Field Application of Herbicides-- Avoiding Danger to Fish

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FIELD APPLICATION OF HERBICIDES--AVOIDING DANGER TO FISH

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Chemical weed and brush control with herbicides is an important land management practice in modern agriculture and forestry. In some cases, herbicides are applied directly to bodies of water for aquatic weed control. More commonly, herbicides are applied to lands adjacent to waterways for general weed and brush control.

The responsible applicator will avoid damage to fishery resources by being fully aware of a particular herbicide's potential hazard to fish. Herbicide applications should be considered hazardous to fish when there is the probability fish will be exposed to herbicide concentrations which are harmful. This bulletin offers information that will aid in selecting the particular herbicides and formulations of least hazard to fish considering the toxicity of the herbicide and the potential for its entry into streams, lakes, or ponds.

Entry of Herbicides into the Aquatic Environment

In aquatic weed control, the effective concentration of herbicide in the water depends on the rate of application, the rate of the spread of the chemical, the size and chemical composition of the body of water, the rate of degradation or adsorption of the chemical on sediments, and the rate of mixing of treated water with untreated water. These factors must be recognized in aquatic weed control programs and allowances made for them in determining the hazard to fish.

In terrestrial weed and brush control operations, the possible entry routes of herbicides into waterways may not be clearly recognized. Large amounts of herbicides may enter the water in a short time when streams and lakes are included in treatment areas. Finely divided spray materials may also drift from the treatment area to surface waters. These mechanisms of entry operate only during application and can be avoided by (a) excluding surface waters from treatment areas, and (b) not spraying when conditions of wind, temperature, and relative humidity can cause significant amounts of drift (15).

Herbicides may move from treated areas in surface and subsurface flow of water. Subsurface flow, or leaching, of herbicides through the soil profile to ground water and finally to surface waters is a slow process, capable of moving only small amounts of chemical relatively short distances (6). The short persistence of most herbicides and their resistance to leaching markedly reduces the potential for stream water pollution by subsurface flow of herbicides.

Surface flow, or runoff, of herbicides can move large amounts of chemical a long distance in a short period of time (1, 16). Surface flow of water occurs when the rate of precipitation exceeds the infiltration capacity of the soil. Chemicals moving in surface flow need not be in solution but may be adsorbed on soil particles. Sheet erosion of soil from areas treated with herbicides is a serious threat to the quality of the aquatic environment. Steep slopes and compacted soils encourage surface flow of water and herbicide residues. However, a heavy ground cover of decaying organic matter and untreated strips of land between treatment areas and streams will decrease the amount of herbicide which reaches the water (18).

The direct application and drift of spray materials to the streams and the surface flow of herbicide residues in surface runoff are the major routes of herbicide entry to streams and lakes. Therefore, any condition or action which reduces the direct application, drift, or runoff of herbicides to surface waters will reduce the hazard to fish.

Herbicide Toxicity to Fish

If an herbicide enters the water, the hazard of the herbicide to fish depends on its toxicity. There are two kinds of toxicity, acute and chronic. Acute toxicity is associated with exposure to relatively large single doses of herbicide for a few hours up to a few days. Acute toxicity is commonly observed as mortality occurring shortly after exposure. Chronic toxicity results from long-term exposure (more than several days) to relatively low levels of herbicide. The effects of chronic exposure would probably not be observed under most field conditions.

The direct application or drift of spray materials to surface waters will occur only for a short time during and after application. The surface runoff of herbicides will be restricted to periods of intense rainfall. Therefore, in most cases the length of time fish will be exposed to herbicides is short, and the acute toxicity is of more immediate concern than chronic toxicity.

It is not possible to rank herbicides in the exact order of their toxicity because acute toxicity varies with the species of fish, the conditions of exposure, and water quality factors such as temperature, dissolved oxygen, hardness, and acidity. However, herbicides can be grouped into general classes based on toxic concentrations. We have used laboratory bioassays reported by various investigators to group the herbicides alphabetically into four tables as follows:

	Laboratory TLm or LD_{50} values 1/
Table 1	1 ppm or less
Table 2	1- 5 ppm
Table 3	5-15 ppm
Table 4	15 ppm or more

1/ The TLm or LD_{50} values are the concentrations which result in the death of 50 percent of the test animals in a stated period of time, usually 24, 48, 72, or 96 hours.

The tables include the trade name of the material, the manufacturer or formulator, the chemical name of the active ingredient, and selected laboratory bioassay references. We caution that some herbicides may have been reformulated since the tests reported here were conducted. New formulations may be more or less toxic than old ones although the trade name remains the same. The toxicity of an herbicide in a laboratory bioassay may be different from its toxicity under field conditions. Several herbicides which are quite toxic to fish in laboratory tests using pure water can be used safely in the field because adsorption on soil and organic matter or rapid degradation by sunlight or microorganisms prevents exposure of fish to harmful concentrations of the chemical.

Careful consideration of the toxicity of mixtures of herbicides is essential because interaction between herbicides may increase their toxicity. These synergistic effects of various formulations have not been well documented.

Basic precautions for using herbicides are as follows: Observe all precautions on the labels of herbicide containers. Avoid improper use and spillage of chemicals. Never clean spray equipment or dispose of empty herbicide containers in streams. When herbicides are to be used in or near water or when conditions exist which favor their entry into water, it is important that formulations of low toxicity to fish be selected.

Table 1. Herbicides Which Kill Fish at 1 ppm[1/] or Less.

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Aqualin	Shell	Acrolein (WSSA)[2/]	Acrylaldehyde	2, 11, 13
Chem-Pels C	CIC	Sodium arsenite[3/]	$NaAsO_2$	8
Chipman 2,4-D Isopropyl Ester 334E	Chipman	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, isopropylester	8
Dow General Weed Killer	Dow	DNBP (WSSA)	4,6-dinitro-0-sec-butylphenol	20
Hydrothol 47	Pennwalt	Endothall (WSSA)	7-oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid, di(N,N-dimethylalkylamine) salt	8
Hydrothol 191	Pennwalt	Endothall (WSSA)	7-oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid, mono(N,N-dimethylalkylamine) salt	8, 9
Treflan	Elanco	Trifluralin (WSSA)	2,6-dinitro-N,N-dipropyl-4-trifluoromethylaniline	4, 8

1/ Parts of herbicide per million parts of water by weight.

2/ (WSSA) indicates common name accepted by the Weed Science Society of America.

3/ Most formulations of sodium arsenite are not as lethal. (See Table 3)

Table 2. Herbicides Which Kill Fish at 1 - 5 ppm.

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Baron	Dow	Erbon	2-(2,4,5-trichlorophenoxy)-ethyl-2,2-dichloropropionate	2
Carbyne	Gulf	Barban (WSSA)1/	4-chloro-2-butynyl-N-(3-chlorophenyl) carbamate	20
Chickweed and Clover Killer	Ortho	Silvex (WSSA)	2-(2,4,5-trichlorophenoxy)propionic acid, isooctyl ester	8
Chipman 2,4-D Butyl Ester 6E	Chipman	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, butyl ester	8
Copper Sulfate2/	Various	Copper sulfate	$CuSO_4$	7, 10, 14
Dacamine 4D	Diamond	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, N-oleyl-1,3-propylenediamine salt	4
Dacamine 4T	Diamond	2,4,5-T (WSSA)	2,4,5-trichlorophenoxyacetic acid, N-oleyl-1,3-propylenediamine salt	4
Esteron 99	Dow	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, propylene glycol butyl ether ester	8
Ordram	Stauffer	Molinate (WSSA)	S-ethyl hexahydro-1H-azepine-1-carbothioate	20

Table 2. (Continued)

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Ramrod	Monsanto	Propachlor	2-chloro-N-isopropylacetanilide	20
Urox Liquid-oil	Allied	Monuron-TCA (WSSA)	3-(p-chlorophenyl)-1,1-dimethyl-urea-trichloroacetic acid	19
Urox 11 Weed Killer	Allied	Monuron-TCA (WSSA)	3-(p-chlorophenyl)-1,1-dimethyl-urea-trichloroacetic acid	19
Urox 22 Weed Killer	Allied	Monuron-TCA (WSSA)	3-(p-chlorophenyl)-1,1-dimethyl-urea-trichloroacetic acid	19
Weedone 48	Amchem	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, ethyl ester	8
Weedone 2,4-DP	Amchem	Dichloroprop (WSSA)	2-(2,4-Dichlorophenoxy) propionic acid, butoxyethanol ester	8
Weedone 2,4,5-TP	Amchem	Silvex (WSSA)	2-(2,4,5-trichlorophenoxy)-propionic acid, butoxyethanol ester	8
Weedone LV4	Amchem	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, butoxyethanol ester	8

1/ (WSSA) indicates common name accepted by the Weed Science Society of America.

2/ Dangerous to salmon and trout at less than 1 ppm, particularly in soft water (50 ppm or less methyl orange alkalinity).

Table 3. Herbicides Which Kill Fish at 5 - 15 ppm.

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Brush-Rhap Low Volatile 4T	Hercules	2,4,5-T (WSSA)[1/]	2,4,5-trichlorophenoxyacetic acid, 2-ethylhexyl ester	8
Caparol 80W	Geigy	Prometryne (WSSA)	2,4-bis(isopropylamino)-6-methylmercapto-s-triazine	9
Casoron W-50	T-H	Dichlobenil (WSSA)	2,6-dichlorobenzonitrile	5, 8
Crop Rider 6D	Diamond	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, butyl ester	4
Dacamine	Diamond	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, N-oleyl-1,3-propylenediamine salt	4
Fenac	Amchem	Fenac (WSSA)	2,3,6-trichlorophenylacetic acid, sodium salt	8
Karmex	DuPont	Diuron (WSSA)	3-(3,4-dichlorophenyl)-1,1-dimethylurea	19
Pramitol 25E	Geigy	Prometone (WSSA)	2-methoxy-4,6-bis(isopropylamino) s-triazine	4, 9
Sodium arsenite	Various	Sodium arsenite	$NaAsO_2$ and As_2O_3	11, 17
Vernam 6E	Stauffer	Vernolate (WSSA)	S-propyldipropylthiocarbamate	20

Table 3. (Continued)

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Weedone Chickweed Killer	Amchem	Silvex (WSSA)[1/]	2-(2,4,5-trichlorophenoxy)-propionic acid, butoxyethanol ester	8
Weedone 638	Amchem	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid	8

[1/] (WSSA) indicates common name accepted by the Weed Science Society of America.

Table 4. Herbicides Which Kill Fish at 15 ppm or Above.

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Aatrex 80W	Geigy	Atrazine (WSSA)[1/]	2-chloro-4-ethylamino-6-isopropyl-amino-s-triazine	4
2,4-D Amine 4	Ortho	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, dimethylamine salt	8
Amizol	Amchem	Amitrole (WSSA)	3-amino-1,2,4-triazole	2
Ammate X	DuPont	AMS (WSSA)	Ammonium sulfamate	8
Aqua-Kleen 20	Amchem	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, butoxyethanol ester	8
Aquathol	Pennwalt	Endothal (WSSA)	7-oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid, disodium salt	8
Aquathol Granular	Pennwalt	Endothal (WSSA)	7-oxabicyclo(2.2.1)haptane-2,3-dicarboxylic acid, dipotassium salt	8
Aquathol K	Pennwalt	Endothal (WSSA)	7-oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid, dipotassium salt	8
Aquathol Plus	Pennwalt	Endothal + silvex (WSSA)	7-oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid, dipotassium salt and 2-(2,4,5-trichlorophenoxy) propionic acid, potassium salt	8

Table 4. (Continued)

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Aquathol Plus Granular	Pennwalt	Endothal + silvex (WSSA)	7-oxabicyclo(2.2.1)heptane-2,3-dicarboxylic acid, dipotassium salt and 2-(2,4,5-trichlorophenoxy) propionic acid, potassium salt	8
Banvel	Velsicol	Dicamba (WSSA)	2-methoxy-3,6-dichlorobenzoic acid, dimethylamine salt	3, 8
Banvel 10G	Velsicol	Dicamba (WSSA)	2-methoxy-3,6-dichlorobenzoic acid	8
Casoron G-4	T-H	Dichlobenil (WSSA)	2,6-dichlorobenzonitrile	8
Chem-Pels 2,4-D	CIC	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, isooctyl ester	8
Chipman 2,4-D Amine No. 4	Chipman	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, dimethylamine salt	8
Chipman 2,4-D Gran 20	Chipman	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, isooctyl ester	8
Chipman 2,4-D Low Volatile Ester 4L	Chipman	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, isooctyl ester	8
Chipman 2,4,5-T Amine 4L	Chipman	2,4,5-T (WSSA)	2,4,5-trichlorophenoxyacetic acid, triethylamine salt	8

Table 4. (Continued)

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Chipman 2,4,5-T Low Volatile Ester 4L	Chipman	2,4,5-T (WSSA)	2,4,5-trichlorophenoxyacetic acid, isooctyl ester	8
Chipman 2,4,5-T Low Volatile Ester 6L	Chipman	2,4,5-T (WSSA)	2,4,5-trichlorophenoxyacetic acid, isooctyl ester	8
Cotoran 80 WP	CIBA	Fluometuron (WSSA)	3-(m-trifluoromethylphenyl)-1,1-dimethylurea	8
Crop Rider Amine 4D	Diamond	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid dimethyl amine salt	4
Crop Rider 20% Aqua Granular	Diamond	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, isooctyl ester (granular)	4
Crop Rider MCPA Amine	Diamond	MCPA (WSSA)	2-methyl,4-chlorophenoxyacetic acid, dimethyl amine salt	4
Crop Rider LV-6D	Diamond	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, isooctyl ester	4
Daconate	Diamond	MSMA (WSSA)	Methanearsonic acid, Monosodium salt	4
Dacthal W-75	Diamond	DCPA (WSSA)	2,3,5,6 tetrachloroterephthalic acid, dimethyl ester	4
Ded-Weed 40	T-H	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, dimethylamine salt	8

Table 4. (Continued)

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Diquat	Ortho	Diquat (WSSA)	6,7-dihydrodipyrido[1,2-a:2',1'-c]-pyrazinediium, dibromide salt	8
Dowpon	Dow	Dalapon (WSSA)	2,2-dichloropropionic acid	8
DSMA Powder	Diamond	DSMA (WSSA)	Methanearsonic acid, disodium salt	4
Dybar	Dupont	Fenuron (WSSA)	3-phenyl-1,1-dimethylurea	19
Dymid	Elanco	Diphenamid (WSSA)	N,N-dimethyl-2,2-diphenylacetamide	8
Esteron 2,4,5 O.S.	Dow	2,4,5-T (WSSA)	2,4,5-trichlorophenoxyacetic acid, propylene glycol butyl ether ester	8
Formula 40	Dow	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, alkanolamine salts	8
IPC 75 WP	FMC	IPC (WSSA)	Isopropyl-N-phenylcarbamate	4
Kalzate A	Guth	MCPA (WSSA)	2-methyl-4-chlorophenoxyacetic acid, potassium salt	9
Kuron	Dow	Silvex (WSSA)	2-(2,4,5-trichlorophenoxy)-propionic acid, propylene glycol	8
Line Rider LV-4T	Diamond	2,4,5-T (WSSA)	2,4,5-trichlorophenoxyacetic acid, isooctyl ester	4

Table 4. (Continued)

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Line Rider LV-6T	Diamond	2,4,5-T (WSSA)	2,4,5-trichlorophenoxyacetic acid, isooctyl ester	4
Lithate 2,4-D	Guth	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, lithium salt	9
MH-30	Uniroyal	MH (WSSA) Maleic hydrazide	1,2-dihydropyridazine-3,6-dione	20
Paraquat CL	Ortho	Paraquat (WSSA)	1,1'-dimethyl-4,4'-bipyridinium dichloride	4, 8
Patoran 50 WP	CIBA	Metobromuron (WSSA)	3-(p-bromophenyl)-1-methoxy-1-methylurea	20
Planavin	Shell	Nitralin (WSSA)	4-(methylsulfonyl)-2,6-dinitro-N,N-dipropylaniline	4
Princep 80W	Geigy	Simazine (WSSA)	2-chloro-4,6-bis(ethylamino)-s-triazine	4
Silvi-Rhap Low Volatile 4TP	Hercules	Silvex (WSSA)	2-(2,4,5-trichlorophenoxy)-propionic acid, 2-ethylhexyl ester	8
Silvisar 510	Ansul	Cacodylic acid (WSSA)	Dimethylarsinic acid	9

Table 4. (Continued)

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Telvar	DuPont	Monuron (WSSA)	3(p-chlorophenyl)-1,1-dimethyl-urea	19
Tenoran 50WP	CIBA	Chloroxuron (WSSA)	N'-4-(4-chlorophenoxy)phenyl-N,N-dimethylurea	8
Tordon 22K	Dow	Picloram (WSSA)	4-amino-3,5,6-trichloropicolinic acid, potassium salt	8
Tordon 101	Dow	Picloram and 2,4-D (WSSA)	4-amino-3,5,6-trichloropicolinic and 2,4-dichlorophenoxyacetic acids, both as triisopropanolamine salts	9
Tordon 212	Dow	Picloram and 2,4-D (WSSA)	4-amino-3,5,6-trichloropicolinic and 2,4-dichlorophenoxyacetic acids, both as triisopropanolamine salts	9
Tordon 225	Dow	Picloram and 2,4,5-T (WSSA)	4-amino-3,5,6-trichloropicolinic and 2,4,5-trichlorophenoxyacetic acids, both as triethylamine salts	9
Ureabor	U.S. Borax	Monuron and borax	3(p-chlorophenyl)-1,1-dimethylurea and disodium tetraborate	19
Urox B	Allied	Bromacil (WSSA)	5-bromo-3-sec-butyl-6-methyluracil	8, 12

Table 4. (Continued)

Trade Name	Manufacturer	Common Name	Chemical Name	Reference
Weedar 64	Amchem	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, dimethylamine salt	8
Weedazol	Amchem	Amitrole (WSSA)	3-amino-1,2,4-triazole	8
Weed-No-More	Sherwin Williams	Silvex and 2,4-D (WSSA)	2-(2,4,5-trichlorophenoxy)-propionic and 2,4-dichlorophenoxy-acetic acids, isooctyl esters	8
Weed-Rhap Amine A-4D	Hercules	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, dimethylamine salt	8
Weed-Rhap Low Volatile Ester 4D	Hercules	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, 2-ethylhexyl ester	8
Weed-Rhap Low Volatile Granular D	Hercules	2,4-D (WSSA)	2,4-dichlorophenoxyacetic acid, 2-ethylhexyl ester	8

1/ (WSSA) indicates common name accepted by the Weed Science Society of America.

LIST OF MANUFACTURERS

Allied - Allied Chemical Corporation

Amchem - Amchem Products Incorporated

Ansul - Ansul Company

Chipman - Rhodia Incorporated, Chipman Division

CIBA - Ciba Agrochemical Company

CIC - Chemical Insecticide Corporation

Diamond - Diamond Shamrock Chemical Company

Dow - Dow Chemical Company

DuPont - DuPont de Nemours and Company

Elanco - Eli Lilly, Elanco Products Division

FMC - FMC Corporation, Niagara Division

Geigy - Geigy Chemical Corporation

Gulf - Gulf Oil Corporation

Guth - Guth Chemical Company

Hercules - Hercules, Incorporated

Monsanto - Monsanto Chemical Company

Ortho - Chevron Chemical Company, Ortho Division

Pennwalt - Pennwalt Corporation

Shell - Shell Chemical Company

Sherwin Williams - Sherwin Williams Company

Stauffer - Stauffer Chemical Company

T-H - Thompson Hayward Chemical Company

Uniroyal - Uniroyal, Incorporated

U. S. Borax - U. S. Borax Chemical Corporation

Velsicol - Velsicol Chemical Corporation

SELECTED REFERENCES

(1) Barnett, A. P., E. W. Hauser, A. W. White, and J. H. Holladay. 1967. Loss of 2,4-D in washoff from cultivated fallow land. Weeds 15: 133-137.

(2) Bond, C. E., R. H. Lewis, and J. L. Fryer. 1960. Toxicity of various herbicidal materials to fishes. In: Transactions second seminar on biological problems in water pollution. U. S. Publ. Health Serv. Robt. A. Taft Sanitation Eng. Center, Tech. Rep. W60-3, Cincinnati, Ohio.

(3) Bond, C. E., J. D. Fortune, Jr., and F. Young. 1965. Results of preliminary bioassays with Kurosal SL and Dicamba. Progr. Fish Cult. 27(1): 49-51.

(4) Bond, C. E. 1966. Progress report on aquatic weed research. Projects 773 and 294. Dep. Fish. Wildlife, Oreg. Agr. Exp. Sta., Oreg. State Univ.

(5) Bond, C. E., D. C. Wilson, and J. Malick. 1967. Progress report on aquatic weed research. Dep. Fish. Wildlife, Oreg. Agr. Exp. Sta., Oreg. State Univ.

(6) Harris, C. I. 1967. Movement of herbicides in soil. Weeds 15: 214-216.

(7) Hilliard, D. K. 1952. The effects of herbicides and related compounds on fish. M.S. thesis on file at Oreg. State Univ.

(8) Hughes, J. S., and J. T. Davis. 1966. Toxicity of pesticides to bluegill sunfish tested during 1961-66. Louisiana Wildlife & Fish. Comm.

(9) Juntunen, E. T., and C. E. Bond. 1968. Progress report. Research on aquatic weed control. Project 773. Dep. Fish. & Wildlife, Oreg. Agr. Exp. Sta., Oreg. State Univ.

(10) Lawrence, J. M. 1962. Aquatic herbicide data. U. S. Dep. Agr. Handb. 231, 133 pp.

(11) Lawrence, J. M., and E. B. Hollingsworth. 1969. Supplement to quatic herbicide data. U. S. Dep. Agr. Supplement to Handb. 231, 126 pp.

(12) Lewis, R. H. 1958. Effects of selected aquatic herbicides on fishes. M.S. thesis on file at Oreg. State Univ.

(13) Lowder, D. E., and E. G. McCoy. 1964. Aquatic plant control. Inland Fisheries Administrative Report No. 64-2. Calif. Dep. Fish & Game.

(14) Meyer, F. A. 1964. Aquatic plant control. Inland Fisheries Administrative Report No. 64-2. Calif. Dep. Fish & Game.

(15) Norris, L. A. 1967. Chemical brush control and herbicide residues in the forest environment. In: Herbicides and vegitation management. pp. 103-123. Oreg. State Univ.

(16) Norris, L. A. 1969. Herbicide runoff from forest lands sprayed in summer. Res. Prog. Reps., West. Soc. Weed Sci. P. 24-26.

(17) Surber, E. W. 1961. Improving sport fishing by control of aquatic weeds. Bur. Sport Fish. & Wildlife. Circ. 128, 49 pp.

(18) Trichell, D. W., H. L. Morton, and M. G. Merkle. 1968. Loss of herbicides in runoff water. Weed Sci. 16: 447-449.

(19) Walker, C. R. 1965. Diuron, Fenuron, Monuron, Neburon and TCA mixtures as aquatic herbicides in fish habitats. Weeds 13: 297-301.

(20) Weed Society of America. 1967. Herbicide Handbook. 293 pp.

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Trade Name	Table
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Aqualin	1
Aquathol	4
Aquathol Granular	4
Aquathol K	4
Aquathol Plus	4
Aquathol Plus Granular	4
Banvel	4
Banvel 10G	4
Baron	2
Brush-Rhap Low Volatile 4T	3
Caparol 80W	3
Carbyne	2
Casoron G-4	4
Casoron W-50	3
Chem-Pels C	1

Trade Name	Table
Chem-Pels 2,4-D	4
Chickweed and Clover Killer	2
Chipman 2,4-D Amine No. 4	4
Chipman 2,4-D Butyl Ester 6E	2
Chipman 2,4-D Gran 20	4
Chipman 2,4-D Isopropyl Ester 334E	1
Chipman 2,4-D Low Volatile Ester 4L	4
Chipman 2,4,5-T Amine 4L	4
Chipman 2,4,5-T Low Volatile Ester 4L	4
Chipman 2,4,5-T Low Volatile Ester 6L	4
Copper Sulfate	2
Cotoran 80 WP	4
Crop Rider 6D	3
Crop Rider Amine 4D	4
Crop Rider 20% Aqua Granular	4
Crop Rider MCPA Amine	4
Crop Rider LV-6D	4
Dacamine	3
Dacamine 4D	2
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Trade Name	Table
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Dybar	4
Dymid	4
Esteron 2,4,5 O.S.	4
Esteron 99	2
Fenac	3
Formula 40	4
Hydrothol 47	1
Hydrothol 191	1
IPC 75 WP	4
Kalzate A	4
Karmex	3
Kuron	4
Line Rider LV-4T	4
Line Rider LV-6T	4
Lithate 2,4-D	4
MH-30	4
Ordram	2
Paraquat CL	4
Patoran 50 WP	4

Trade Name	Table
Planavin	4
Pramitol 25E	3
Princep 80W	4
Ramrod	2
Silvi-Rhap Low Volatile 4TP	4
Silvisar 510	4
Sodium arsenite	3
Telvar	4
Tenoran 50WP	4
Tordon 22K	4
Tordon 101	4
Tordon 212	4
Tordon 225	4
Treflan	1
Ureabor	4
Urox B	4
Urox Liquid-oil	2
Urox 11 Weed Killer	2
Urox 22 Weed Killer	2
Vernam 6E	3
Weedar 64	4
Weedazol	4
Weed-No-More	4

Trade Name	Table
Weed-Rhap Amine A-4D	4
Weed-Rhap Low Volatile Ester 4D	4
Weed-Rhap Low Volatile Granular D	4
Weedone Chickweed Killer	3
Weedone 48	2
Weedone 2,4-DP	2
Weedone 2,4,5-TP	2
Weedone LV4	2
Weedone 638	3