attaches to host in spring.	Dodder seedlings, some annual weeds; DCPA provides some control of attached dodder.	Supplement with cultural practices described previously to obtain full season control; DCPA registered for use only on seed crops.
Diuron (1.5–3.2) or simazine (1).	In winter when legumes are dormant or semi-dormant.	Many annual weeds-----	Apply before germination of weeds or while still seedlings; remove or burn crop residue before treating; simazine registered only for use on seed crops in Pacific Northwest.
DNBP (1.25–2.2) plus 20–50 gal. diesel or weed oil plus 50–100 gal. water.	After first hay crop is removed but before regrowth starts.	Annual broadleaved weeds.	
		ESTABLISHED GRASSES	
Plant in rows and cultivate between rows.	----------	Summer annuals--------	Not satisfactory where heavy winter rains occur and winter annuals are primary weeds.
Dicamba or prometryne (2–3.2) in eastern Oregon; IPC (4) in eastern Washington.	Soon after first post-harvest irrigation.	Downy brome----------	Remove all crop residue by burning or mechanical means immediately after harvest.

TABLE 4.—*Weed control in close-drilled field crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
ESTABLISHED GRASSES—continued			
2,4-D, 2,4,5-T, MCPA, or silvex (0.5-0.75) or dicamba (0.25-0.5).	After seedling crop grasses have 3–5 leaves; established crop grasses not treated after boot stage but can be re-treated after harvest.	Most broadleaved weeds..	Easier to control small, actively growing, young weeds than large, slowly growing, old weeds; use higher rates only on well-established stands.
ESTABLISHED LEGUMES [1]			
Mechanical tillage (shallow) or flaming fields with field weed burners.	When weeds are seedlings before seeding crop, between hay and seed crops, and in dormant stages.	Many annual weeds.....	Species present will determine when tillage can be practiced.
2,4-DB (0.5–2).....	Any time during growing season before legumes bud.	Many annual and perennial broadleaved weeds that are not legumes and that are not resistant to 2,4-D.	Treat weeds when less than 3 inches tall, or preferably when less than 1 inch tall, and growing actively; use higher rates only for established legumes; not registered for use on lespedeza.
DNBP (1.9–2.5) or PCP (4–6) in 5–10 gal. diesel oil, or endothall (0.52–0.65) in 5–10 gal. water, or diquat (0.5–0.75) in 20–40 gal. water.	Preharvest.....	Desiccation of all weeds before harvest.	Treatment before legume seeds are mature may reduce their yield and quality; legumes as well as weeds are desiccated by treatment; DNBP not registered for use on lespedeza; diquat not registered for use on lespedeza or birdsfoot trefoil.
ESTABLISHED LEGUMES [2]			
IPC (3–4).....	In winter when legumes are dormant or semidormant.	Winter annual grasses, chickweed.	Apply before germination of weeds or while still seedlings; burn or remove crop residue before treating; use only after legumes have several true leaves.
ESTABLISHED GRASSES [3]			
Atrazine (1–1.2), CIPC (2–3), diuron (1–3.2), IPC (2–4), or simazine (1–2).	Preemergence to weeds in fall or while weeds are very small.	Winter annuals, except CIPC and IPC will not control many broadleaved winter annuals.	Treatments listed may be unsatisfactory in area other than Washington or Oregon; remove or burn all crop residue before treating; IPC or CIPC may reduce seed yields of grasses if applied after Nov. 1; bluegrass and other grasses may be severely injured by atrazine or simazine in areas outside Washington and Oregon; atrazine registered for use only on perennial ryegrass; diuron not registered for use on creeping red fescue; IPC not registered for use on orchardgrass, bluegrass, tall fescue; simazine not registered for use on bluegrass.
ESTABLISHED TREFOIL			
Diuron (1.6).....	In winter when trefoil is dormant or semidormant.	Many annual weeds.....	Apply before germination of weeds or while seedlings; burn or remove crop residue before treating.

See footnotes at end of table.

TABLE 4.—*Weed control in close-drilled field crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
FLAX			
Select fields relatively free of weeds; tillage of land in late summer and early fall is helpful.	Late summer, early fall	Perennials, annuals	Late-summer or fall tillage may not be desirable in some areas where wind may seriously erode soil.
Spring tillage	Before planting	Wild oats	Spring tillage delays sowing of flax; practice is successful in some areas but may be detrimental to flax yields; use early varieties where sowing is delayed.
Diallate (1.5–2)	In spring before sowing	do	Incorporate herbicide in soil.
Barban (0.31–0.37)	When wild oats are in 2-leaf stage.	do	Apply in top spray.
MCPA (amine or sodium salts) (0.12–0.60) or 2,4-D (amine salt) (0.12–0.25).	When flax is 2–6 inches tall and weeds are small.	Many broadleaved weeds	Apply in top spray; higher rates than those listed required only in Southwestern United States; MCPA less likely to injure flax than 2,4-D; do not apply MCPA or 2,4-D after flax reaches early bud stage; varieties differ in tolerance to herbicides.
TCA (5), dalapon (0.75), or mixtures of these two with MCPA (0.25).	do	Most annual grasses	Apply in top spray; mixture controls both grasses and broadleaved weeds.
RICE			
Use of weed-free crop seed.	At planting	Barnyardgrass, beakrush, curly indigo, Mexican weed, red rice, sesbania.	Use weed-free rice seed to prevent or hold down infestations of listed weeds.
Rotate with row crops such as soybeans, cotton, grain sorghums, safflower.		Many grasses, broadleaved weeds, sedges, aquatic weeds.	Reduces infestations of listed weeds; in some cases can help eradicate some weeds.
Rotate with pasture		Reduces infestations of aquatic weeds, broadleaved weeds, sedges.	Does not reduce grass infestations.
Phosphate fertilization of other crops preceding rice or of rice just before it is flooded for first time.	In previous seeding or just before first flooding.	Barnyardgrass and most annual grasses in dry seeded rice.	Reduces competition of listed weeds with rice; phosphate applied in standing water stimulates aquatic weeds; may be applied preplant to water-seeded rice without stimulating barnyardgrass but may increase problems with aquatic weeds.
Rotate with other small grains combined with summer fallow after harvest of other small grains.		Many annual weeds, perennials such as bulrush, cattail, knotgrass, perennial spikerush.	Reduces infestations of listed weeds; in some cases can help eradicate some weeds.
Thorough seedbed preparation of adequately dried land to kill all weed growth before seeding and repeated shallow cultivations at 1- to 3-week intervals in spring before planting.	Late summer, fall, and early spring before planting.	Deep-rooted perennials, aquatic weeds, most annual weeds.	Reduces infestations but does not eradicate listed weeds.

TABLE 4.—*Weed control in close-drilled field crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		RICE—continued	
Water management at seeding.	From several days before planting to 4 weeks after seeding rice.	Barnyardgrass, brachiaria, curly indigo, sesbania, sprangletop.	White barnyardgrass not controlled unless water is held 6–8 inches deep for 3–4 weeks; water seeding encourages some aquatic weeds such as algae, ducksalad, annual spikerush, annual umbrella-sedge; therefore, dry seeding rice by drilling or broadcasting helps control these aquatic weeds.
Flood rice to depth of 4–8 inches just after rice and grassy weeds emerge.	Flood when grass weeds have 1–3 leaves and hold for 1–3 weeks.	Barnyardgrass, most annual grasses.	Timely and complete draining of water helps control many aquatic weeds including algae and ducksalad.
Timing of nitrogen application to rice.	Variable	Barnyardgrass, other annual grasses, aquatic weeds.	In absence of effective cultural or chemical control of listed weeds, delay nitrogen application until weeds are flowering to reduce competition with rice (this period of flowering usually occurs 50–60 days after seeding rice).
Molinate (3)	Immediately before flooding and seeding.	Barnyardgrass, sprangletop, annual umbrella-sedge in water-seeded rice.	Incorporate 3–4 inches deep immediately after application; cross-disking or cross-harrowing with implements going 4–6 inches deep has been satisfactory; safe only on water-seeded rice.
MCPA, silvex, 2,4-D, or 2,4,5-T (0.5–1.5); amine salt or low-volatile ester formulations.	After rice is well tillered but before jointing.	Arrowhead, burhead, curly indigo, ducksalad, fimbristylis, gooseweed, Mexican weed, redstem, sesbania (coffeebean), smartweed, spikerush, umbrella-sedge, waterhyacinth, waterhyssop, waterplantain, waterprimrose.	Severe injury may occur if rice is treated in early-tillering, late-jointing, booting, or early-heading stages; for emergency treatments in early stages of rice growth, 2,4,5-T, MCPA, and silvex will cause less injury than 2,4-D; rapidly growing weeds are easier to kill than slow growing weeds; therefore soil moisture should be adequate to promote rapid weed growth; water levels should be lowered if necessary to expose weed foliage to sprays; mixtures may be better than single herbicides where several species are present; for example, 2,4-D (0.5) plus 2,4,5-T (0.5) is more effective than either one at 1 lb. where both ducksalad and curly indigo are present; treat only when temperature is 70°–95° F.; do not mix these herbicides with other pesticides or any material other than water; nitrogen applied to rice before treatment may increase its susceptibility; nitrogen applied 7–21 days before treatment has increased susceptibility more than nitrogen applied 1–6 days before herbicide application; rain 1–6 hours after spraying may reduce effectiveness.

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TABLE 4.—*Weed control in close-drilled field crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		RICE—continued	
Propanil (4.5–6)	When grassy weeds are through water and oldest grass is 6–8 inches above water (42–50 days after seeding).	Barnyardgrass, other annual grasses, broadleaved weeds, sedges.	Do not alter water depth immediately before or after spraying; if, before spraying, deep flood is lost by levee failure, reflood rice to shallow depth (2–3 inches); treat when grass has resumed rapid growth and is 5–6 inches tall (similar to shallow-water culture); spray droplets of 200–400 micron diameter are preferable to coarser or finer sprays; do not mix propanil with other pesticides or additives; insecticides such as carbaryl, parathion, and methyl parathion may cause injurious interactions if used within 15 days before or after propanil application.
Propanil (4–4.5)	Usually 35–45 days after seeding when oldest grass is 5–6 inches above water and broadleaved weeds and sedges are just above water.	Barnyardgrass, other annual grasses, broadleaved weeds.	Spray droplets of 200–400 micron diameter are preferable to finer or coarser droplets; if grasses are not prevalent weeds, water may be lowered but not drained to expose foliage of nongrassy weeds; in such case water level may be raised after spraying as rice develops and temperature increases; do not mix propanil with other pesticides or additives; insecticides such as carbaryl, parathion, and methyl parathion may cause injurious interactions if used within 15 days before or after propanil application.
Propanil (3–5) in 10–15 gal. water for aerial spraying or in 15–25 gal. water for ground spraying.	Soon after crop and weed emergence when grassy weeds have 1–3 leaves and broadleaved weeds or sedges are 1–5 inches tall.	Barnyardgrass, brachiaria, curly indigo, fimbristylis, gooseweed, sesbania (coffeebean), annual spiderrush, annual umbrella-sedge, many other annual weeds.	May be used in drill-, broadcast-, or water-seeded rice; if rice is water seeded, drain or lower water to expose weed foliage; control is improved by flushing field 2–3 days before spraying if soil is dry; postpone spraying for warmer temperatures if below 50° F. at night and below 70° during day; flooding may begin 24 hours after application and should be completed in 2–4 days; spray droplets of 200–400 micron diameter are preferable to finer or coarser spray; do not mix herbicides with other pesticides or additives; insecticides such as carbaryl, parathion, and methyl parathion applied 15 days before or after propanil have severely injured rice.
		WHEAT	
Diuron (1)	After planting but before emergence.	Most small-seeded annual weeds.	Follow recommendations of State agricultural experiment station or extension service weed specialists; suggested only for winter wheat in Northwestern United States.
		BARLEY	
Diallate (1–1.25)	Preemergence before crop sprouts are ½ inch long.	Wild oats	Incorporate in soil.

TABLE 4.—*Weed control in close-drilled field crops*—Continued

Treatment	Time of application	Weeds controlled	Remarks
BARLEY, OATS, AND WHEAT			
2,4-D or MCPA (0.25–1).	After cereals are well tillered (usually 4–8 inches tall) but before boot stage.	Cocklebur, dock, field bindweed, lambsquarters, mustard, pigweed, plantain, prickly lettuce, ragweed, shepherds-purse, smartweed, sunflower, wild radish, wild vetch, yellow-rocket.	Wheat is most tolerant of these to 2,4-D; oats is least tolerant but more tolerant to MCPA; in Northeastern, North Central, and Midwestern United States 0.5 pound per acre or less is recommended.
BARLEY AND WHEAT UNDERSOWN WITH LEGUMES			
Postemergence 2,4-D or MCPA (0.12–0.25).	After cereals are well tillered (usually 4–8 inches tall) but before boot stage.	Mustard, yellow-rocket, other broadleaved weeds.	Use only if weed infestation is serious enough to result in reduction or loss of legume stands and reduced cereal yield; cereal canopy may help protect legumes from herbicides; waiting later than early joint stage is inadvisable; use lowest gallonage and pressure possible to reduce penetration of cereal and weed canopy; these rates are frequently inadequate for Southern, Northwestern, and Western United States; check with local authorities for clearances and safety of higher rates.
DURUM WHEAT AND HARD RED SPRING WHEAT			
Triallate (1)	In fall before spring planting.	Wild oats	Incorporate in soil.
Barban (0.25–0.37)	When wild oats are in 2-leaf stage but not after crop reaches 4-leaf stage.	do	
FALL-SEEDED BARLEY, OATS, AND WHEAT			
Dicamba (0.25)	Postemergence in spring before joint stage.	Wild buckwheat, corncockle, cowcockle, dogfennel, most weeds susceptible to 2,4-D.	Mixtures of 0.12 lb. of dicamba and 0.12 lb. of 2,4-D per acre will control mustards better than dicamba alone.
SPRING-SEEDED OATS AND WHEAT			
Dicamba (0.12) for oats and (0.12–0.25) for wheat.	Postemergence during 2- to 5-leaf stage of crop.	Wild buckwheat, corncockle, cowcockle, dogfennel, most weeds susceptible to 2,4-D.	Mixtures of 0.12 lb. of dicamba and 0.12 lb. of 2,4-D per acre will control mustards better than dicamba alone.

[1] Includes alfalfa, birdsfoot trefoil, alsike, ladino, red, and white clover, and lespedeza.

[2] Includes alfalfa, birdsfoot trefoil, and crimson, ladino, red, subterranean, and white clover.

[3] Includes bentgrass, bluegrass, creeping red fescue, orchardgrass, perennial ryegrass, and tall fescue.

TABLE 5.—*Control of perennial weeds in cropland*

[Numbers in parentheses=pounds of active ingredient per acre unless otherwise indicated]

Treatment	Time of application	Weeds controlled	Remarks
		ALL KINDS	
Methyl bromide fumigation, 1 lb. per 100 sq. ft.	Any time during spring, summer, or fall.	All weeds, weed seed, rootstocks.	Apply under gasproof cover after thorough tillage of soil; methyl bromide is very dangerous to man and warmblooded animals; most users employ personnel specially trained in its use; for control in small, specialized areas.
Intensive cultivation	Frequency depends on species and climatic conditions.	Most perennial weeds	More than one season required to control some species; system may be combined with competitive crops and chemicals; follow local recommendations.
		BROADLEAVED WEEDS	
Amitrole (4)	After harvest of crop, but before Oct. 1.	Canada thistle, hoarycress, leafy spurge, poison-ivy.	Re-treat as necessary; frequently used as spot treatment; mixture of amitrole and ammonium thiocyanate is also effective.
Picloram (1–2.5)	Foliage during growing season or in late fall as soil treatment.	Many perennial broadleaved weeds except hoarycress.	Not registered for use on cropland except as spot treatment; in which case crops in treated areas must not be used for food, feed, or grazing for at least 2 years.
Silvex (3)	Late fall or early spring	Smooth bedstraw	Usually re-treatment will be necessary; observe treated areas and re-treat as required.
Sodium chlorate (640–960) (or sodium chlorate-fire retardant mixture).	During growing season	Most perennial broadleaved weeds.	Soil sterilants; primarily used to treat small patches; treatments will sterilize soil from 1 to several years; spring or fall preferred to summer treatments in some areas; **sodium chlorate without fire retardant creates severe fire hazard when in contact with combustible materials such as clothing and wooden floors.**
2,3,6-TBA (15–20) or PBA (35–40).	do	Field bindweed, most other broadleaved perennial weeds.	Treatment may prevent crop production for 1–3 years; not registered for use on cropland except as spot treatment.
2,4-D (0.5–2)	Actively growing foliage, usually bud stage.	Canada thistle, field bindweed, hoarycress, sowthistle.	Usually re-treatment will be necessary; observe treated areas and re-treat as required; check labels for restrictions as to crop species and other precautions.
2,4-D (1–4)	do	Bur-ragweed, dogbane, leafy spurge, Russian knapweed.	Do.
		GRASSES	
Atrazine or simazine (2–4) followed by plowing and planting of corn.	Fall or spring before planting corn.	Quackgrass	Chemical residues in soil may injure crops other than corn year after treatment.
Dalapon (4–5) followed by plowing 2 weeks later and planting of corn 4 weeks after treatment.	In spring when quackgrass is 4–10 inches tall.	do	Re-treatments may be necessary.

TABLE 5.—*Control of perennial weeds in cropland*—Continued

Treatment	Time of application	Weeds controlled	Remarks
		GRASSES—continued	
Spot spraying with dalapon at 1 lb. or TCA at 2 lb. per 5 gal. water; or aromatic oils.	During growing season from hand applicators while weeds are less than 15 inches tall; to foliage or stems of weeds.	Most grasses; oils will also kill tops of broadleaved weeds; will control but not eradicate perennial grasses.	Add ½ pt. surfactant to each 5 gal. spray mixture for herbicides mixed in water; spraying lower 6 inches of weeds is usually adequate; keep contact with crop plants to minimum as these treatments will kill or injure most crops; usually not practical when weeds to be sprayed exceed 1 plant per 20 feet of row.
Dalapon (5–20) followed by disking after 2 weeks.	In spring when grass is 15 inches tall or after clipping any time when grass is this height.	Johnsongrass	Use followup program for seedling control.
EPTC (3–6)	To freshly tilled soil in early spring.	Quackgrass	Thoroughly work soil before and after application.
MH (4) followed by plowing in 4–8 days.	To foliage in early spring.	do	Corn or sugarbeets may be planted as soon as soil preparation is completed; not registered for use on other agronomic crops.
TCA (25–50) or dalapon (5–20).	To foliage and soil surface 1 week before plowing in late fall or early spring.	Most perennial grasses	Plant to clean-tilled crops in following year; use preemergence herbicides to control seedlings; spot treat all survivors.
		RUSHES	
Amitrole (4)	When weeds are 12–18 inches tall.	Horsetail rush	Spray foliage.
		SEDGES	
Amitrole (4) followed by disking after 2 weeks.	In spring; repeat as needed for 2–3 years.	Purple nutsedge	Follow label instructions and restrictions.
Incorporate EPTC or vernolate (3) in soil.	In spring	Yellow and purple nutsedge.	Herbicide labels specify crops that can be planted after each treatment.
2,4-D (1–2)	4–5 applications during growing season for 2 years.	Purple nutsedge	More effective where heavily fertilized crops or grasses can be grown in conjunction with herbicide treatment.

WEED CONTROL IN HORTICULTURAL CROPS

Weed control in horticultural crops is a highly complex problem because of the large number of different types of crops and their specific cultural, climatic, and soil requirements plus the many species of weeds associated with these environmental and cultural conditions. Horticultural crops include vegetables, deciduous tree fruits and nuts, citrus and subtropical fruits and nuts, small fruits, and ornamental plants.

Several methods of weed control are used separately and in various combinations in horticultural crops because of the complexity of the weed problem. Mechanical cultivation is usually effective in controlling weeds between the rows but does not efficiently control weeds within the row because of the proximity of weed and crop plants. In periods of continued or excessive rainfall, mechanical cultivation is impossible and the weeds normally controlled by this method overgrow the crop. Hand hoeing and hand pulling of weeds have been used to supplement mechanical cultivation in many crops in the past. The scarcity and cost of labor in recent years, however, have made hand weeding impractical in many instances and impossible in others.

Cultural practices involving suitable rotation of broadcast and row crops and crops of differing growth habits can be used to limit the vigor and spread of certain weeds. For example, sweetpotatoes are very strong competitors and can be used effectively in rotations to suppress weeds. Broadcast-planted soybeans and sorghum are also effective smother crops for use in rotation.

The inefficiency of mechanical cultivation, the scarcity of hand labor, and the limitations of crop-rotation practices have stimulated intensive research in chemical weed control. The development of effective herbicides is providing the farmer with new technological tools of great potential for use in combination with cultural and mechanical methods of weed control in horticultural crops.

Examples of herbicides presently in commercial use for horticultural crops are given in tables 6–11. This information is intended to show the broad general areas of herbicidal effectiveness on these crops. Rate ranges are given, because specific rates vary with locality and depend on climate, soil composition, and cultural practices. Excellent weed-control recommendations based on local research have been prepared by many weed specialists in State agricultural experiment stations. These recommendations are revised annually to keep abreast of current research. These sources provide specific herbicide and rate recommendations for each locality. The reader should consult these specialists for specific rates and methods for safe and effective use on specific crops for local areas.

Herbicides are selected on the basis of their weed specificities. For example, one herbicide may be highly effective on germinating annual weed grasses and ineffective on germinating broadleaved weeds. Conversely, others may be effective on only broadleaved weeds. The grower must therefore identify the weed and know its time of emergence and growth as a basis for selecting the correct herbicide and time of application.

The formulation to be used, whether spray or granules, will depend on the weed problem. In general, granules should be used in postemergence or posttransplanting treatments after clean cultivation to take advantage of the physical selectivity of this form as a means of minimizing injury to the crop. Granules may also be used as preplanting and preemergence treatments as a matter of convenience.

VEGETABLES

More than 50 vegetable crops are grown commercially in the United States. Chemical weed-control methods can fill a critical need in their production. Examples of effective chemical methods are given in table 6.

TABLE 6.—*Weed control in vegetables*

Crop and herbicide	Pounds of active ingredient per acre	Time of application
Asparagus:		
Amiben	3	Preemergence.
Dalapon	7–14	Preharvest, postharvest.
Monuron	1–1.5	Do.
Sesone	2–4	Do.
Simazine	2–4	Do.
Beans, lima:		
Amiben	2	Preemergence.
CDAA	4	Do.
CDEC	6	Do.
CIPC	2–4	Do.
DNBP (alkanolamine salt).	3–9	Do.
Trifluralin	0.75	Preplant, soil incorporated.
Beans, pole:		
CIPC	2–4	Preemergence.
EPTC	3	Preplant, preemergence, postemergence, soil incorporated.
Beans, snap:		
CDAA	4	Preemergence.
CDEC	6	Do.
CIPC	2–4	Do.
DCPA	6–12	Do.
DNBP (alkanolamine salt).	3–9	Do.
EPTC	3	Preplant, preemergence, postemergence, soil incorporated.
Trifluralin	0.75	Preplant, soil incorporated.
Beets:		
CDEC	2–4	Preemergence.
Endothall	6.5	Do.
Pyrazon	4	Preemergence, postemergence; see area restrictions on label.
Sodium chloride	200–300	Postemergence.
TCA (sodium salt).	6–9	Preemergence.
Broccoli:		
CDEC	2–4	Preplant, pretransplant, posttransplant.
DCPA	10. 5	Preemergence, posttransplant.
Trifluralin	1	Preplant, posttransplant, soil incorporated.
Brussels sprouts:		
CDEC	2–6	Preemergence, postemergence, pretransplant, posttransplant.
DCPA	10. 5	Preemergence, posttransplant.
Trifluralin	1	Preplant, posttransplant, soil incorporated.

TABLE 6.—*Weed control in vegetables*—Continued

Crop and herbicide	Pounds of active ingredient per acre	Time of application
Cabbage:		
CDAA	4–6	Preemergence, posttransplant.
CDEC	2–6	Preplant, preemergence, pretransplant, posttransplant.
DCPA	10. 5	Preemergence, posttransplant.
Trifluralin	1	Preplant, soil incorporated for transplants.
Cantaloup:		
CDEC	2–4	Preemergence.
DCPA	10. 5	Do.
NPA (sodium salt)	2–6	Preemergence, posttransplant, lay-by.
Caraway, Stoddard solvent.	(1)	Preemergence, postemergence.
Carrots:		
CIPC	2–6	Do.
DCPA	10. 5	Seed crop only at planting or transplanting.
Linuron	1–2	Preemergence, postemergence.
Stoddard solvent	(1)	Do.
Cauliflower:		
CDEC	2–6	Preplant, preemergence, pretransplant, posttransplant.
DCPA	6–10	Preemergence, posttransplant.
Trifluralin	1	Preplant, soil incorporated for transplants.
Celery:		
CDAA	4	Posttransplant.
CDEC	2–4	Preemergence, posttransplant.
Stoddard solvent	(1)	Preemergence, postemergence.
Chicory, CDEC	2–4	Do.
Collards:		
CDEC	2–4	Do.
CIPC	1–2	Do.
DCPA	10.5	Do.
Corn, sweet:		
CDAA	4	Preemergence.
CDAA plus TCBC.	1.25 plus 2.5.	Do.
CDEC	6	Do.
DNBP (alkanolamine salt).	7.5–9	Do.
Linuron	1	Do.
Simazine	2–4	Preplant, preemergence, soil incorporated.
2,4-D	0.25–0.5	Preemergence, postemergence.
2,4-DEP	6	Immediately after planting.
Cucumbers:		
CDEC	2–4	Preemergence.
NPA (sodium salt).	2–6	Preemergence, posttransplant.

See footnotes at end of table.

TABLE 6.—*Weed control in vegetables*—Continued

Crop and herbicide	Pounds of active ingredient per acre	Time of application
Dill, Stoddard solvent.	(1)	Preemergence, postemergence.
Eggplant, DCPA	10.5	Transplant, lay-by.
Endive, CDEC	2–4	Preemergence.
Escarole, CDEC	2–4	Do.
Garlic:		
CIPC	2–4	Preemergence, postemergence.
DCPA	6–10	Preemergence, transplant.
Hanover salad:		
CDEC	2–4	Preemergence.
CIPC	1–2	Do.
Kale:		
CDEC	2–4	Do.
CIPC	1–2	Do.
DCPA	10.5	Do.
Lentils:		
Diallate	1.5	Preplant, preemergence, soil incorporated.
IPC	4	Preplant, preemergence, postemergence, soil incorporated.
Lettuce:		
CDEC	2–4	Preemergence, pretransplant.
IPC	3–4.5	Preemergence.
Mint:		
CIPC	2–4	Do.
Diuron	1–2	Do.
DNBP (alkanolamine salt).	3–4.5	Do.
Mustard greens:		
CDEC	2–4	Do.
DCPA	10.5	Do.
Okra:		
CDEC	2–4	Do.
Trifluralin	1	Preplant, soil incorporated.
Onions:		
CDAA	6	Preemergence, postemergence.
CIPC	4–8	Do.
DCPA	10.5	Preemergence, posttransplant.
KOCN	16–20	Preemergence, postemergence.
Monuron	1.6	Do.
Sulfuric acid	(2)	Postemergence.
Parsley, Stoddard solvent.	(1)	Preemergence.
Parsnips:		
Linuron	1.5	Postemergence.
Stoddard solvent	(1)	Preemergence, postemergence.
Peas:		
CDAA	4	Preemergence.
CIPC	4–6	Preplant, preemergence, soil incorporated.
Diallate	1.4–1.5	Do.
DNBP (alkanolamine salt).	6–9 1.5–2	Preemergence. Postemergence.
IPC	4–8	Preplant, postemergence.

TABLE 6.—*Weed control in vegetables*—Continued

Crop and herbicide	Pounds of active ingredient per acre	Time of application
Peas—Con.		
MCPA (amine or sodium salt).	0.75	Postemergence as prebloom.
MCPB	0.25–0.75	Early postemergence.
Peas, southern:		
DCPA	6–10	Preemergence.
Trifluralin	0.25–1	Preplant, soil incorporated.
Peppermint:		
Diuron	2.4	Last cultivation before emergence.
Monuron	2.4	Do.
Peppers:		
Amiben	3–4	At transplanting or lay-by.
DCPA	6–10	Posttransplant.
Diphenamid	5	Immediately after seeding or within 1 month after transplanting.
Trifluralin	1	Preplant, soil incorporated postemergence on direct seeding, posttransplant.
Potatoes:		
CDAA	3–4	Preemergence, lay-by.
Dalapon	3	Preplant, preemergence, lay-by.
DCPA	6–10	At planting.
Diallate	1.5	Preplant, soil incorporated.
Diphenamid	4–6	Immediately after planting.
DNBP (alkanolamine salt).	3–6	Preemergence.
EPTC	3–6	Preplant, soil incorporated, drag-off, lay-by incorporated.
Linuron	1	Preemergence.
Sesone	3.6	Preemergence, postemergence, lay-by.
2,4-DEP	4	After clean cultivation at lay-by.
Pumpkins, NPA (sodium salt).	4	Preemergence.
Radish, CIPC	2	Do.
Spinach:		
CDEC	2–4	Preemergence, postemergence.
CIPC	1–2	Preemergence.
IPC	3–6	Preemergence, postemergence.
Squash, amiben	3–4	Do.
Sweetpotatoes:		
Amiben	3	At transplanting.
CDAA	4	Posttransplant.
DCPA	6–10	Do.
Diphenamid	4–6	At transplanting.
EPTC	7.5	Do.

TABLE 6.—*Weed control in vegetables*—Continued

Crop and herbicide	Pounds of active ingredient per acre	Time of application
Tomatoes:		
Amiben	3	Posttransplant.
CDEC	2–4	Preemergence, posttransplant.
DCPA	10.5	Lay-by.
Diphenamid	4–6	Immediately after seeding or within 1 month after transplanting.
Pebulate	4	Preplant, postemergence, soil incorporated.
Trifluralin	1	Preplant, soil incorporated for transplants or postemergence on direct seeding.
Turnip greens:		
CDEC	2–4	Preemergence.
CIPC	1–2	Do.
DCPA	10.5	Do.
Turnips, CDEC	2–4	Do.
Upland cress, CIPC	2	Do.
Watermelons, NPA (sodium salt).	2–6	Preemergence, posttransplant.

[1] 50–100 gal. per acre.
[2] 114 gal. per acre.

DECIDUOUS TREE FRUITS AND NUTS

Many different cultural methods and combinations of methods are used in deciduous tree fruit and nut crop production. Principal among these are sod culture, strip sod and cultivation, and clean cultivation.

Herbicides are being used effectively on several of these crops. In certain of the nut crops, bare soil culture is maintained with herbicidal oils. Sod culture is often combined with the use of herbicides to control perennial woody and annual herbaceous weeds not controlled by mowing. Clean cultivation may be conveniently combined with herbicide treatments to control germinating weed seed and sprouting perennial weeds to extend the periods between cultivations and thereby minimize root and trunk injury.

Examples of herbicides that have proved useful on deciduous tree fruit and nut crop plantings in some regions are presented in table 7. They indicate the general areas of usefulness of herbicides for these crops. Specific rates and methods for safe and effective local use are available from weed research specialists in State agricultural experiment stations.

TABLE 7.—*Weed control in deciduous tree fruits and nuts*

Crop and herbicide	Pounds of active ingredient per acre	Time of application
TREE FRUITS		
Apples:		
AMS	54 in 100 gal. water.	In wetting spray to poison-ivy in full leaf.
CIPC	8	During dormancy.
Dalapon	11	As spot spray around base of trees over 4 years old to control grass.
Dichlobenil	6	Early spring or after clean cultivation.
Diphenamid	6	After clean cultivation but not within 90 days of harvest.
Diuron	3. 2	Winter or spring.
DNBP (butylphenol).	1. 9	Coarse spray to ground cover when weeds are small.
Simazine	2–4	In spring before weeds emerge.
Apricots:		
Aromatic oil emulsion.	(1)	Directed spray on young growing weeds.
Dalapon	11	As spot spray around base of trees to control grass when weeds are small.
Cherries:		
Dichlobenil	4–6	Granules preemergence to weeds.
Simazine	2–4	Soil treatment in late fall or early spring on dormant crop more than 1 year old.
Olives:		
Aromatic oil emulsion.	(1)	Directed spray on young growing weeds.
Diuron	1. 6	Split application fall and spring.
Simazine	2–4	Broadcast single directed application to soil before weeds emerge; apply in late fall or midwinter.
Peaches:		
Aromatic oil emulsion.	(1)	Directed spray on young growing weeds.
Dalapon	11	Spot spray on growing grass when weeds are small.
Dichlobenil	6	Granules in early spring.
Diphenamid	6	After clean cultivation, not within 90 days of harvest.

See footnote at end of table.

TABLE 7.—*Weed control in deciduous tree fruits and nuts*—Continued

Crop and herbicide	Pounds of active ingredient per acre	Time of application
TREE FRUITS—continued		
Peaches—Con.		
DNBP (butylphenol).	1.9	Directed coarse spray to ground cover when weeds are small.
Simazine	4	As soil application around established trees before weeds emerge; after harvest to early spring.
Pears:		
AMS	54 in 100 gal. water.	In wetting spray to poison-ivy in full leaf.
Aromatic oil emulsion.	(1)	Directed spray on young growing weeds.
Dalapon	11	Spot spray on growing grass when weeds are small.
Dichlobenil	6	Granules in early spring.
Diuron	1.6	Directed spray during dormancy, winter and spring.
DNBP	1.9	Directed coarse spray on ground cover.
Simazine	4	Directed spray during dormancy on well-established trees.
Plums:		
Aromatic oil emulsion.	(1)	Directed spray on young growing weeds.
Dalapon	11	Spot spray on growing grass when weeds are small.
Dichlobenil	6	Granules in early spring.
DNBP	1.9	Directed coarse spray on ground cover when weeds are small.
Simazine	4	Directed soil treatment on well-established plantings when weeds are small.
TREE NUTS		
Almonds, aromatic oil emulsion.	(1)	Directed spray on young growing weeds.
Walnuts, aromatic oil emulsion.	(1)	Do.

[1] 40–100 gal. per acre.

CITRUS AND SUBTROPICAL FRUITS AND NUTS

Citrus and subtropical fruit and nut crops include all citrus crops, avocados, dates, macadamia nuts, pineapples, and many other crops. Weed problems are many and varied because of the wide distribution of these crops, their perennial nature, and the variety of cultural practices used. Weeds waste irrigation water in plantings of many of these crops. Weeds also harbor insects, diseases, nematodes, and rodents that cause severe economic losses.

Herbicides used in combination with mechanical cultivation are economical, effective, and convenient to use. In many instances damage caused by close cultivation can be avoided and the periods between cultivations lengthened by using herbicides.

Aromatic oil emulsions have been used effectively for more than 20 years in many citrus orchards in the West without reducing fruit yield and quality or visibly injuring the groves with respect to tree physiology or soil structure. Newer organic chemical herbicides have been developed and are proving useful in areas where oils cannot be used and on weeds not controlled by oils. Many additional promising new herbicides are being investigated for use on these crops.

Examples of herbicides that have proved useful on citrus and subtropical fruit and nut crops in some regions are presented in table 8. They show the general areas of usefulness of herbicides for these crops. Specific rates and methods for safe and effective local use are available from weed research specialists in State agricultural experiment stations.

TABLE 8.—*Weed control in citrus and subtropical fruits and nuts*

Crop and herbicide	Pounds of active ingredient per acre	Time of application
Avocados:		
Aromatic oil emulsion.	(1)	Directed spray on young growing weeds.
Monuron	1.6	Soil treatment in spring and fall under well-established trees in California (selected areas only).
Simazine	2–4	Apply to orchard floor before weeds emerge, following final preparation of grove.

See footnote at end of table.

TABLE 8.—*Weed control in citrus and subtropical fruits and nuts*—Continued

Crop and herbicide	Pounds of active ingredient per acre	Time of application
Citrus (grapefruit, lemons, oranges):		
Aromatic oil emulsion.	(1)	Directed spray on young growing weeds.
Diuron	1.6	Soil treatment in fall and spring in groves established 1 year or more in Arizona and California (selected areas only).
Simazine	2	During rainy season on established plantings of lemons in Arizona and California.
	9.6	Oranges in Texas and Florida.
Dates, aromatic oil emulsion.	(1)	Directed spray on young growing weeds.
Limes, aromatic oil emulsion.	(1)	Do.
Macadamia nuts:		
Dalapon	9	On established grass before crop harvest and after gleaning nuts.
Diuron	2–4	Soil treatment; directed spray immediately after harvest.
Simazine or atrazine.	2–4	Soil treatment before harvest and after gleaning nuts.
Pineapples:		
Diuron	1.6–3.2	Soil treatment immediately after planting or after harvest.
Monuron	1.6–3.2	Do.
Simazine	3.2–4	Do.

[1] 40–100 gal. per acre.

SMALL FRUITS

Small fruits include cane fruits, cranberries, grapes, and strawberries. Highly specialized weed-control methods are required because of the different growth habits and stature and the perennial nature of these crops. Many weed species must be controlled in summer and winter in many production areas.

Parts of these crop plants are above ground at all times. It has therefore become a general practice to use directed, coarse, low-pressure sprays that avoid herbicide contact with the

crop wherever possible. In some crops, such as cranberries and strawberries, the use of directed sprays is not possible. Here highly selective herbicides such as granular formulations are most useful.

Examples of herbicides that have been used successfully on small fruit crops in some production areas are given in table 9. Specific rates and methods of application are not given, because climate, soil composition, cultural practice, and crop variety affect performance, selectivity, persistence, and injurious effects of herbicides. Specific recommendations for safe and effective local use of herbicides based on local research are available from weed specialists in State agricultural experiment stations.

TABLE 9.—*Weed control in small fruits*

Crop and herbicide	Pounds of active ingredient per acre	Time of application
Blackberries:		
CIPC	2–6	Soil treatment in dormant crop.
Diuron	1–2	Soil treatment in dormant crop 1 year old or more.
Simazine	2–4	During dormancy of crop.
Blueberries:		
CIPC	6–12	Do.
Diuron	1–2	Soil treatment in dormant crop 1 year old or more.
Simazine	2–4	During dormancy of crop.
2,4-D	0.25–0.5	Before burn during dormancy.
Cranberries:		
Dalapon	8.8	Postharvest as directed spot spray on growing grasses.
Dichlobenil	1–4	Granules, prebloom or postharvest.
Ferrous sulfate	800	Spring to mid-summer.
Simazine	2–4	Soil treatment in dormant crop in Massachusetts only.
2,4-D	0.25–0.5	On growing weeds during dormancy of crop.
Gooseberries, diuron.	1–2	Soil treatment in dormant crop 1 year old or more in early winter.
Grapes:		
CIPC	10–14	Directed spray in early spring on dormant crop.
Dalapon	15	Directed spot spray on growing grass during vegetative growth of crop.
Diuron	1–2	Soil treatment in dormant crop established at least 3 years.
DNBP (alkanolamine salt).	1.25	Dormant application to ground under trellis.
Simazine	2–4	Soil treatment from late fall to early spring on crop established at least 3 years.
Raspberries:		
CIPC	2–6	During dormancy of crop or at time of planting.
Diuron	1–2	Soil treatment in early winter on dormant crop established at least 1 year.
Sesone	2–4	Directed soil treatment in dormant or vegetative crop.
Simazine	2–4	During dormancy of crop.
Strawberries:		
CIPC	1–2	During dormancy to control established and germinating chickweed.
DCPA	9	Soil treatment after transplanting or lay-by cultivation.
DNBP (amine salts).	3–4.5	During dormancy in early spring or after harvest in Northwestern States only.
EPTC	4	New beds—1 month after planting; old beds—following clean cultivation after harvest.
Sesone	3–4	Soil treatment after transplanting and postharvest avoiding flowering and fruiting period.
Simazine	1	3–4 weeks after planting.
2,4-D	0.25–0.5	Spray young growing weeds after harvest.
2,4-DEP	4	Preplant or post-transplant in nonharvest year; postharvest in production fields.

TABLE 9.—*Weed control in small fruits*—Con.

ORNAMENTAL PLANTS

Ornamental plants, including shade trees, shrubs, herbaceous annuals and perennials, and bulb crops, form the bulk of plant species in horticultural crops. Some ornamental genera include numerous species and many varieties. Weed problems are widely different because of the individual soil, climatic, and cultural requirements of many of these plants. The number of herbicides available for home or other landscaped plantings is limited because many kinds of plants are grown together. Weeds in commercial plantings of individual species or varieties are controlled by mechanical cultivation, hand weeding, herbicides, cultural practices including rotations, and various combinations of these methods.

Ornamental plant families, genera, species, and even varieties respond differentially to herbicides. Great care is therefore necessary in selecting and using herbicides on them. As a result, soil fumigant herbicides are used in many nurseries. Soil fumigant herbicides are applied, kill many annual and perennial weeds, and are dissipated before planting the crops. Most crops can be planted within a few days after fumigants have been used. General use of soil fumigant herbicides is restricted by the cost of material and time required for treatment. Comparatively low-cost selective herbicides are therefore often used to control specific groups of weeds.

Examples of herbicides that are useful on ornamentals in certain regions are presented in table 10. These examples indicate the general areas of herbicide usefulness and their potential value in these crops. Specific rates and methods for safe and effective local use are available from weed research specialists in State agricultural experiment stations.

TABLE 10.—*Weed control in ornamental plants*

Herbicide	Pounds of active ingredient per acre	Tolerant plants
CDEC	4–6	Use directed spray or granules on soil in established ornamental plantings: Azalea, euonymus, gladiolus, iris, juniper, *Potentilla*, privet, spirea, yew.
CIPC	6–10	Use directed spray or granules on soil in established plantings: Arborvitae, aster, *Astilbe*, azalea, balsam, barberry, birch, bluebell, boxwood, camellia, carnation, cedar, chrysanthemum, columbine, coralbell, creeping juniper, dahlia, delphinium, dianthus, Dutch iris, English ivy, forget-me-not, forsythia, fuchsia, gladiolus, honeysuckle, hydrangea, laurel, lilac, lily, magnolia, *Mahonia*, maple, mock-orange, narcissus, pachysandra, peony, periwinkle, poplar, privet, rhododendron, rose, spirea, tulip, viburnum, wintercreeper, yew.
DCPA	10–15	Use directed spray or granules on soil in established ornamental plantings: Ageratum, alyssum, aster, azalea, babysbreath, barberry, bleedingheart, candle larkspur, chrysanthemum, coleus, columbine, coralbell, dahlia, euonymus, evening-primrose, feverfew, forget-me-not, forsythia, gladiolus, golden marguerite, lantana, lupine, marigold, moss rose, mourning bride, mourning pinks, petunia, pokerplant, purple coneflower, rose, salvia, scarlet sage, snapdragon, variegated privet, verbena, yew, zinnia.
Dichlobenil	4–6	Use directed spray or granules on soil in established ornamental plantings: American elm, barberry, boxelder, boxwood, Chinese elm, cottonwood, eastern redcedar, euonymus, fir, forsythia, green ash, hackberry, holly, honeylocust, juniper, pine, privet, pyracantha, rose, Russian-olive, spruce, yew.
Diphenamid	4–6	Use directed spray or granules on soil in established ornamental plantings: Evergreen, deciduous trees.
DNBP (alkanolamine salt).	10. 5	Use directed spray or granules on soil in established ornamental plantings: Dahlia, Dutch iris, gladiolus, lilac, lily, narcissus, privet, spirea, tulip, yew.
Neburon	4	Use directed spray or granules on soil in established plantings: Arborvitae, *Chamaecyparis*, euonymus, firethorn, forsythia, honeysuckle, juniper, pine, privet, yew.
NPA (sodium salt).	4–6	Use directed spray or granules on soil in established ornamental plantings: Azalea, cottonwood, holly, maple, plum, rhododendron.

TABLE 10.—*Weed control in ornamental plants*—Continued

Herbicide	Pounds of active ingredient per acre	Tolerant plants
Sesone	3–4	Use directed spray or granules on soil in established plantings: Arborvitae, balsam, barberry, bayberry, camellia, cedar, crabapple, daffodil, dahlia, elm, forsythia, gladiolus, heather, hemlock, honeysuckle, hydrangea, iris, juniper, laurel, lilac, lily, maple, mockorange, *Picea*, pine, redcedar, rose, spirea, spruce, viburnum, white birch, yew.
Simazine	2–3	Use directed spray on soil in established ornamental plantings: American elm, arborvitae, Austrian pine, barberry, blue spruce, boxelder, boxwood, bush-honeysuckle, *Caragana*, cotoneaster, dogwood, Douglas-fir, Fraser fir, hemlock, honeylocust, juniper, *Mahonia*, mugo pine, multiflora rose, Norway spruce, redcedar, red oak, red pine, red spruce, rose, Russian-olive, Scotch pine, Siberian elm, white-cedar, white pine, white spruce, yew.
Stoddard solvent.	(1)	In directed spray on emerged weed seedlings between rows: Most ornamentals.
Trifluralin	0. 5–1	In directed spray or granules on soil in established plantings of gladiolus, many other ornamentals.

[1] 50–100 gal. per acre.

WEED CONTROL IN HORTICULTURAL PLANT BEDS AND NURSERIES

The growing of vegetable and ornamental transplants in plant beds and nurseries is a major horticultural industry. Seeds are planted in open fields in the South and in hotbeds in the cooler areas. High rates of seeding are used and weeds that emerge with the crops cannot be removed mechanically. Weed separation and removal by hand are difficult and time consuming. Plants involved include tomatoes, peppers, eggplant, celery, petunias, marigolds, and many other vegetable and ornamental plants.

Large numbers of ornamental plants are vegetatively propagated from cuttings. Weeds are difficult and expensive to control in slathouses, coldframes, and liner plantings in the field. Plants propagated vegetatively include azaleas, camellias, rhododendrons, pyracantha, and ilex.

Weed seed and the underground parts of perennial weeds in coldframes, hotframes, and slathouses are usually controlled by soil fumigation. Field plantings of large populations of plants often include soil fumigation as a preparatory measure. Cultural practices, including selected rotation procedures, should supplement the use of herbicides.

Soil fumigant herbicides and their use are described briefly in table 11. Specific details for effective use of fumigants under local conditions are available from weed research specialists in State agricultural experiment stations.

TABLE 11.—*Weed control with soil fumigant herbicides in horticultural plant beds and nurseries*

Herbicide	Pounds of active ingredient per 100 sq. ft.	Method of application after preparation of soil for planting
DMTT	0. 67	Apply wettable powder suspended in water in sprinkling can or sprayer or mix powder with sand and spread in lawn spreader; mix herbicide to depth of 5–6 inches; sprinkle-irrigate with 1–2 inches of water; wait 3 weeks or longer before planting.
Methyl bromide.	1–2	Cover soil with plastic sheet; inject methyl bromide under plastic; allow soil to remain covered 24–48 hours; remove cover and aerate 72 hours or longer before planting.
SMDC	0. 67–1	Apply herbicide with sprinkling can or hose proportioner; mix herbicide to depth of 5–6 inches; sprinkle-irrigate immediately to desired depth of control; plant 14–30 days after treatment depending on soil composition and moisture content.

WEED CONTROL IN GREENHOUSES

Weeds in greenhouse bench and potting soils and under the benches generally can be controlled with herbicides and by steam sterilization.

Weeds in bench and potting soils can be controlled with soil fumigant herbicides, such as methyl bromide, DMTT, or SMDC, before the soil is brought into the greenhouse or potting room. Rates and methods of using these herbicides are briefly described in the preceding discussion on weed control in plant beds and nurseries. Specific details for use are given by the manufacturers,

and information on techniques for specific problems can be obtained from weed research specialists in State agricultural experiment stations.

Weeds under the benches and around pots in the benches can be controlled by using a coarse spray of Stoddard solvent. The weeds should be small at the time of treatment. A complete spray coverage of the weed foliage is necessary. Direct the spray to avoid contact with the foliage or stalks of crop plants or move the pots from the bench area during spraying. Keep fresh air moving into the greenhouse during treatment and for 2 to 4 hours thereafter.

Great care must be exercised to avoid crop injury when herbicides are used in maintenance programs in greenhouses. Crop injury may result from using volatile herbicides that produce generalized effects on all plants or from persistent herbicides that remain in soils for long periods. Stoddard solvent is suggested for greenhouse use because it avoids these hazards. It will kill many species of young growing broadleaved weeds and weed grasses within a few hours after application and does not leave a chemical residue.

WEED CONTROL IN FORAGE CROPS, PASTURES, AND RANGELANDS

Weeds, including brush, are undesirable in forage crops and grazing lands because they reduce production of palatable forage, some injure livestock through needles and thorns, many are poisonous, others impart undesirable flavors, and in general they reduce the quantity and quality of animal products. Improved crop-production practices, including proper fertilization, drainage of soils where necessary, judicious mowing and grazing practices, and disease and insect control, contribute to the vigor of forage plants, which, in turn, aid in preventing weed problems and in some cases will reduce weed populations. This is particularly true for many annual weeds developing from new seedlings each year.

Some weed species, however, are favored by the same conditions responsible for vigorous growth of forage plants; for example, curly dock and chickweed are favored by high fertility in humid regions. Also, where woody plants tend to dominate the vegetation, they must be removed to achieve efficient production of forage because most will not yield to ordinary management practices. In addition, many persistent perennial weeds will not succumb to the known agronomic practices within a reasonable time. Fortunately selective herbicides are now available that will aid in dealing with many of these problems.

Selective herbicides, by killing unwanted species, may hasten the succession to more desirable plants. Many pastures and rangelands are so depleted of desirable species that a long time would be required for natural succession to take place if only improved grazing management is practiced. Here seeding adapted forage species may be necessary. By selective control of the undesirable species, along with improved grazing practices, the recovery of native forage plants and other desirable species may be greatly speeded.

The herbicides 2,4-D, 2,4,5-T, silvex, and MCPA are not poisonous to livestock, wildlife, or man at the application rates used to control weeds in forage crops, pastures, and rangelands and do not injure most forage grasses. If no poisonous plants are present in the treated area, livestock other than milk cows need not be removed during or after application. Milk cows should be removed from the pastures for a week after spraying because of possible residues in the milk. If poisonous weeds or poisonous woody plants are known to occur in pastures or on rangelands, remove the livestock from the area for at least 3 weeks after treatment. Several herbicides, including 2,4-D, 2,4,5-T, and MCPA, are known to produce marked changes in the chemical composition of treated plants. Some herbicides affect the palatability of certain plants, and livestock will graze some treated species that they normally would not eat.

Single applications of foliage sprays will often control mesquite, sand sagebrush, big sagebrush, perennial ragweed, and other weeds on permanent pastures and rangelands. However, repeated treatments are usually needed for most woody plants and perennial weeds (table 12). For satisfactory control of mixed stands of oak species and buckbrush, for instance, repeated annual applications for 2 or more years, with not more than 2 years intervening between treatments, are normally required. Where native grasses are present, it is often desirable to defer the grazing during the growing season for 1 or 2 years.

TABLE 12.—*Weed control in forage crops, pastures, and rangelands*

[Numbers in parentheses=pounds of active ingredient per acre unless otherwise indicated]

Crop and treatment	Time of application	Weeds controlled	Remarks
		FORAGE CROPS	
Alfalfa and birdsfoot trefoil:			
New seedings:			
CIPC (2)	Postemergence, late fall or early winter.	Chickweed	Do not use if grass is planted with legume.
Dalapon (2)	4 weeks after seeding or when grasses are less than 3 inches tall.	Crabgrass, foxtail	Stunts alfalfa temporarily; repeat treatments later in summer; no injury to trefoil; do not feed first year's growth to dairy cows or animals being finished for slaughter.
Dalapon (2–4) plus 2,4-DB (1.5).	When weeds are 2–3 inches tall.	Weed grasses, broadleaved weeds.	Repeat dalapon treatment for grasses that germinate in summer; do not feed first year's growth to dairy cows or animals being finished for slaughter.
DNBP (0.75–1.5)	When weeds are small and seedlings have 2 or more true leaves.	Chickweed, henbit, pepperweed, weed bromegrass.	Often injures birdsfoot trefoil; use in alfalfa or alfalfa-grass mixtures only.
DNBP amine salts (0.75–1.5) in 20–40 gal. water.	After emergence of alfalfa seedlings when weeds are small.	Bitterweed, lambsquarters, mustard, pigweed, ragweed, sneezeweed, tarweed.	Injures trefoil.
EPTC (2–4)	Immediately before planting alfalfa or birdsfoot trefoil.	Weed grasses, some broadleaved weeds.	Mix with soil by disking or vigorous harrowing; herbicide volatile, lost if applied on wet soil or allowed to remain on surface for short time.
2,4-DB amine salts or esters (1–1.5) in 5–20 gal. water.	Postemergence when weeds are less than 3 inches tall.	Broadleaved weeds	Can be applied at later stage of growth than DNBP; do not graze or feed treated plants to livestock within 30 days after application.
Established stands:			
CIPC (2)	In fall when legumes are dormant and weeds small.	Chickweed	
Diuron (2)	In fall after crop is dormant or early spring.	Annual weeds in Northwestern States.	Stands must be at least 1 year old.
Diuron (3)	do	Downy bromegrass	Do.
DNBP amine salts (2) in 20–40 gal. water.	In fall when legumes are dormant and weeds small.	Chickweed, henbit, yellow-rocket seedlings.	Re-treatment in late winter or early spring necessary for heavy infestations.
2,4-D or MCPA (0.12–0.25).	Early *dormant* stage of legume.	Sensitive broadleaved weeds.	Use only as emergency measure if weed infestation threatens crop.
Alfalfa:			
CIPC granular (6)	Before or during dodder emergence and/or after first cutting.	Dodder	Timing critical.[1]
Weed burner	Stubble following first cutting.	do	Kill top growth with light flame; burn patches clean when vegetation has dried.
Clovers—alsike, crimson, ladino, red, and white—new seedings:			
CIPC (2)	Late fall or early winter	Chickweed	Do not use if grass is mixed with clover.
CIPC, EPTC, or IPC (4).	Immediately before planting clover.	Weed grasses, some broadleaved weeds.	Disk into soil before weed germination.
IPC (4)	Postemergence when clover has at least 3 true leaves.	do	Do not use if grass is mixed with clover.

See footnote at end of table.

TABLE 12.—*Weed control in forage crops, pastures, and rangelands*—Continued

Crop and treatment	Time of application	Weeds controlled	Remarks
FORAGE CROPS—continued			
Clovers—ladino, red, and sweet:			
New seedings:			
DNBP (0.75–1.5) in 20–40 gal. water.	When weeds are small and clovers have 2 or more true leaves.	Chickweed, henbit, pepperweed, weed bromegrass.	Do not graze treated areas or feed treated forage to livestock before first cutting.
DNBP amine salts (0.75–1.5) in 20–40 gal. water.	After emergence of clover seedlings when weeds are small.	Bitterweed, lambsquarters, mustard, pigweed, ragweed, sneezeweed, tarweed.	Do.
2,4-DB (1–1.5) in 20–40 gal. water.	Postemergence when weeds are less than 3 inches tall.	Broadleaved weeds	Can apply at later stage of legume growth than DNBP.
Established stands:			
CIPC (2)	In fall when clovers are dormant and weeds small.	Chickweed	
DNBP amine salts (2) in 20–40 gal. water.	do	Chickweed, henbit, yellow-rocket seedlings.	Re-treatment in late winter or early spring necessary for heavy infestations.
2,4-D or MCPA (0.12–0.25).	Early dormant stage of clover.	Sensitive broadleaved weeds.	Use only as emergency measure if weed infestation threatens seed crop.
PASTURES AND GRASS-SEED FIELDS			
Grasses:			
New seedings:			
Summer fallow	1 year before planting grass.	Perennial weeds including bermudagrass, Canada thistle, johnsongrass, quackgrass.	Reduce or eradicate these species before planting grasses.
Thorough tillage in intertilled crops.	1–2 years preceding planting grass.	Annual broadleaved weeds, annual grasses.	Where winter annual grasses are problem, delay grass seeding until after last hard freeze in spring if rainfall or irrigation is sufficient to establish seedlings before heat and summer drought start.
Silvex (0.5–0.75)	After grass seedlings have reached 2–4 leaf stage.	Chickweed, henbit, knotweed.	Do not exceed 0.5 lb. of silvex per acre until grasses become well established.
2,4-D amine salts or esters (0.75).	do	Broadleaved weeds	If land is heavily infested with seeds of annual grasses, delay application until broadleaved weeds are 12–15 inches tall to aid in preventing germination of weedy grasses.
Sprigged stands of bermudagrass, simazine, or diuron (3.2).	Just before or just after sprigging before weeds emerge.	Annual broadleaved and weed grasses.	Use 1.5 lb. of herbicide per acre on sandy soil; delay grazing or hay harvest at least 5 months after treatment.
Seed fields:			
CIPC or IPC (2–3)	Late fall	Winter annual weeds in Northwestern States.	Especially effective on annual grasses.
Diuron (2–3)	Late fall, established fields.	Winter annual weeds including bromegrass.	Do not use on light sandy soils.

TABLE 12.—*Weed control in forage crops, pastures, and rangelands*—Continued

Crop and treatment	Time of application	Weeds controlled	Remarks
PASTURES AND GRASS-SEED FIELDS —continued			
Pastures:			
Renovation on soils too hilly or stony to be plowed, dalapon (7.4).	Late summer	Sod, weed grasses	Graze turf heavily during summer, then kill undesirable grasses; disk dead sod 3–5 weeks after treatment and seed; control broadleaved weeds by selective herbicides in new seeding with 2,4-D or 2,4,5-T.
In humid areas, amitrole (1) plus dalapon (4).	Late summer	Broadleaved weeds, weed grasses.	Combination gives excellent control of sod and some broadleaved weeds; disk dead sod 3–5 weeks after treatment and reseed; do not graze for 8 months after treatment.
PERMANENT PASTURES AND RANGELANDS			
Pastures:			
Fertilize adequately, mow when grass becomes coarse, graze area intensively.		Broomsedge	Consult local authorities for recommended rates and times of fertilizer application.
2,4-D amine salts or esters (0.5–1).	Usually late spring	Bitterweed, boneset, burdock, Canada thistle, chicory, dandelion, ironweed, pigweed, ragweed, sneezeweed, tarweed.	Spray while weeds are actively growing; in humid area where legumes are in pasture, delay treatments until initial rapid growth of legumes has passed; remove milk cows from pasture for 7 days after spraying.
2,4-D esters (1–2)	Between February and May.	Curly dock, wild garlic, wild onion.	If second application is necessary, treat between October and December; remove milk cows from pasture for 7 days after spraying.
2,4-D, 2,4,5-T, MCPA, or silvex (1–2).	When weeds are most susceptible.	Broadleaved weeds	May injure legumes, then seriousness of weed infestation will determine use of herbicide; remove milk cows from pastures for 7 days after spraying; if poisonous weeds or woody plants are in area, remove livestock for 3 weeks after treatment.
2,4,5-T amine salts or silvex (1–2).	Fall, winter, or spring	Bedstraw, chickweed, henbit, knawel.	These herbicides kill lespedeza and seriously injure true clovers; remove milk cows from pasture 7 days after spraying.
Rangelands:			
Silvex low-volatile esters (0.67).	May 15–June 30	Yucca	
Silvex or 2,4,5-T low-volatile esters (0.5–1).	Full leaf stage and growing actively.	Shinnery oak	Tops killed with 1 application; to reduce stands make 2–3 annual applications; in drought years or if foliage damaged by frost, defer spraying until next year.
2,4-D (1.5–2) in 3–5 gal. oil, water, or oil-water emulsion.	After spring growth and before soil moisture is depleted in upper 8–10 inches.	Big sagebrush	Properly timed mowing also controls sagebrush; can be done where terrain is not too rough.
2,4-D (3) in 5 gal. oil or oil-water emulsion.	New twig growth 3 inches or longer and before soil moisture is depleted in upper 8–10 inches.	Rabbitbrush	More difficult to control than sagebrush; do not apply when soil moisture is critically low.

TABLE 12.—*Weed control in forage crops, pastures, and rangelands*—Continued

Crop and treatment	Time of application	Weeds controlled	Remarks
PERMANENT PASTURES AND RANGELANDS —continued			
Rangelands—Con.			
2,4-D esters (1) in 1–4 gal. water, diesel oil, or oil-water emulsion.	In May or early June with 6–8 inches of new growth.	Sand sagebrush	Diesel oil preferred for lowest gallonage.
2,4-D esters (1–2) in 3–4 gal. water, diesel oil, or oil-water emulsion.	After full foliage (usually last part of May).	Buckbrush	Repeated annual sprayings may be necessary; correct timing important.
2,4-D esters (1.5–3)	Early spring, 3- to 5-leaf stage.	Deathcamas	Spraying ineffective if treatment is delayed.
	Fully emerged but before flower stems appear.	Low larkspur	Do not graze sprayed areas for at least 3 weeks after treatment.
2,4-D esters (2)	Bud to early bloom stage.	Locoweed, princesplume, silvery lupine, two-grooved milkvetch, waterhemlock, woody aster.	Repeated annual applications may be necessary; do not graze sprayed areas for at least 3 weeks after treatment.
	Early bolting stage	Tansy-ragwort	
2,4-D esters (3–5)	Prebloom stage	Orange sneezeweed	
2,4-D low-volatile esters (2).	Early branching, prebloom stage.	Halogeton	Near trails and bed grounds.
2,4,5-T esters (1) plus 2,4-D (2).	Full leaf stage after rapid growth.	Post oak	Mixture may be used if 2,4,5-T makes up at least ⅓ of mixture and use of 2,4-D is not hazardous; re-treatment within 2 years is necessary.
2,4,5-T esters or silvex (2).	Actively growing plants in late vegetative or early bud stage.	Timberline milkvetch	
	Full leaf stage after rapid growth.	Blackjack oak, post oak	Re-treat for 2–3 consecutive years.
2,4,5-T esters or silvex (2–4).	Late vegetative growth but before buds form.	Tall larkspur	Do not graze sprayed areas for at least 3 weeks after treatment.
2,4,5-T low-volatile esters (0.33).	Foliage in spring when soil moisture is adequate for growth.	Velvet mesquite	In arid Southwest re-treat within 2 years.
2,4,5-T low-volatile esters (0.5).	50–90 days after first leaves appear in spring.	Honey mesquite	Tops killed; re-treatment necessary in 5–7 years.
2,4,5-T low-volatile esters (8) in 100 gal. diesel oil.	When soil is dry	Agarita, catclaw, elbowbush, huisache, mesquite.	Apply to frills, stumps, or basal trunks.
2,4,5-T low-volatile esters (12–20) in 100 gal. diesel oil.	Basal spray summer or winter.	*Baccharis*, bayberry, beech, birch, *Ceanothus*, chestnut, chinkapin, cottonwood, hackberry, honeylocust, hydrangea, madrone, manzanita, mescalbean, mulberry, narrowleaf spirea, Osage-orange, pecan, prickly-ash, red haw, retama, sassafras, silver maple, spicebush, sumac, tree of heaven, walnut, wild chinaberry, willow.	Do.
2,4,5-T low volatile esters (16) in 100 gal. diesel oil.	Summer or winter	Ash, black gum, blackjack oak, bur oak, elm, hickory, pin oak, post oak, red maple, red oak, sweetgum, sycamore, water oak, white oak, willow oak.	Do.
2,4,5-T or silvex low-volatile esters (8) in 100 gal. diesel oil.	When plants are growing rapidly.	Chalk cactus, prickly-pear, tasajillo.	Wetting spray.
2,4,5-T low volatile esters (32) in 100 gal. diesel oil or undiluted.	Any time	Hardwood species more than 1 inch in diameter.	Tree injector or other injecting equipment; apply in cuts 2 inches apart at base of tree.

[1] See U.S. Department of Agriculture Farmers' Bul. 2211, Controlling Dodder in Alfalfa.

Annual weeds usually are most easily killed with herbicide foliage sprays while they are small. However, more nearly adequate control often results if spraying is delayed until germination and emergence of such weeds are mostly completed. Such delays may result in a higher overall percent control than if the treatments were applied earlier at the most susceptible stage of the early germinating weeds, because weeds germinating after spraying with the phenoxy herbicides are largely unaffected.

The most susceptible stage for perennial weeds varies greatly with the species and climatic conditions. Many perennial weeds are most susceptible when actively growing and at the late vegetative or early bud stages. However, some species, such as deathcamas and wild garlic, are most susceptible much earlier in their life cycle. Also, environmental conditions critically affect responses of species to herbicides. Therefore, details for controlling individual species usually should be obtained from local agricultural authorities.

For further information on the control of many range weeds, see the handbook on Chemical Control of Range Weeds, U.S. Department of Agriculture and U.S. Department of Interior, issued December 1966. The relative susceptibility of many common woody species to herbicides is given in U.S. Department of Agriculture Farmers' Bulletin 2158, Chemical Control of Brush and Trees. Also, the relative susceptibility of many weeds to 2,4-D, MCPA, 2,4,5-T, silvex, and 2,4-DB is tabulated in Farmers' Bulletin 2183, Using Phenoxy Herbicides Effectively.

WEED CONTROL IN LAWNS AND OTHER TURF AREAS

Good turf care, including proper liming, fertilization, watering, proper height and time of cutting, and control of insects and diseases, should accompany any program of weed control in lawns and other turf areas. Controlling weeds without correcting other lawn management problems will usually be disappointing. Vigorous turf is required to fill in the bare spots remaining after weeds are controlled. In addition, a vigorous dense turf will greatly aid in preventing reinfestation.

Table 13 contains information about herbicides that may be used to control weeds in lawns and other turf areas. Follow explicitly all directions on the container label. For further information on controlling lawn weeds with herbicides and for data on the susceptibility of many lawn weeds to phenoxy herbicides, see U.S. Department of Agriculture Home and Garden Bulletin 7ϑ, Controlling Lawn Weeds With Herbicides, and Farmers' Bulletin 2183, Using Phenoxy Herbicides Effectively.

TABLE 13.—*Weed control in lawns and other turf areas*

[Numbers in parentheses=pounds of active ingredient]

Treatment	Time of application	Weeds controlled	Remarks
		NEW SEEDINGS	
Methyl bromide (1) per 100 sq. ft.	When soil temperature is above 65° F.	Weed grasses and broadleaved weeds—all plant parts including seeds and seedling parts; also disease organisms, nematodes, insects.	Well-prepared, moist seedbed; apply under gastight cover; follow manufacturer's instructions; seed lawn 2–3 days after application; this soil fumigant is *deadly poison.*
Siduron (0.25) per 1,000 sq. ft.	Before weed-grass germination.	Crabgrass, other annual grasses.	Treat before, during, or after seeding; water within 3 days if no rain; use only on bluegrass and fescue lawns.
		ESTABLISHED LAWNS (WITH WEED GRASSES)	
Benefin, 1.5 oz. per 1,000 sq. ft.	Before weed emergence	Crabgrass	Do not overseed within 3 months after treatment.
Bensulide, 4–5 oz. per 1,000 sq. ft.	do	do	Do not overseed within 6 months after treatment.

TABLE 13.—*Weed control in lawns and other turf areas*—Continued

Treatment	Time of application	Weeds controlled	Remarks
ESTABLISHED LAWNS (WITH WEED GRASSES)—continued			
Calcium arsenate (10–16) per 1,000 sq. ft.	Late March or early April, before weed emergence.	Crabgrass	*Poisonous chemical;* keep children and animals off sprayed areas until after first rain.
DCPA (0.25) per 1,000 sq. ft.	do	do	
DSMA and similar arsonates (1.5–2.5) per acre.	After weed-grass emergence; re-treat at 7- to 10-day intervals until control is obtained.	Crabgrass, dallisgrass, goosegrass, sandbur.	Follow instructions on label; may slightly discolor turf.
Siduron (0.25-0.5) per 1,000 sq. ft.	Before weed-grass germination.	Crabgrass, other annual grasses.	
	Spot treatment when grasses actively growing.	Clumps of nimblewill, orchardgrass, quackgrass, timothy.	Will injure all grasses in treated spot; carefully treat weeds; if applied in warm moist soil, possible to reseed in 3–6 weeks.
Dalapon (0.25) in 1 gal. water per 1,000 sq. ft.	July; repeat 3–4 weeks later; water between applications.	Bermudagrass	Lawn grasses also killed by treatment; reseed 3 weeks after second application if temperatures are high, 6 weeks if temperatures are low; if soil is dry, water thoroughly before seeding.
DMTT plus SMDC (0.5–1) per 100 sq. ft.	Early August; repeat 4–6 weeks later.	do	Follow manufacturer's directions; reseed 3–4 weeks after second application.
Petroleum naphtha, 1 gal. per 1,000 sq. ft. (use full-strength coarse spray).	Spot treatment when grasses actively growing.	Clumps of nimblewill, orchardgrass, quackgrass, timothy.	Carefully treat weeds; also will kill lawn grasses.
ESTABLISHED LAWNS (WITH BROADLEAVED WEEDS)			
Dicamba (0.25) per acre.	When weeds are actively growing.	Chickweed, clover, henbit, knotweed, purslane, red sorrel.	Do not exceed recommended rate; stay away from shrubs and other ornamental plants.
Endothall (2) in 50–100 gal. water per acre.	When plants are small	Burclover, henbit, knotweed, pennywort.	May discolor foliage of ryegrass and bluegrass; keep children and animals off sprayed areas until after first rain.
Silvex (1–1.5) per acre or 0.4–0.5 oz. per 1,000 sq. ft.	Actively growing weeds	Burclover, chickweed, ground-ivy, henbit, knotweed, pennywort, violet, white clover, woodsorrel.	Fasten piece of kitchen sponge to end of stick or broom handle, dip sponge into solution, and spot treat broadleaved weeds by pressing moist sponge against crown of each plant; delay mowing 24–48 hours.
2,4-D amine salts or low-volatile esters (1) per acre (liquid or granular).	do	Buckhorn plantain, curly dock, dandelion.	Fasten piece of kitchen sponge to end of stick or broom handle, dip sponge into solution, and spot treat broadleaved weeds by pressing moist sponge against crown of each plant; delay mowing 24–48 hours; fall treatments allow cool-season lawn grasses to take over space left by dead weeds.
2,4-D amine salts or low-volatile esters (1–2) per acre plus detergent.	Late fall; repeat in late winter or early spring each year.	Knotweed, wild garlic, wild onion.	Follow directions on label; several successive fall and sprung treatments necessary for control.
2,4-D (1) plus dicamba (0.25) amine salts per acre.	When weeds are small	Chickweed, clover, henbit, knotweed, red sorrel.	Do not exceed recommended rate and avoid flowers and shrubs; esters and amines not compatible.
2,4-D (0.5) plus silvex (0.5) low-volatile esters per acre.	When weeds are small in cool weather of early spring.	do	Do not allow spray to drift onto trees and shrubs.

WEED CONTROL IN NONCROPLAND

CONSTRUCTION AIDS

Ditchbanks, fence rows, floodways, road and utility rights-of-way, and other uncultivated areas should be designed, constructed, and managed in a manner to enhance efficient vegetation control. Ditchbanks should be shaped to provide uniform crowns and slopes, and a roadway should be maintained on one bank or each bank for efficient and economic use of mowers, burners, and spraying machinery. Shaping ditches, grades, and back slopes along highways to avoid steep or irregular contours provides similar advantages. Fencing ditch rights-of-way and providing suitable livestock guards in lieu of gates greatly facilitate livestock grazing for weed control on ditchbanks. The livestock must be managed to avoid overgrazing.

Using metal fenceposts and metal or concrete structures in or along ditches and highways greatly facilitates the use of weed burners without damage to the posts and structures. Set corner posts and utility line poles in concrete to eliminate brace rods and wires, which are obstacles to weed-control treatments.

CULTURAL, BIOLOGICAL, AND MECHANICAL CONTROL

Seeding ditchbanks, fence rows, and rights-of-way to adapted species of low-growing grasses or other desirable plants usually provides sufficient competition to reduce greatly the weed problem and increase the effectiveness and economy of grazing, mowing, or selective herbicides used for vegetation control. Establishment of suitable stands of the desired competitive vegetation is much easier on recently constructed ditchbanks or road rights-of-way than on those already heavily infested with weeds. Frequently weed growth can be eliminated by repeated burning or by spraying with a nonpersistent herbicide and then grass or other revegetation mixture can be successfully established.

Grazing by livestock, where practicable and safe, usually provides effective and often the most economical means of vegetation control on ditchbanks and floodways. Other than grazing by livestock, only a few biological agents effectively control weeds on noncropland. Examples are insects that control Scotch-broom, gorse, and St. Johnswort in fence rows and other uncultivated areas.

Repeated mowing or burning with a butane, liquid propane, or petroleum burner tends to eliminate or reduce tall weed species and encourages the dominance of more desirable low-growing vegetation. Mowing or burning must be repeated three to eight times each growing season to maintain effective control of undesirable plants.

CONTROL WITH HERBICIDES

Choice of Herbicides and Rates

In choosing an herbicide or a mixture of herbicides and the rate of application for weed control in a noncrop area, the user should consider several environmental and site characteristics. They include (1) the dominant kind of vegetation present—annuals, deep-rooted herbaceous perennials, grasses, broadleaved weeds, mixed vegetation, or woody plants; (2) the objective—total vegetation control (soil sterilization—bare soil), selective control of broadleaved weeds and tall coarse grasses from short competitive and soil-binding grasses, or control of tall woody plants; (3) the type and fertility of soil—medium loam, heavy clay, or light sandy or gravelly loam with high or low organic matter content; and (4) the amount and distribution of precipitation.

Many herbicides that are effective on broadleaved weeds are not effective on weedy grasses and vice versa, but some herbicides are effective on both types. Usually the herbicides that are most soluble in water or oil and are applied in sprays give the most rapid kill of top growth. Herbicides that are less soluble in water usually remain in the soil longer and provide weed control during a longer time. The minimum amount of precipitation required to leach soil-applied chemicals into the soil around weed roots to make the herbicide effective ranges from 2 to 5 inches.

Persistence of an herbicide in soil tends to be longer under conditions of low precipitation, fine or tight texture of soil, low organic content, nonsubmergence by water, and low micro-organism content of the soil. Higher rates of application are usually required on heavier soils and soils high in organic matter and in regions of greater precipitation. More frequent application of herbicides may be required to maintain weed control on lighter soils and in areas of greater precipitation. Generally, repeated annual applications of soil sterilant herbicides at relatively light rates are more effective and economical than less frequent applications at heavier rates, especially for control of annual and shallow-rooted perennial weeds and seedlings of deep-rooted perennial weeds.

Few chemicals used alone will kill all species of plants under all climatic and soil conditions and at rates that are economically feasible. Mixtures of herbicides with different solubilities in water and different weed specificities are used much more commonly for complete vegetation control in noncrop areas than are used for selective weed control on either cropland or noncrop areas. Mixtures are finding wide use for soil sterilization where the soil is unproductive and remains bare for varying lengths of time. Usually each herbicide component in a mixture is applied at a rate

lower than the rate that would be required if it were used alone, and the total rate of the mixture is usually less than that of the major component herbicide if used alone. The herbicides most commonly used in mixtures are the sodium borates, sodium chlorate, simazine, and the phenylurea compounds. However, most of the other herbicides suitable for weed control on noncrop areas are available in one or several mixtures.

Soil sterilization is expensive and is practical only where complete vegetation control is desirable and soil erosion is not an important factor. Such areas are around signposts, bridge abutments, trestles along highways and railroads, utility poles, and buildings, under guardrails and transformer cages, along pipelines, on tank farms, near structures, above concrete linings along canals, and in parking lots and other noncultivated land where accessibility, visibility, fire prevention, and other considerations justify the expense.

Use of Herbicides for Woody Plants in Noncropland

The control of undesirable woody plants with herbicides along ditchbanks, roadsides, and utility lines or on flood plains and other noncrop areas differs from that on pastures and rangelands in the following respects: (1) The noncrop areas of woody plants frequently are in narrow strips so that aerial spraying often is not possible or feasible. (2) These areas usually are adjacent to or near crops or ornamentals that are sensitive to phenoxy-type herbicides. (3) Much greater care must be used in spraying woody plants. Dormant basal spray, frill, or stump treatments frequently must be substituted for foliage sprays along irrigation canals, reservoirs, lakes, and ponds to avoid contamination of water with herbicides not registered for use in water. (4) Noncrop areas generally are closer to adequate supplies of water so that use of high-volume drenching sprays is more economical and feasible than on rangelands. (5) Rapid control or elimination of undesirable woody plants in noncrop areas frequently is more critical and economically feasible than it is in rangeland. Consequently higher rates of herbicides and more expensive application methods, such as drenching foliage sprays, aerial spraying with a helicopter, basal sprays, and cut-surface treatments, are commonly used on noncrop areas.

Special Precautions in Use of Herbicides in Noncropland

Despite the absence of food or feed crops and usually of desirable ornamental plants in noncrop areas, all general precautions for safe use of herbicides described on page 3 should be followed. Do not allow livestock to graze ditchbanks, rights-of-way, or similar noncrop areas sprayed with herbicides not registered for use on pastures and do not feed hay harvested from such areas.

Avoid contamination of water to be used for irrigation in canals, ponds, or reservoirs by herbicides not registered for use in aquatic areas or on irrigated crops. Apply such herbicides on banks of irrigation and drainage canals, ponds, and reservoirs only when there is no water in the canal.

Use only amine or low-volatile esters of 2,4-D, silvex, or 2,4,5-T for spray applications in noncrop areas that are near sensitive crops or other desirable plants and prevent spray drift onto the desirable plants. Use of low spraying pressure and higher volumes of water or oil reduces the danger of spray drift. Additional protection against spray drift onto desirable plants is provided by using invert emulsions of ester formulations and of particulating or other thickening agents with water-soluble herbicides.

Suggested Uses of Herbicides in Noncropland

Examples of herbicide treatments that have been used successfully in noncropland are given in table 14. These examples show the scope of herbicide usage in noncropland. They are also guides for the use of herbicides under local conditions. However, rate ranges rather than specific rates are given. Times of application are given in general terms because local climate, soil composition, and slope of land, proximity to canals or ponds or desirable plants, and other site conditions affect the performance and persistence of herbicides and methods required for their safe use. Spot treatments for control of perennial weeds should be used where possible, especially where there is likelihood of contaminating water or injuring nearby desirable plants. Specific details for the safe and effective local use of herbicides can be obtained from weed specialists in the State agricultural experiment stations.

TABLE 14.—*Weed control in noncropland (ditchbanks, fence rows, floodways, industrial sites, and railroad, highway, and utility line rights-of-way)* [1]

[Numbers in parentheses=pounds of active herbicide per acre]

Weed and treatment	Time of application	Remarks
BROADLEAVED HERBACEOUS WEEDS (SELECTIVE CONTROL IN DESIRABLE GRASSES)		
Annuals, shallow-rooted perennials, and seedling perennials:		
Dicamba (0.5–1)	Early weed growth in spring	Kills only top growth of most perennials.
2,4-D (1–2)	Early growth to first bloom	Repeat as necessary to maintain control during growing season.
2,4,5-T (1–2)	do	Use for weeds difficult to control with 2,4-D, e.g., nightshade.
Deep-rooted and other hard-to-kill perennials:		
PBA (20–60)	Spray succulent foliage growth, preferably during period of adequate rainfall.	Some grasses injured by heavier rates.
Picloram (2–3)	Rapid vegetative growth to early bloom in spring or summer, vigorous rosette growth in fall, or soil application in fall.	Use special care to avoid spray drift on desirable plants or contamination of water to be used for irrigation; apply only as thickened spray; picloram persists for 3 years in some soils.
Picloram plus 2,4-D mixture (follow instructions on label).	Rapid vegetative growth to early bloom in spring or summer, vigorous rosette growth in fall.	Do.
TCBP (8–16)	During early growth or in fall when ground is not frozen.	Repeat as necessary to eliminate or reduce stand.
2,3,6-TBA (10–30)	Spray succulent foliage growth, preferably during period of adequate rainfall.	Some grasses injured by heavier rates.
2,4-D (2–4)	Rapid vegetative growth to early bloom in spring or summer, vigorous rosette growth in fall.	Repeat as necessary to eliminate or reduce stand.
2,4,5-T (2–4)	do	Use for weeds difficult to control with 2,4-D, e.g., perennial horsenettle.
WEEDY GRASSES WHERE CONTROL OF BROADLEAVED WEEDS NOT NECESSARY		
Annuals and seedling perennials:		
Aromatic oil, 40–80 gal. per acre	Spray young growth	Repeat as necessary to maintain control.
Dalapon (5–10)	Spray young growth 4–8 inches tall	Do.
DNBP or PCP fortified fuel oil, 40–80 gal. per acre.	Spray young growth	Use 2–3 pt. DNBP or 2–3 qt. PCP per 100 gal. fuel oil.
Established perennials (bermudagrass, johnsongrass, paragrass, quackgrass, reed canarygrass):		
Aromatic oil (120–160 gal. per acre)	do	Repeat every 3–4 weeks during growing season to eliminate or reduce stand.
Dalapon [2] (10–15)	Spray young growth 6–18 inches tall.	Repeat as necessary to suppress growth.
Dalapon [2] (20–30)	Early growth to early heading	Repeat every 6–8 weeks or as necessary to eliminate or reduce stand; lighter rates repeated more frequently sometimes more effective.
DNBP fortified fuel oil, 120–160 gal. per acre.	Spray young growth	Same as with aromatic oil; use 2–3 pt. DNBP per 100 gal. fuel oil.
DSMA or MSMA, 2.5–5 lb. per 100 gal. water per acre.	When weeds are actively growing	Add 1–2 pt. surfactant and spray until thoroughly wet.
Sodium TCA (100–150)	On aftermath growth in fall or as soil treatment.	More effective when adequate precipitation follows; may seed desirable grasses next season.

See footnotes at end of table.

TABLE 14.—*Weed control in noncropland (ditchbanks, fence rows, floodways, industrial sites, and railroad, highway, and utility line rights-of-way)* [1]—Continued

Weed and treatment	Time of application	Remarks
WEEDY GRASSES WHERE CONTROL OF BROADLEAVED WEEDS NOT NECESSARY—continued		
Established perennials (Phragmites, reed canarygrass):		
Amitrole (8–12)	On young growth before heading	Repeat 2–3 times each growing season to eliminate or reduce stand; lighter rates will suppress growth; use only in drainage ditches and marshes.
Amitrole-T (4–6)	do	Do.
PERENNIAL SEDGES ON IRRIGATION AND DRAINAGE DITCHBANKS		
Tall sedges along irrigation and drainage ditches, around ponds (e.g., Nebraska sedge):		
Amitrole or amitrole-T (5–10)	On young growth 10–15 inches tall	Repeat 2–3 times each growing season to suppress growth; use only in drainage ditches and marshes.
Amitrole or amitrole-T (10–20)	On young growth before heading	Repeat every 6–8 weeks as necessary to eliminate stand; use only in drainage ditches and marshes.
Dalapon [2] (15–30)	On young growth 10–15 inches tall	Repeat as necessary to suppress growth to desired extent; use only in drainage ditches and marshes.
DNBP fortified fuel oil, 120–160 gal. per acre.	do	Repeat every 4–6 weeks as necessary to eliminate stand; use 2–3 pt. DNBP per 100 gal. fuel oil; avoid contamination of irrigation or potable water.
2,4-D (60–80)	do	Repeat as necessary to eliminate stand; permits survival and spread of Kentucky bluegrass; avoid contamination of irrigation or potable water.
MIXED HERBACEOUS BROADLEAVED AND GRASS WEEDS		
Annuals, biennials, shallow-rooted perennials, and seedling perennials (*lower rates*); established deep-rooted and other hard-to-kill perennials (*higher rates*):		
Amitrole or amitrole-T (3–5; 6–12)	Early growth to first bloom	Repeat as necessary to maintain control or to eliminate or reduce stand; do not use along irrigation canals, reservoirs, lakes, ponds.
Amitrole plus simazine mixture (follow instructions on label).	do	Gives longer lasting control than amitrole alone; do not use along irrigation canals, reservoirs, lakes, ponds.
AMS (50–100; 400–1,000)	do	Mix ½–2 lb. per gal. water and spray to wet foliage; 1 formulation registered for use adjacent to reservoirs, lakes, ponds, canals, and streams including domestic water supplies at rates up to 200 lb. per acre.
Aromatic oil, 40–80 and 120–160 gal. per acre.	Spray young growth	Repeat as necessary to maintain control or every 3–4 weeks to eliminate or reduce stand.

See footnotes at end of table.

TABLE 14.—*Weed control in noncropland (ditchbanks, fence rows, floodways, industrial sites, and railroad, highway, and utility line rights-of-way)* [1]—Continued

Weed and treatment	Time of application	Remarks
MIXED HERBACEOUS BROADLEAVED AND GRASS WEEDS—continued		
Annuals, biennials, shallow-rotted perennials, and seedling perennials (*lower rates*); established deep-rooted and other hard-to-kill perennials (*higher rates*)—Con.		
Borate (sodium), 30–120 lb. per 1,000 sq. ft.; (1,300–5,200).	Before period of adequate precipitation.	Apply broadcast as soil treatment.
Borate mixtures with sodium chlorate and/or other chemicals (follow instructions on label).	Soil applications before period of adequate precipitation; spray applications on early growth to first bloom.	Use where soil sterilization (bare soil) desired.
Bromacil (3–6; 10–25)	Early growth to first bloom or before period of adequate precipitation.	Apply higher rates before period of greatest precipitation or when bottom or margins of canals, ditches, or ponds are not submerged by water.
Chlorate (sodium) (300–600; 700–1,300).	Spray foliage and make soil applications before period of adequate precipitation.	Observe all precautions to avoid fire hazard.
Chlorate mixtures with borates or other chemicals (follow directions on label).	do	Fire hazard usually less but caution necessary.
Dalapon plus 2,4-D or 2,4,5-T or silvex (5–10 plus 1–2; 15–30 plus 2–4).	Early growth to early bloom or heading.	Use 2,4,5-T where broadleaved weeds resistant to 2,4-D are present.
Dicamba (1–4; 4–8)	When weeds in active growth stage	Higher rates equally effective as soil application before period of adequate precipitation.
Diuron or monuron (5–20; 20–80)	Before period of adequate precipitation.	Diuron gives longer soil sterility; monuron more effective on deep-rooted weeds.
DNBP or PCP fortified fuel oil, 40–80 and 120–160 gal. per acre.	Young growth to first heading	Repeat as necessary to maintain control or every 3–4 weeks to eliminate or reduce stand; use 2–3 pt. DNBP or 2–3 qt. PCP per 100 gal. fuel oil.
Erbon (120–160)	When weeds are young and succulent or during period of adequate precipitation.	Make soil applications in late fall or winter in regions of wet winters and dry summers.
Ethylene glycol bis(trichloroacetate) (10–20).	Spray when weeds are about 12 inches tall.	Apply in fuel oil in sufficient volume to give complete coverage of all foliage.
Monuron-TCA (20–40; 40–66)	When weeds are young and succulent or during period of adequate precipitation.	Make soil applications in late fall or winter in regions of wet winters and dry summers.
Oil, 40–50 gal. per acre aromatic or fortified fuel oil plus 2,4-D ester (2–3).	Young growth to first heading	Apply same as for aromatic or fortified fuel oil; more economical and often more effective than oil alone.
Paraquat (cation) (0.5–2)	Spray young growth	Repeat as necessary to maintain control; kills top growth only of perennials.
Prometone (10–15; 20–60)	Spray early growth to first heading	Mix in water or oil; oil spray kills top growth quicker.
Simazine or atrazine (5–20; 20–40)	Spray early growth to first heading; soil applications before period of ample precipitation.	Simazine requires more precipitation for effective root kill; remains effective in soil longer.

See footnotes at end of table.

TABLE 14.—*Weed control in noncropland (ditchbanks, fence rows, floodways, industrial sites, and railroad, highway, and utility line rights-of-way)* [1]—Continued

Weed and treatment	Time of application	Remarks
	UNDESIRABLE WOODY PLANTS	
Alder, *Baccharis*, boxelder, cottonwood, poplar, sycamore, willow, and other species susceptible to 2,4-D, 2,4-D (2–4).	At full leaf in spring or early summer.	Apply in 100–300 gal. water per acre with ground equipment, or in 5–10 gal. water per acre or oil-water or invert emulsion by airplane or helicopter.
Mixed species including some susceptible to 2,4-D, 2,4-D plus 2,4,5-T (brush-killer mixture) (2–4) of 2:1 or 1:1 mixture.	do	Do.
Species resistant to 2,4-D or in areas near crops susceptible to 2,4-D:		
AMS (7–10) in 2 gal. water	Spray over freshly cut stump or in frills or notches cut around base of tree.	Cut notches every 6 inches around circumference of tree; crystals may be sprinkled liberally over cut stumps or in frills or notches.
AMS (60) in 100 gal. water	At full leaf in spring or summer	Spray to thoroughly wet foliage; with airblast mist-spray equipment use 100–400 lb. per 100 gal. water and apply at lower volume; to apply in oil-water emulsion follow directions on label; use mist spray only in areas far removed from crops.
Fenuron (east of Rocky Mountains) (12–25).	Just before or during period of adequate precipitation.	Apply broadcast or in grid pattern at 1–2 teaspoonfuls 3 ft. apart; apply same rate around base of individual trees or clumps of brush for spot treatments; increase rate 50 percent for cherry, dogwood, elderberry, Osage-orange, persimmon, sassafras.
FenuronTCA (12–25)	Spray at full leaf stage or broadcast before or during period of adequate precipitation.	Available in liquid, granular, and pelleted formulations for spray or broadcast applications.
Picloram (6–8.5)	Broadcast granules just before or during period of adequate precipitation.	Highest rate is necessary for ash, black gum, and oak; for spot treatments under individual trees or clumps of brush broadcast 1–2 tablespoonsful per 30 sq. ft. of soil surface; picloram persists for 3 years in some soils.
Picloram plus 2,4-D mixture (follow instructions on label).	Spray at full leaf during vigorous growth.	Use extreme care to avoid drift of spray to nearby desirable plants; spray solution may be applied to cut stumps or in frills; apply only in thickened spray; picloram persists in some soils for 3 years.
Silvex (2–4)	Spray at full leaf during active growth; spring treatments best for some species (e.g., saltcedar).	Silvex especially effective on maple, mulberry, palmetto, redbud, saltcedar (*Tamarix* sp.), trumpetvine.
2,3,6-TBA (10–20)	Spray foliage and soil when conditions suitable for active growth.	Especially effective on woody vines.
2,4,5-T (2–4)	Spray at full leaf during active growth; spring treatments best for some species (e.g., saltcedar).	Especially effective on brambles, mesquite, oak, Osage-orange.

[1] All herbicides listed are registered under the Federal Insecticide, Fungicide, and Rodenticide Act for suggested uses at time of publication, but some herbicides registered for use may not be included. Rates are in terms of acid equivalent or active ingredient of herbicide and not necessarily or usually of commercial formulation.

[2] When stand of perennial grass or sedge weakens, herbicide treatments are less frequent, and broadleaved weeds begin to invade, add amine or low-volatile ester formulation of 2,4-D at 1 to 2 lb. per acre.

CONTROL OF AQUATIC WEEDS

CONSTRUCTION AIDS

Deepening the edges of ponds, lakes, and reservoirs to 2 or more feet and filling in marshy spots prevent or reduce growth of emersed weeds such as cattail and waterprimrose. Also, fertilizers and herbicides control submersed weeds at the shoreline more effectively when the water is not shallow. Removal of stumps, logs, and other obstructions from ponds, lake margins, and access channels facilitates the use of underwater weed mowers.

A uniform gradient and absence of high or low spots in the bottom of an irrigation canal permit thorough draining of water and effective and economical control of submersed waterweeds in 3 or 4 days of drying. Deep canals with steep gradients and rapid waterflow provide less favorable conditions for growth of rooted submersed weeds.

Lining irrigation and drainage canals with concrete or asphalt usually prevents or reduces the growth of rooted submersed weeds. However, filamentous algae may grow on concrete linings and structures and greatly reduce waterflow capacity. Also, silt deposits on the bottom of lined canals will support obstructive growth of rooted submersed weeds in water as deep as 8 or 10 feet. A few species will grow at depths of 25 or 30 feet.

Careful designing and spacing of checks, weirs, turnouts, bridges, and other structures along canals minimize interference with the operation of equipment for mechanical or chemical control of aquatic weeds. Shaping ditchbanks to provide uniform crowns and slopes and maintaining roadways on one or both banks are essential for efficient chaining, dragging, mowing, or spraying operations to control aquatic weeds.

MANAGEMENT PRACTICES

As supplements to proper design and construction of canals, ponds, lakes, and reservoirs, a number of management practices can be utilized to control aquatic weeds or prevent them from becoming a problem. These practices include draining, flooding, fertilization, and livestock grazing.

Draining.—For control of submersed weeds in irrigation canals with uniform bottom gradients, drain completely and let canals dry for 3 or 4 days. Repeat as necessary when water is not critically needed for irrigating crops.

To control cattails and certain other emersed weeds in ponds, marshes, and wet lands, drain water off, plow the ground, and let it dry for a few weeks.

Flooding.—Maintain the water level at a depth of 3 feet or more for several months to control cattails and certain other emersed weeds.

Fertilization.—Frequent application of NPK (nitrogen, phosphorus, potassium) mineral fertilizers in ratios of 8–8–2, 10–10–5, or higher stimulates a dense growth or "bloom" of microscopic algae, which shades the pond bottom and prevents or reduces the growth of rooted submersed weeds in the Southern States. To control rooted submersed weeds and waterlilies in ponds with stable water levels, apply 100 to 200 pounds per acre of NPK mineral fertilizer (analysis 8–8–2) beginning in late winter or early spring and at 10-day intervals thereafter until a white disk placed 12 to 14 inches below the water surface is invisible. Subsequently apply fertilizer as necessary to maintain the algae "bloom." Fertilization does not control submersed weeds where the outflow or change of water in a month exceeds the water storage capacity of the canal or pond or in cooler waters of the Central and Northern States.

Livestock Grazing.—Intensive grazing by livestock, where practicable and safe, provides effective and economical control of most kinds of emersed and marsh species, including aquatic grasses, sedges, rushes, reeds, cattails, alligatorweed, watercress, and willows. Avoid grazing where it causes serious erosion of steep banks or loose soil. Ducks often effectively control duckweed in small ponds.

HAND AND MECHANICAL CONTROL

Although the traditional hand and mechanical methods of controlling aquatic weeds have recently been replaced to a considerable extent by herbicides, the hand and mechanical methods are still advantageous in many situations.

Control of submersed weeds by mechanical methods often is less costly than chemical methods in canals with flows of water greater than 70 c.f.s. However, in canals that supply water for sprinkler irrigation, mechanical methods are undesirable because fragments of dislodged weeds that remain in the water often clog sprinkler heads, valves, screens, and other irrigation equipment.

Hand Pulling.—Young plants of cattail, buttonbush, willow, and certain other emersed or marsh species can be eliminated by hand pulling. However, frequent inspection of the channel, pond, or marsh and pulling when plants are young and few in number are necessary for effective and economical control.

Underwater Mowing.—Self-propelled and boat-mounted mowers that cut off submersed or emersed weeds below the water surface at depths of 6 inches to 6 feet are available.

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

For killing small patches of waterlilies and watershield, cut leaves off below the water surface

at frequent intervals. Five or six cuttings a year may be necessary.

For temporary control of submersed waterweeds in large canals, around boat docks, and in fishing and swimming areas of ponds and lakes, mow off as deeply as possible and remove dislodged weeds. In canals the dislodged weeds should be trapped downstream and removed by dragline or other device to prevent them from lodging against structures, clogging the canal, and causing overflows, canal breaks, or washed-out structures. In ponds and lakes weed debris accumulating in shallow water along the shoreline because of wave action can be removed by draglining, cabling, conveying, or other mechanical means.

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

BIOLOGICAL CONTROL

A few species of fish (e.g., Israeli carp, *Tilapia*) are the only organisms that can be recommended to control certain species of submersed weeds. Other organisms under study include certain insects to control alligatorweed and water-hyacinth; a large fresh-water snail to control algae, submersed weeds, waterfern, and possibly water-hyacinth; and several low-growing submersed species, such as waterplantain and dwarf sagittaria, as effective competitors with ranker growing, more troublesome pondweeds in large irrigation canals.

To control branched filamentous algae (*Pithophora*) in southern ponds, stock with fifty 5-inch or larger fingerling Israeli carp per acre. Under these temperature conditions the Israeli carp will not muddy the water and will not spawn successfully.

CHEMICAL CONTROL

Copper sulfate was first used to control algae in 1904, and sodium arsenite was used to control water-hyacinth in 1902 and submersed weeds in 1927. However, most of the 19 herbicides now registered by the U.S. Department of Agriculture for use in controlling one or more aquatic weeds were discovered since 1945. Herbicides often give more effective, longer lasting, and less expensive control of aquatic weeds than do mechanical or hand methods.

Special Precautions in Use of Aquatic Herbicides

A few aquatic herbicides, such as sodium arsenite, are poisonous to humans and warm-blooded animals and must be handled and used with great care and according to special procedures. Some herbicides are toxic to fish, but several do not injure fish at concentrations required to kill weeds. Most aquatic herbicides do not injure crops irrigated with water at concentrations required for weed control, but a few may injure crops at low concentrations.

Only limited information is available on the persistence and fate of herbicides in water, aquatic soil, fish, aquatic plants, and crops irrigated with treated water. Therefore, in addition to following all general precautions for the safe use of herbicides described on page 3 and the special precautions in table 15, the user of an aquatic herbicide must follow carefully all label instructions and restrictions regarding aquatic situations in which the herbicide should not be used, including treated water for livestock, potable purposes, and irrigation of crops. He must know how much time should elapse after herbicide treatment and before treated water may be used for drinking, fishing, swimming, and irrigating crops.

Suggested Uses of Herbicides for Control of Aquatic Weeds

Examples of herbicide treatments that have been used successfully and safely for control of aquatic weeds are given in table 15. These examples show the scope of herbicide usage for aquatic weed control. They are also guides for the use of herbicides under local conditions. However, rate ranges rather than specific rates are given and times of application are given in general terms, because local climate, altitude, water temperature, water uses, and site conditions affect the performance and persistence of herbicides and procedures required for effective and safe use. Specific details for the safe and effective local use of aquatic herbicides can be obtained from aquatic weed specialists of State and Federal agencies familiar with the particular local situation.

TABLE 15.—*Control of aquatic weeds (irrigation canals, drainage ditches, streams, lakes, ponds, reservoirs, marshes)*

Type and kind of aquatic weed or aquatic site	Herbicide [1]	Rate or concentration [2]	Remarks
FLOATING WEEDS (UNATTACHED, TOPS ABOVE WATER)			
Alligatorweed (floating mats), duckweed, waterfern (*Salvinia*), waterlettuce:			
General control (all weeds).	2,4-D amine salts or low-volatile esters.	2–4 lb. per 100 gal. diluent.	Spray to uniformly wet foliage when weeds actively growing; include 10 gal. fuel oil and 1 pt. emulsifier for waxy hard-to-wet foliage or in rainy season; repeat every 4–6 weeks.
Near crops sensitive to 2,4-D:			
Duckweed (nonflowing water).	Diquat (cation)	0.5–1 p.p.m.w	Inject into water or spray on foliage when actively growing; much less effective in muddy water.
Water-hyacinth	Amitrole-T	1–1.5 lb. per acre	Apply as surface spray in 150–200 gal. water or as aerial spray in 7.5 gal. water per acre when actively growing; add 0.12 lb. fenac per acre for more rapid foliage kill; use only in drainage ditches and marshes.
Water-hyacinth and waterlettuce.	Diquat (cation)	1–1.5 lb. per acre	Apply as surface spray in 150–200 gal. water or as aerial spray in 7.5 gal. water per acre when actively growing.
More positive eradication—alligatorweed floating mats.	Ester of silvex	8 lb. per acre	Apply as spray in 150–200 gal. water per acre at first bloom; re-treat when regrowth 2–4 inches above water; 2–4 applications required for control; use for irrigation or domestic purposes.
EMERSED AND MARGINAL WEEDS (ROOTED UNDER WATER, TOPS ABOVE WATER, OR GROWING ON WET SOIL)			
Broadleaved species:			
General control	2,4-D, 2,4,5-T, or silvex.	2–4 lb. per acre	Apply as spray in 200 gal. water per acre to uniformly wet foliage when weeds actively growing; reduce volume but not rate when foliage wet; repeat as necessary.
Arrowhead, lotus, pickerelweed, smartweed, spatterdock, spikerush, waterprimrose, white waterlily, other plants with waxy leaves.	2,4-D (low-volatile ester).	1–4 lb. per acre	Apply in oil or in oil-water emulsion (1:10 or 1:20) in sufficient volume to give uniform coverage; spray when plants actively growing.
Rooted, emersed alligatorweed.	Ester of silvex (spray).	8 lb. per acre	Apply as spray in 150–200 gal. water per acre at first bloom; re-treat when regrowth 2–4 inches above water; 2–4 applications required for elimination.
Grass and grasslike species:			
Perennial grasses and sedges, e.g., cutgrass, johnsongrass, knotgrass, paragrass, quackgrass, common reed (*Phragmites*), ripgut sedge.	Amitrole or amitrole-T.	8–16 lb. per acre	Apply in 100–400 gal. water per acre as ground spray or in 10–15 gal. water per acre as aerial spray when plants 6–18 inches tall and before heading; some grasses, e.g., reed canarygrass, require 50 percent less amitrole-T than amitrole; use only in drainage ditches and marshes.
	Dalapon	20–30 lb. per acre	Apply in 100–400 gal. water per acre as ground spray or in 5–15 gal. water per acre as aerial spray when grasses 6–18 inches tall and before heading; add 3–4 pt. wetting agent per 100 gal. water; repeated light applications at 5–10 lb. per acre are more effective on some species, e.g., paragrass; use only in drainage ditches and marshes.

See footnotes at end of table.

TABLE 15.—*Control of aquatic weeds (irrigation canals, drainage ditches, streams, lakes, ponds, reservoirs, marshes)*—Continued

Type and kind of aquatic weed or aquatic site	Herbicide [1]	Rate or concentration [2]	Remarks
EMERSED AND MARGINAL WEEDS (ROOTED UNDER WATER, TOPS ABOVE WATER, OR GROWING ON WET SOIL)—continued			
Grass and grasslike species—Continued.	2,4-D (low-volatile esters).	4–6 lb. per acre	Apply in 1:20 oil-water emulsion at 150–300 gal. per acre; make initial application at first heading and repeat on regrowth before heading; 3–4 applications necessary for elimination.
Bulrushes and cattails	Amitrole	6–12 lb. per acre	Apply at fully headed or postheading stage in late summer or early autumn in sufficient volume of spray to give uniform coverage by ground or aerial equipment; apply at earlier growth stage for control during current season and repeat as necessary to eradicate regrowth; use only in drainage ditches and marshes.
	Dalapon	15–30 lb. per acre	Same as for amitrole except include 3–4 pt. of wetting agent or 5–10 gal. diesel oil plus 1 pt. emulsifier per 100 gal. spray.
SUBMERSED WEEDS (TOPS MOSTLY UNDER WATER, USUALLY ROOTED OR ANCHORED)			
Ponds, lakes, and reservoirs:			
Algae, blue-green	Copper sulfate (pentahydrate, dark blue).	0.1–0.5 p.p.m.w	Apply crystals or powder at early stage of algae growth by any method to give rapid and uniform dispersions; repeat as necessary to maintain control; safe in potable water.
	Dichlone	0.02–0.05 p.p.m.w	Same as copper sulfate except not safe in potable water.
Algae, filamentous	Copper sulfate (pentahydrate, dark blue).	0.5–1 p.p.m.w	In soft water safe on most fish except trout; safe in potable water.
		1–2 p.p.m.w	In hard water injurious to most fish; safe in potable water.
	Endothall (dimethylamine salts).	0.05–0.2 p.p.m.w	Apply uniformly over surface or inject below water surface.
Rooted or anchored weeds, e.g., bladderwort, cabomba, coontail, *Elodea*, naiad, pondweeds, waterchestnut, water crowfoot, watermilfoil, water pennywort, waterprimrose, waterstargrass, wildcelery.	Sodium arsenite (arsenic trioxide equivalent).	2–10 p.p.m.w	Consult weed specialists in State agricultural experiment stations or extension service or fish and wildlife specialists for necessary use permit and regulations; apply at early stage of weed growth; use lower concentrations in total area treatments and higher concentrations for margins, spot treatments, or cold water; follow label directions on use of treated water.
	Endothall (disodium salt).	1–4 p.p.m.w	Same as for sodium arsenite; increase concentration to 5 p.p.m.w. for spot treatments; follow label directions on use of treated water.
	Endothall (dimethylamine salts).	0.5–2.5 p.p.m.w	Use only for spot treatments or where some fish kill is not objectionable.
	Fenac	15–20 lb. per acre	Apply to temporarily exposed lake or pond bottoms and shorelines when soil is not frozen; keep water down at least 3 weeks; follow label directions on use of treated water.
Same weeds except alga and chara.	Dichlobenil	7–10 lb. per acre	Apply to temporarily exposed lake or pond bottoms and shorelines; follow label directions on use of treated water.
		10–15 lb. per acre	Broadcast over water surface before or as soon as new growth begins in spring; increase rates in water deeper than 3 ft. and for spot treatment.

See footnotes at end of table.

TABLE 15.—*Control of aquatic weeds (irrigation canals, drainage ditches, streams, lakes, ponds, reservoirs, marshes)*—Continued

Type and kind of aquatic weed or aquatic site	Herbicide [1]	Rate or concentration [2]	Remarks
SUBMERSED WEEDS (TOPS MOSTLY UNDER WATER, USUALLY ROOTED OR ANCHORED)—continued			
Ponds, lakes, and reservoirs—Continued			
Same weeds except *Elodea* and wild-celery.	Diquat (cation)	0.5–1.5 p.p.m.w	Apply over surface or inject below water surface; double rates for spot treatments; follow label directions on use of treated water.
		0.25–0.5 p.p.m.w	Low concentrations sufficient for some weeds e.g., naiad in small ponds.
Same weeds except curlyleaf pondweed, some other pondweeds, *Elodea*, wild-celery.	Ester of 2,4-D (granule or pellet form).	20–40 lb. per acre	Apply uniformly over water surface by boat or helicopter at early stage of weed growth; use heavy rates for more resistant species or extremely acid or alkaline water; esters of 2,4-D toxic to some species of fish at these rates.
	Potassium salt of silvex (granule or liquid form).	1.5–2 p.p.m.w. or 5 lb. per acre-ft.	Apply uniformly over surface of water or inject liquid below surface at early stage of weed growth; not effective in spot treatments.
Irrigation and drainage canals with flowing water—most submersed species except waterplantain.	Aromatic solvents (xylene).	8–10 gal. per c.f.s. (600–740 p.p.m.v. in 30 minutes or 300–370 p.p.m.v. in 60 minutes).	Add 1–1.5 percent emulsifier and inject into canal at one station during 30–60 minutes before weeds become matted at surface; add 4–5 gal. per c.f.s. to moving "zone" of treated water at intervals of 2–4 miles down canal depending on weed density; avoid fire hazard.
		1–2.5 gal. per c.f.s	Inject into canal at beginning of weed infestation during ½–4 hours using especially adapted equipment; effective kill 6–20 miles downstream depending on weed density.
	Acrolein	0.1–0.6 p.p.m.v	Inject in large canals (200–2,000 or more c.f.s.) at one location during period of 8–48 hours; within this range use lower concentrations and longer periods of application as size of canal increases; apply from special cylinders under nitrogen gas pressure.
Drainage and irrigation canals with flow stopped or greatly reduced.	Diquat (cation)	0.25–1 p.p.m.w	Apply above or below water surface continuously along canal; allow at least 12 hours' exposure of weeds to treated water.
	Acrolein	4–7 p.p.m.v	Apply below water surface continuously along canal with especially adapted equipment; toxic to fish.
	Endothall (dimethylamine salt).	1.5–4 p.p.m.w	Same as diquat except toxic to fish.
Reservoirs and large canals carrying flowing water for potable use:			
Continuous feed method	Copper sulfate (pentahydrate).	0.6–1 p.p.m.w	Begin applications early in season at 1 p.p.m.w.; gradually reduce to 0.6 p.p.m.w. in late summer as water temperature rises.
Repeated "slug" treatments.	do	0.33–2 lb. per c.f.s	Make initial application early in growing season and repeat as necessary to maintain control; use light rates for soft water and heavier rates for water high in salts, especially carbonates; apply large crystals on concrete bottom or apron or suspend in water in burlap bags; crystals dissolve very slowly.

[1] All herbicides listed are registered under Federal Insecticide, Fungicide, and Rodenticide Act for suggested uses at time of publication, but some herbicides registered for use in control of aquatic weeds may not be included.

[2] Rates and concentrations are in terms of acid equivalent or active ingredient of herbicide and not necessarily or usually of commercial formulation.

CROP, SITE, AND TOPIC INDEX

Specific crops, sites, or areas for which weed-control suggestions are given and special control topics are listed alphabetically under the headings Crops: crops, grazing lands and turf, noncropland, and aquatic weeds.

WEED INDEX BY CROPS OR SITES

Specific weeds discussed in this handbook are listed alphabetically by the common names approved by the Weed Society of America followed by the scientific names. Names of some families and types of weeds are also included.

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