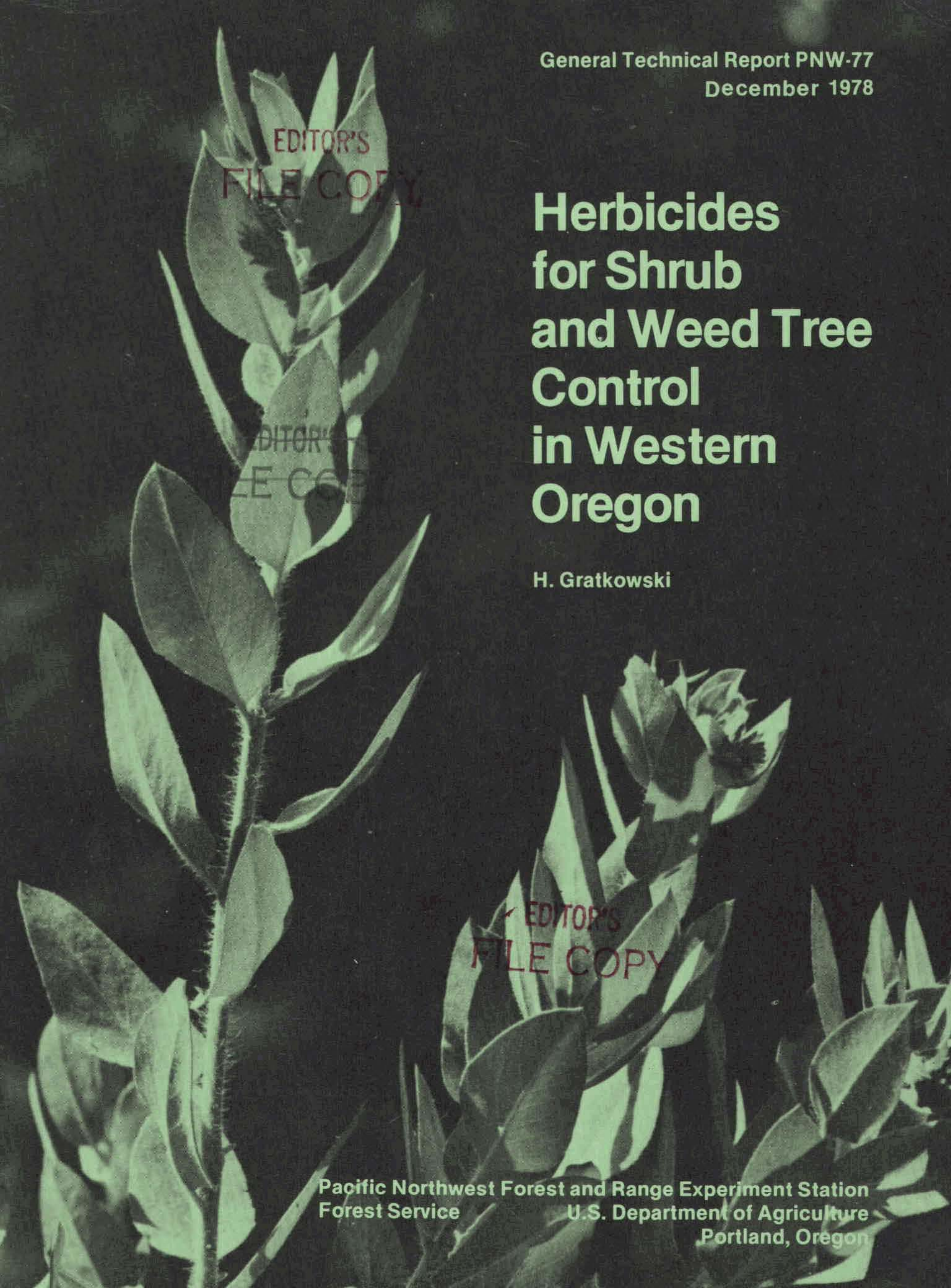

General Technical Report PNW-77
December 1978

Herbicides for Shrub and Weed Tree Control in Western Oregon

H. Gratkowski

Pacific Northwest Forest and Range Experiment Station
Forest Service
U.S. Department of Agriculture
Portland, Oregon

Abstract

Herbicides were tested on 16 common shrubs and weed trees during the past 24 years. The woody plants included snowbrush ceanothus, deerbrush ceanothus, mountain whitethorn, varnish-leaf ceanothus, sprouting and nonsprouting forms of greenleaf manzanita, hairy manzanita, hoary manzanita, golden chinkapin, golden evergreenchinkapin, Saskatoon serviceberry, Pacific madrone, salmonberry, western thimbleberry, scrub tanoak, and canyon live oak. Chemicals tested included 2,4-D, dichlorprop, 2,4,5-T, silvex, 2,4-DB, amitrole, amitrole-T, 2,3,6-TBA, AMS, picloram, Krenite™, triclopyr, and an experimental carbamate compound. Low volatile esters of 2,4-D and 2,4,5-T proved the most effective and versatile herbicides for silvicultural use in western Oregon.

Results of the screening tests are related to comparable data from small plot tests and project-scale aerial spray trials. To aid silviculturists, useful treatments and the most effective herbicide are shown in bold-face type for each shrub and weed tree.

KEYWORDS: Herbicides (-forest weed control, brush control, silviculture Oregon (western).

PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key--out of the reach of children and animals--and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: All recommendations for operational uses of pesticides were registered for such uses by the Federal Environmental Protection Agency at the time of this publication. Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

Common Measures and Metric Equivalents

1 inch	2.54 centimeters
1 foot	0.305 meter
1 mile	1.609 kilometers
1 acre	0.405 hectare
1 gallon, United States	3.785 liters
1 pound, avoirdupois	0.454 kilogram
1 pound/acre	1.121 kilograms/hectare
1 aehg or 1 aihg	0.454 kg/378.53 liters

Terms and Abbreviations

Drip point	Foliage of each plant was sprayed until all leaves had been treated and spray was running off and dripping from approximately one-half of the individual leaves.
ae	Acid equivalent; active ingredient in terms of amount of the parent acid that was converted to the amine, salt, or ester in a spray mixture or solution.
ai	Active ingredient; the amount of phytotoxic chemical compound in a spray mixture or solution.
aehg	Acid equivalent per 100 gallons of spray mixture or spray solution.
aihg	Active ingredient per 100 gallons of spray mixture or spray solution.

For additional definitions that may be useful to those using this publication, see USDA Forest Service General Technical Report PNW-37 (Gratkowski 1975), p. 39-44, "Glossary of Agricultural Chemical Terms."

Contents

Introduction

Selecting the herbicide or herbicides that will safely, effectively, and economically control shrubs or weed trees that compete with crop trees is vital in silviculture (Gratkowski 1975). Using the most effective herbicide will minimize the amount of chemical needed to attain a desired degree of brush control for site preparation or release of young conifers. It can also minimize both cost of treatment and possible environmental contamination by reducing or eliminating the need for repeated treatments that may be necessary with less effective herbicides.

This publication provides data showing effects of chemicals I have tested to control shrubs and weed trees during the past 24 years. Except for salmonberry, tabulated data are only from tests I conducted or studies in which I participated, but applicable results of other investigators are discussed in the text. This information was compiled to aid silviculturists in selecting the most effective herbicides for 16 shrub and tree species that affect silviculture in western Oregon forests. The information may also preclude additional testing of many chemicals that proved ineffective.

Screening Tests

A series of screening tests were started during 1955 to determine the effect of selected herbicides applied as foliage sprays on 13 brush species and varieties in southwestern Oregon (Gratkowski 1959). Additional tests were installed in later years as promising new herbicides became available. Some results of tests on shrubs, conifers, grasses, and forbs have been published (Gratkowski 1961, 1968, 1971, 1976, 1977). This publication supplements results of the 1955 tests with applicable data from small plot studies and project-scale trials of herbicides on native shrubs and weed trees from 1956 through 1976. Data are also provided for three species not included in the 1955 tests.

SPECIES AND STUDY AREAS

Six of the shrubs and weed trees are abundant in the southern end of the Cascade Range and eastern Oregon; 10 are common in the Coast Ranges and Siskiyou Mountains. Generally, shrubs are most difficult to control where environmental conditions are most favorable for growth. Therefore, tests on each species were installed in areas where the plants were especially large, vigorous, and abundant, indicating environmental conditions near optimum for their growth and survival. A species is much more easily controlled near the geographical limits of its range or on sites where one or more environmental factors are near a critical level for survival and growth of the species. Herbicides effective on the test areas will be even more effective on such critical sites.

Brush species and varieties[1/] treated in the designated areas were:

Coast Ranges and Siskiyou Mountains

Hairy manzanita	*Arctostaphylos columbiana*
Hoary manzanita	*Arctostaphylos canescens*
Greenleaf manzanita (burled, sprouting)	*Arctostaphylos patula*
Varnishleaf ceanothus	*Ceanothus velutinus* var. *laevigatus*
Pacific madrone	*Arbutus menziesii*
Western thimbleberry	*Rubus parviflorus*
Salmonberry	*Rubus spectabilis*
Scrub tanoak	*Lithocarpus densiflorus* var. *montanus*
Canyon live oak	*Quercus chrysolepis*
Golden evergreenchinkapin	*Castanopsis chrysophylla* var. *minor*

Cascade Range

Greenleaf manzanita (no burl, nonsprouting)[2/]	*Arctostaphylos obtusifolia*
Deerbrush ceanothus	*Ceanothus integerrimus*
Snowbrush ceanothus	*Ceanothus velutinus*
Mountain whitethorn	*Ceanothus cordulatus*
Golden chinkapin	*Castanopsis chrysophylla*
Saskatoon serviceberry	*Amelanchier alnifolia*

[1/] Common and scientific names are in accordance with Kelsey and Dayton (1942), except for golden chinkapin, which is in accordance with Little (1953).

[2/] Although exact identity of this manzanita has not yet been established, it is the nonsprouting green-leaved manzanita prevalent in the southern end of the Cascade Range and in central Oregon. It has been variously identified as greenleaf manzanita (*Arctostaphylos patula* Greene), Howell manzanita (*A. hispidula* Howell), *A. patula* Greene ssp. *platphylla* (Gray) P.V. Wells, and as *A. obtusifolia* Piper. The nonsprouting characteristic, compared with sprouting of the burled form of greenleaf manzanita in the Siskiyou Mountains, is of special interest to foresters; this nonsprouting green-leaved manzanita can be killed more easily with herbicides at far less cost.

HERBICIDES[3/]

Thirteen chemicals were included in intensive screening tests. These were:

2,4-D	(2,4-dichlorophenoxy)acetic acid
2,4,5-T	(2,4,5-trichlorophenoxy)acetic acid
dichlorprop	2-(2,4-dichlorophenoxy)propionic acid
silvex	2-(2,4,5-trichlorophenoxy)propionic acid
2,4-DB	4-(2,4-dichlorophenoxy)butyric acid
amitrole	3-amino-1,2,4-triazole
amitrole-T	amitrole plus ammonium thiocyanate
2,3,6-TBA	A mixture of six isomers of trichlorobenzoic acid, mostly the 2,3,6-trichloro isomer
AMS	Ammonium sulfamate
picloram	4-amino-3,5,6-trichloropicolinic acid
8726-M	2,4,5-trichloro-6-nitrophenyl carbamate
triclopyr	3,5,6-trichloro-2-pyridinyloxyacetic acid
Krenite™	Ammonium ethyl carbamoylphosphonate

The chemicals were in several forms. The first four listed were low-volatile propylene glycol butyl ether esters in liquid formulations containing 4 pounds acid equivalent per gallon. 2,4-DB also was a liquid formulation containing 2 pounds of dimethyl amine per gallon. Amitrole is a fine white crystalline powder containing 50 percent active ingredient; amitrole-T is a liquid with 2 pounds active ingredient of amitrole and 2 pounds of ammonium thiocyanate per gallon. AMS was in the form of water soluble crystals, 95 percent active ingredient by weight. Picloram was tested alone as the potassium salt and as a triisopropanolamine salt in combination with similar amines of either 2,4-D alone or 2,4-D plus 2,4,5-T. 2,3,6-TBA was a water-soluble solution of the sodium salt in a formulation that contained 1.5 pounds acid equivalent per gallon. Triclopyr was tested both as a triethylamine salt and as an ethylene glycol butyl ether ester. Krenite was a liquid formulation of the active ingredient.

3/ Chemicals were provided by several companies, especially Dow Chemical U.S.A. and Amchem Products, Inc.

METHODS

Selection of herbicides and carriers was based on habit, and stem and leaf characteristics of each species; and all herbicides were applied as foliage sprays to drip point.[4/] Carriers were either water or diesel oil-in-water emulsions. Percentage of oil by volume in the spray solution is indicated in each table. All solutions and emulsions were applied as small-droplet sprays with a 3-gallon knapsack sprayer.

Phenoxy herbicides, especially 2,4-D and 2,4,5-T, were considered the most promising chemicals and given the most extensive tests in the 1955 study. They proved to be the most effective and versatile chemicals in that study and in project-scale trials and were used as standards for comparing relative effectiveness of new herbicides in subsequent screening tests.

Although most formulations were tested on 20 shrubs of each species, a few chemicals considered potentially less useful for forest brush control were screened on only 10 shrubs of selected species. The smaller tests were exploratory, but they produced useful information and are included in the tables for applicable species of shrubs and weed trees. Sprayed plants were examined in early autumn at the end of the first and second growing seasons after spraying Unless specifically noted, all tables show effect of the sprays at the end of the second growing season.

Effects of Foliage Sprays on Shrubs and Weed Trees

Effects of the herbicides on individual species and varieties are described in the pages that follow, and degree of susceptibility to herbicides is shown in parentheses for each shrub or weed tree. Species rated highly susceptible were readily killed with low concentrations of 2,4-D or 2,4,5-T in water. A rating of moderately susceptible indicates that aerial parts of the shrubs were readily killed, but most plants resprouted. A rating of resistant means that only parts of the stems and branches died back after being sprayed with herbicides; none of the treated plants were killed.

Tabulated data for many species are too extensive for quick evaluation. To aid silviculturists, I have evaluated the data and designated the best herbicide and/or treatment for each species. This information is printed in boldface type.

4/ See "Terms and Abbreviations," inside back cover.

The geographical range of each species is described briefly. Most of this information was compiled from taxonomic texts supplemented by personal knowledge of areas where I observed the species during 27 years of fieldwork. Although range data for shrubs and weed trees are incomplete, the information may assist in identifying problem brush species and choosing effective herbicides to control them.

HAIRY MANZANITA (Highly susceptible)

Hairy manzanita (fig. 1) is an erect shrub, 3 to 10 feet tall, with thick, ovate gray-green leaves 1 to 2½ inches long. Its leaves and branchlets are usually covered with long, stiff hairs, and its white flowers are in short, dense panicles. This is one of the most widespread manzanitas in the Pacific Northwest. It is abundant at low elevation on the west slope of the Cascade Range and at low to mid-elevations in the Coast Ranges from British Columbia to southern California. Hairy manzanita is especially abundant along the coast in southwestern Oregon. In all areas, this shrub usually occurs as scattered plants or in small groups interspersed with other brush species. It does not crown-sprout when the aerial parts are killed by fire or chemicals.

Figure 1.--Hairy manzanita is a common shrub in the Coast Ranges and at low elevations in the Cascade Range.

One hundred mature hairy manzanita shrubs were sprayed during mid-July 1955 in the Coast Ranges west of Roseburg, Oregon. Stems were growing and new leaves were developing. Berries were full grown but not ripe.

Hairy manzanita was easily killed with a low concentration of low volatile esters of 2,4-D in water applied as a foliage spray. 2,4-D proved more effective than 2,4,5-T on this species (Table 1).

Table 1--*Effects of herbicides on hairy manzanita at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1/]		Number	Percent	Number	Inches	- - - Percent - - -		
2,4-D	1	Water	20	0	0	0	100	100	Gratkowski (1959)
2,4-D	2	Water	20	0	0	0	100	100	
2,4-D	2	5% DO[2/]	20	0	0	0	100	100	
2,4,5-T	1	Water	20	0	0	0	79	65	
2,4,5-T	2	Water	20	0	0	0	100	100	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution.

2/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

The relative value of the diesel oil emulsion compared with a water carrier could not be determined from these tests, since all treatments killed the plants. The diesel oil emulsion, however, was as effective as the water carrier and seemed to wet the pubescent foliage much more readily.

Low volatile esters of 2,4-D are recommended for foliage sprays to control hairy manzanita during the growing season. For treating individual shrubs, a 2 aehg formulation of low volatile esters in an oil-in-water emulsion carrier should prove satisfactory. Two pounds acid equivalent per acre in either water or an oil-in-water emulsion carrier should be adequate for aerial sprays on this species, which is extremely susceptible to phenoxy herbicides.

HOARY MANZANITA (Highly susceptible)

Hoary manzanita is an erect shrub, 2 to 6 feet high, with densely white-pubescent leaves and branchlets that give a gray appearance to the entire crown (fig. 2). Its range extends from southern California northward through the Coast Ranges into southwestern Oregon, where it is relatively common in the Coast Ranges, the Siskiyou Mountains, and on the west slope of the Cascade Range. Like hairy manzanita, it is usually found as individual plants or in small clumps among other

Figure 2.--Hoary manzanita shrubs 4,000 feet above sea level in the Siskiyou Mountains.

brush species; large, pure stands of this species do not seem to develop in southwestern Oregon. The shrubs do not resprout after fire or when the tops are killed with herbicide.

Both 2,4-D and 2,4,5-T were tested on hoary manzanita in the Siskiyou Mountains west of Grants Pass, Oregon. The shrubs were sprayed early in July, during their late flowering stage. Some fruits were fully developed, and new leaves were unfolding.

Hoary manzanita proved extremely susceptible to both 2,4-D and 2,4,5-T applied as foliage sprays during active growth (table 2). Within the range of dosage tested, 2,4-D was as effective as 2,4,5-T. Since 2,4-D is less expensive than 2,4,5-T, use of **2,4-D is recommended for controlling hoary manzanita.** Although this species, like other manzanitas, proved resistant to late summer aerial sprays of 2,4,5-T applied to release ponderosa pine (Gratkowski 1977), it is very susceptible to phenoxy herbicides from early spring through midsummer.

Again, relative value of an oil-in-water emulsion compared with a water carrier could not be determined from these tests. Sprays containing low concentrations of 2,4-D in either carrier killed all the sprayed plants.

Table 2--*Effects of herbicides on hoary manzanita at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1/]		Number	Percent	Number	Inches	- - - Percent	- - -	
2,4-D	1	Water	20	0	0	0	100	100	Gratkowski (1959)
2,4-D	2	Water	20	0	0	0	100	100	
2,4-D	2	5% DO[2/]	20	0	0	0	100	100	
2,4,5-T	1	Water	20	0	0	0	97	85	
2,4,5-T	2	Water	20	0	0	0	100	100	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution.

2/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

GREENLEAF MANZANITA (no burl) (Highly susceptible)

A nonsprouting green-leaved manzanita (see footnote 2, page 2) without burls at the root crown is the most abundant and common manzanita on the west slope of the Cascade Range in southwestern Oregon. Extensive, relatively pure stands of the species are present at elevations of 2,500 to 5,000 feet in eastern Jackson County, but it usually occurs in mixture with other brush species. This manzanita is abundant in extensive brushfields along the crest of the Cascade Range near Mount McLoughlin, northeast of Medford. West of the crest of the Cascade Range, the shrubs attain heights of 8 to 9 feet. The green-leaved manzanita prevalent in central Oregon appears to be the same species; but the shrubs are much smaller, averaging only 2 to 4 feet in height.

As indicated above, this manzanita does not form a burl at the root crown, and tests have shown that it does not crown-sprout when the tops are cut off a few inches above the soil surface or when the stems and branches are killed with herbicides (fig. 3).

One hundred and twenty large, mature shrubs were sprayed during late July in the Cascade Range near Mount McLoughlin. The shrubs were growing, and new shoots were 2 to 3 inches long on most plants. The largest new leaves were almost full size, and new berries were full grown.

This **nonsprouting greenleaf manzanita can be killed with either 2,4-D or 2,4,5-T (table 3), but 2,4-D is more effective and economical.** Although diesel oil emulsions were not noticeably more effective than water carriers, thorough coverage seemed more easily obtained with emulsion carriers.

*Figure 3.--Remnants of a nonsprouting greenleaf manzanita (*Arctostaphylos obtusifolia*) shrub sprayed with 2,4-D more than 15 years before.*

Table 3--*Effects of herbicides on nonsprouting greenleaf manzanita in the Cascade Range at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1]		Number	Percent	Number	Inches	- - - Percent - - -		
2,4-D	1	Water	20	0	0	0	99	85	Gratkowski (1959)
2,4-D	1	5% DO[2]	20	0	0	0	97	80	
2,4-D	2	Water	20	0	0	0	100	95	
2,4-D	2	5% DO	20	0	0	0	99	100	
2,4,5-T	2	Water	20	0	0	0	96	85	
2,4,5-T	2	5% DO	20	0	0	0	95	95	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution.

2/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

Complete spray coverage of all foliage on the exterior of the crown is necessary; foliage missed or sprayed too lightly remains alive for years after spraying, even though the rest of the crown dies. Plants with some live foliage or stem sprouts ("flagged" plants), however, did not sprout from other stems or from roots. Thorough coverage will insure maximum top-kill and minimize or eliminate such flagging in the crowns.

A small, replicated minimum-dosage test was installed during 1956 to determine the least amount of 2,4-D required per acre to insure an acceptable degree of control for this green-leaved manzanita. Low volatile propylene glycol butyl ether esters of 2,4-D were applied on 1/100th-acre plots at rates of 1, 2, and 4 pounds ae per acre in water and in oil-in-water emulsion carriers. Observation indicated 2 to 4 pounds ae per acre would be necessary in midsummer foliage sprays.

This information was used in prescribing rates of application for a 100-acre test of aerial spraying to control manzanita on the Rogue River National Forest. Three areas were sprayed with commercial formulations of isooctyl esters of phenoxy herbicides on June 10, 1958 (Gratkowski and Anderson 1968). The herbicides were applied in oil-in-water emulsions containing 1 gallon of black diesel oil in a total of 7 gallons of spray per acre. Results (table 4) indicate that **late spring aerial application of 3 pounds ae per acre of low volatile esters of 2,4-D will insure almost complete mortality of this nonsprouting green-leaved manzanita for site preparation** in southwestern Oregon. **To release young Douglas-fir or Shasta red fir,** less complete control is acceptable; **aerial application of 2 lb ae of 2,4-D or 2,4,5-T is recommended.** Choice of either herbicide or a brushkiller mixture of the two will depend upon species composition of brushfields containing this manzanita.

In central Oregon, Dahms (1961) indicated that adequate control of the smaller shrubs can be obtained with as little as 1 pound ae of 2,4-D per acre in either water or emulsion carriers. Drier and more

Table 4--*Effect of early June aerial applications of herbicides on nonsprouting greenleaf manzanita*[1/]

Treatment		Acres	Shrubs with stem sprouts	Shrub kill	
Chemical	Pounds per acre			Aerial parts	Complete plant
	ae[2/]			Percentage	
2,4-D	2	20	26	97	74
2,4-D	4	60	4	[3/]100	96
2,4-D plus 2,4,5-T	2 } 1 }	20	4	[3/]100	96

[1/] From Gratkowski and Anderson (1968), USDA For. Serv. Res. Pap., PNW-72, 8 p.

[2/] Acid equivalent.

[3/] A few stem tips were alive on 2 of the 50 plants examined in each of these treatments.

critical environmental conditions in central Oregon probably are responsible for both the smaller size of the shrubs and relatively easier control.

GREENLEAF MANZANITA (with burl) (Moderately susceptible)

Sprouting greenleaf manzanita is by far the most important species of manzanita in the Coast Ranges and Siskiyou Mountains. From southwestern Oregon, its range extends southward at high elevations in the inner North Coast Ranges of California and in the Sierra Nevada to southern California. This manzanita is a major component of mixed brushfields, and extensive, relatively pure stands of the species are found on many sites.

Its importance stems not only from its wide range and abundance but also from its resistance to silvicultural control. Greenleaf manzanita forms a conspicuous burl at the root crown. When the crown of a shrub is killed by cutting, fire, or chemicals, large numbers of new sprouts develop from dormant buds in the burl (fig. 4). The burl makes silviculturally acceptable control more difficult and expensive. As a result, foresters must distinguish between this species and the nonsprouting green-leaved manzanita in the Cascade Range.

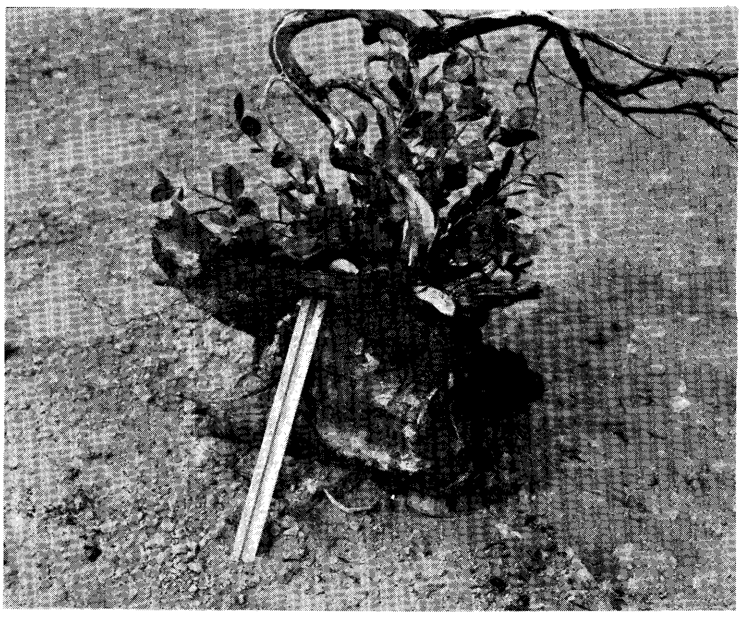

Figure 4.--Greenleaf manzanita (Arctostaphylos patula) *in the Siskiyou Mountains sprouted from burls at the root crown the year after tops of the shrubs were killed with an aerial spray of 2,4-D and 2,4,5-T.*

All chemicals listed in table 5 were tested as foliage sprays on mature greenleaf manzanita shrubs at an elevation of 4,000 feet in the Siskiyou Mountains. The shrubs were growing, new leaves were developing, and fruits were full grown but not ripe.

Table 5--*Effects of herbicides on burled (sprouting) greenleaf manzanita at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1/]		Number	Percent	Number[2/]	Inches	- - - Percent	- - -	
2,4-D	2	Water	20	70	M	5	95	15	Gratkowski (1959)
2,4-D	4	Water	20	90	M	7	96	10	
2,4-D	2	5% DO[3/]	20	75	M	2	91	20	
2,4,5-T	1	Water	20	100	M	6	89	0	
2,4,5-T	2	Water	20	100	M	7	84	0	
2,4,5-T	1	5% DO	20	95	M	5	90	5	
2,4-DB	4	Water	20	40	M	7	99	50	Previously unpublished data
AMS	20	4% DO[4/]	20	90	M	6	87	5	
8726-M	2	Water	20	100	M	6	90	0	

[1/] Pounds acid equivalent per 100 gallons of spray mixture or spray solution; for AMS read aihg (active ingredient per 100 gallons).

[2/] M = number of basal sprouts equal to or more than the original number of stems at ground level.

[3/] Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

[4/] Oil-in-water emulsion carrier containing DO equivalent to 4 gallons per 100 gallons of spray mixture.

Greenleaf manzanita proved moderately resistant to foliage sprays of 2,4-D and 2,4,5-T in the initial tests. Aerial parts of the shrubs were readily killed by the phenoxy herbicides, but most shrubs produced large numbers of sprouts from buds in the burls.

As with other *Arctostaphylos* spp., low volatile esters of 2,4-D were more effective than similar esters of 2,4,5-T on this manzanita. A water carrier was as effective as an oil-in-water emulsion, but the emulsion seemed to wet the foliage more readily and thoroughly. Since 2,4-D is not only more effective but also costs less than 2,4,5-T, use of **2,4-D in a light oil-in-water emulsion is recommended for foliage sprays to control greenleaf manzanita.**

Greenleaf manzanita was the only one of five shrub species on which the dimethyl amine of 2,4-DB was more effective than low volatile esters of 2,4-D and 2,4,5-T. If additional species should prove susceptible to 2,4-DB, this chemical may have some silvicultural value. Since greenleaf manzanita was the only one of five species so susceptible to 2,4-DB, this does not seem likely and 2,4-DB cannot be considered a substitute for the phenoxyacetic herbicides 2,4-D or 2,4,5-T.

Results of tests on individual shrubs and aerial spray applications indicate that--beyond an effective minimum dosage--lower concentrations and smaller amounts of phenoxy herbicides produce better results than more concentrated sprays or greater amounts of herbicide per acre. In tests on individual shrubs (table 5), 2 lb aehg foliage sprays of phenoxy herbicides were better than 4 lb aehg sprays. And in aerial sprays (Gratkowski and Philbrick 1965), 3 pounds ae of 2,4-D per acre was more effective than a greater dosage of phenoxy herbicides (table 6). One possible explanation is that excessive rates of herbicide kill leaf tissues too rapidly, reduce photosynthesis, and thus reduce absorption and translocation of phenoxy herbicide into stems and roots, where the chemicals exert their greatest phytotoxic effect (Leonard and Crafts 1956).

Table 6--*Mortality after a midsummer aerial application of herbicides on mature greenleaf manzanita in the Siskiyou Mountains*[1]

Treatment			Number of shrubs sampled	Plants with basal sprouts	Top-kill	Complete shrub killed
Herbicide	Pounds per acre	Carrier				
	ae[2]			- - - -	Percent	- - - - - -
2,4-D	3	Emulsion	20	70	100	30
2,4-D plus 2,4,5-T	2 2	Emulsion	20	85	82	15
2,4-D plus 2,4,5-T	4 4	Emulsion	20	100	91	0

1/ From Gratkowski and Philbrick (1965), J. For. 63:922.

2/ Acid equivalent.

DEERBRUSH CEANOTHUS (Highly susceptible)

This deciduous species of *Ceanothus* with blue to white flowers that resemble lilac is one of the most widespread shrub species in western Oregon and Washington but rare east of the Cascade Range. It grows on a variety of sites and soils in the Coast Ranges, the interior valleys, and the Cascade Range (fig. 5).

Deerbrush ceanothus is found in many brushfields on forest land and sometimes forms extensive, relatively pure stands. In the Cascade Range, it is often found intermingled with redstem ceanothus in brushfields. Deerbrush ceanothus also occurs as underbrush in sparsely timbered areas. It is considered a good browse species and a valuable component of shrub cover on big game summer range (Sampson and Jespersen 1963). The shrubs stump-sprout after cutting (McMinn 1951) and crown-sprout after the tops are killed with herbicides.

Mature shrubs of deerbrush ceanothus in the Cascade Range were sprayed with seven different herbicides and combinations of herbicides. All chemicals were applied as foliage sprays. When treated, the shrubs were in the late flowering--early fruiting stage. Twig growth had ceased, and all leaves were fully developed.

Figure 5.--A mature deerbrush ceanothus shrub in the Cascade Range.

Of the six chemicals tested, **low volatile esters of 2,4-D are recommended for foliage sprays to control deerbrush ceanothus.** By the third summer after treatment, both phenoxy herbicides, amitrole, and 2,3,6-TBA were effective on this species. All four chemicals had killed 80 to 95 percent of the sprayed plants (table 7). The 2,4-D sprays, however, are most economical and produce a degree of control equal to that obtained with the best of the other chemicals.

In a final examination 2 years after treatment in the 1955 tests, water proved more effective than a diesel oil emulsion as a carrier for 2,4-D on deerbrush. In earlier examinations, the emulsion had appeared better.

AMS and 2,4-DB cannot be considered replacements for phenoxy herbicides on deerbrush ceanothus. Neither chemical produced an acceptable degree of control when applied as foliage sprays during the summer of 1956.

In aerial sprays to release ponderosa pine and Douglas-fir on the Willamette National Forest (Gratkowski 1977), low volatile esters of 2,4,5-T in water carriers produced excellent control of deerbrush and redstem ceanothus (*Ceanothus sanguineus* Pursh). Two pounds ae of 2,4,5-T were applied in 8 gallons of spray per acre on separate areas in March and early September. March sprays were no more effective than September sprays; both resulted in excellent control of deerbrush and redstem ceanothus. Because March application damaged and killed many young ponderosa pines, however, only late summer foliage sprays were recommended for releasing pines from brush competition.

Table 7--*Effects of herbicides on deerbrush ceanothus at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1/]		Number	Percent	Number[2/]	Inches	- - - Percent	- - -	
2,4-D	1	Water	20	70	5	8	100	80	Gratkowski (1959)
2,4-D	2	Water	20	60	6	10	100	90	
2,4-D	2	5% DO[3/]	20	45	7	14	100	80	
2,4,5-T	2	Water	20	75	4	11	100	85	
amitrole	4	Water	20	40	5	4	98	95	
2,3,6-TBA	2	Water	10	78	5	10	95	80	
2,4-D plus amitrole	1 plus 4	Water	10	100	7	15	100	30	
2,4-DB	1	Water	20	65	M	13	30	0	Previously unpublished data
AMS	10	Water	20	85	M	13	99	15	
AMS	10	4% DO[4/]	20	100	M	15	94	0	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution; for amitrole and AMS, read aihg (active ingredient per 100 gallons).

2/ Average number of basal sprouts produced by individual sprayed shrubs that resprouted after treatment. M = number of basal sprouts equal to or more than the original number of stems at ground level.

3/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

4/ Oil-in-water emulsion carrier containing DO equivalent to 4 gallons per 100 gallons of spray mixture.

SNOWBRUSH CEANOTHUS (Moderately susceptible)

Snowbrush ceanothus, often called "slick-leaf ceanothus" or "sticky laurel," is one of the most common pioneer evergreen shrub species on new burns and cuttings in the Cascade Range and on the intermountain plateau east of the Cascade Range in Oregon and Washington. It is found from coastal British Columbia southward in the Cascade Range and Sierra Nevada to central California and eastward to Colorado and South Dakota. In the Coast Ranges of California, Oregon, and Washington, and at elevations up to 3,000 feet on the west slope of the Cascade Range in Oregon, snowbrush ceanothus is replaced by varnishleaf ceanothus, which is similar in appearance.

Mature snowbrush ceanothus shrubs can be 8 to 9 feet tall on the west slope of the Cascade Range. Germination of dormant seeds in the forest soil is induced by heat of forest fires, slash burning, and to a smaller degree by solar radiation heating surface soil in which the seeds are buried. Extensive, relatively pure stands of this large, evergreen shrub are common on burns and cuttings. In addition, snowbrush is frequently a major component of mixed brushfields at mid-elevations and high elevations throughout its range. The shrubs stump-sprout when aerial parts are lopped (fig. 6) or killed by fire or chemicals, adding to the problem of silvicultural control.

Figure 6.--Sprouts of snowbrush ceanothus lopped 3 years before have again overtopped many small Douglas-firs in this area. A few of the larger trees were released and will now outgrow the brush sprouts.

Initially, five herbicides were screened on snowbrush ceanothus in the Cascade Range in southwestern Oregon. When sprayed in late July 1955, stems were growing and a few blossoms were present on the shrubs. Most of the new leaves were smaller than the older leaves.

In the 1955 tests and subsequent retreatment of sprouts (Gratkowski 1959, 1968), **low volatile esters of 2,4,5-T proved most effective and useful for controlling snowbrush ceanothus** (table 8). Although other chemicals also killed aerial parts of the shrubs, 2,4,5-T was more effective in killing roots. Crown sprouts were least abundant on shrubs sprayed with 2,4,5-T.

Other chemicals tested cannot be considered adequate substitutes for silvicultural use of 2,4,5-T on snowbrush. Dichlorprop, for example, killed a few more shrubs than 2,4,5-T; but sprouts were much more abundant on the remaining shrubs. In addition, dichlorprop is not as effective as 2,4,5-T on many other brush species. Dichlorprop, therefore, would not be as effective as 2,4,5-T in brushfields composed of many different shrub species and weed trees--a common problem in Pacific Northwest forests.

Undiluted oil carriers are not needed when phenoxy herbicides are used to control snowbrush ceanothus, even in early spring budbreak sprays, for herbicides are intercepted as foliage sprays on evergreen

Table 8--*Effects of herbicides on snowbrush ceanothus at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1]		Number	Percent	Number[2]	Inches	- - - Percent	- - -	
2,4-D	2	5% DO[3]	20	85	M	20	96	20	Gratkowski (1959)
2,4-D	4	5% DO	20	90	M	19	100	20	
2,4,5-T	2	5% DO	19	80	F	18	100	30	
2,4,5-T	4	5% DO	20	75	F	18	100	40	
dichlorprop	2	5% DO	10	80	M	20	99	50	
silvex	2	5% DO	10	100	M	23	100	0	
amitrole	8	Water	10	50	F	9	32	0	
dichlorprop plus amitrole	2 } 4 }	Water	10	70	F	12	97	70	
2,4-DB	2	4% DO[4]	20	65	F	18	18	0	Previously unpublished data
AMS	20	4% DO	20	95	M	13	93	5	
AMS	40	4% DO	20	55	M	14	100	45	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution; for amitrol and AMS, read aihg (active ingredient per 100 gallons).

2/ M = number of basal sprouts equal to or more than original number of stems. F = number of basal sprouts less than original number of stems at ground level.

3/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

4/ Oil-in-water emulsion carrier containing DO equivalent to 4 gallons per 100 gallons of spray mixture.

species regardless of season of application. Therefore, an oil-in-water emulsion is generally used as the carrier when phenoxy herbicides are applied to control snowbrush ceanothus. An emulsion carrier is more effective than a water carrier in wetting and penetrating the hard, sticky cuticle on the evergreen leaves.

During the past 20 years, results of aerial sprays have verified that **good control of snowbrush ceanothus can be obtained with** phenoxy herbicides in oil-in-water emulsion carriers. For example, a single **budbreak aerial application of 2 lb ae per acre of low volatile esters of 2,4,5-T in an emulsion carrier containing 3/4 gallon of diesel oil in 10 gallons of spray per acre** produced an 88-percent top-kill, and 19 percent of the shrubs were dead at the end of the second summer (Gratkowski and Stewart 1976). Experience with late summer aerial sprays, however, has shown that 2,4,5-T in a water carrier can control snowbrush ceanothus enough to safely release ponderosa pines (Gratkowski 1975, 1977).

Seasonal susceptibility.--In a study of changes in susceptibility from late spring through late summer, mature snowbrush ceanothus shrubs on two areas were foliage sprayed on 10 dates starting on June 24 and ending September 15 (Gratkowski 1977). The two spray areas were located 40 miles apart on the west slope of the Cascade Range: one area was west of Crater Lake; the second was 40 miles north near Quartz Mountain. On each treatment date, 10 shrubs were sprayed to drip point with a 2 lb aehg formulation of 2,4,5-T in an oil-in-water emulsion carrier.

Snowbrush ceanothus remained highly susceptible to 2,4,5-T throughout the entire period (table 9). In addition, more than 20 years experience has shown that snowbrush is susceptible to phenoxy herbicides from budbreak in early spring throughout the growing season. Therefore, **foresters may choose any time from budbreak through late summer to control snowbrush with low volatile esters of 2,4,5-T. The season selected within this period need depend only on silvicultural objectives.**

Table 9--*Seasonal effect of low volatile esters of 2,4,5-T applied as foliage sprays to drip point on mature snowbrush ceanothus shrubs in the Cascade Range*[1]

Treatment: Date of treatment	Treatment: Concentration	Treatment: Carrier	Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed
	aehg[2]		Number	Percent	Number[3]	Inches	Percent	Percent
July 1	2	1% DO[4]	20	10	F	39	98	90
July 8	2	1% DO	20	10	M	15	98	90
July 15	2	1% DO	20	0	0	0	100	100
July 22	2	1% DO	20	0	0	0	100	100
July 29	2	1% DO	20	0	0	0	100	100
Aug. 10	2	1% DO	20	15	M	22	98	85
Aug. 20	2	1% DO	20	0	0	0	100	100
Aug. 30	2	1% DO	20	10	F	13	100	90
Sept. 15	2	1% DO	20	5	F	16	100	95

1/ From Gratkowski (1977), For. Sci. 23:2-12.

2/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution.

3/ F = number of basal sprouts less than original number of stems originating at ground level. M = number of basal sprouts equal to or more than original number of stems. 0 = none.

4/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 1 gallon per 100 gallons of spray mixture.

VARNISHLEAF CEANOTHUS (Moderately susceptible)

Although taxonomic texts usually list varnishleaf ceanothus as a Coast Range brush species, it is a common shrub at midelevations on the west slope of the Cascade Range in western Oregon. From California its range extends northward in the Coast Ranges to British Columbia. In western Oregon, varnishleaf ceanothus is abundant in the Coast Ranges, the Siskiyou Mountains, and generally at elevations up to 2,500 feet in the Cascade Range. At that elevation, it merges with snowbrush ceanothus, whose range extends across the crest of the Cascade Range to the Rocky Mountains. In the mountains between Cottage Grove and the middle fork of the Willamette River, varnishleaf ceanothus occupies sites up to 4,000 feet above sea level. Extensive, relatively pure stands of this species occupy many burns and clearcuts in the southern end of the Cascade Range.

Like snowbrush ceanothus, varnishleaf ceanothus is often called "slick-leaf ceanothus" or "sticky laurel," and many foresters make no distinction between the species (snowbrush) and the variety (varnishleaf). Unlike snowbrush, however, individual varnishleaf ceanothus shrubs can grow to a height of 20 feet with a crown diameter of 25 feet and stems exceeding 6 inches in diameter at the base. This has an important silvicultural implication. Since varnishleaf shrubs grow much taller than snowbrush, young conifers will remain suppressed beneath varnishleaf for a much longer time (Gratkowski and Lauterbach 1974). Both forms develop a large number of fast-growing stump sprouts after cutting or fire, and both crown-sprout to a limited degree after being sprayed with low volatile esters of 2,4-D or 2,4,5-T.

Susceptibility tests.--Eight different formulations of seven herbicides were applied as foliage sprays on large mature shrubs of varnishleaf ceanothus in the Siskiyou Mountains. The sprays were applied during early July when the shrubs were in full bloom, stems were growing, and some new leaves were full size.

2,4,5-T proved the most effective herbicide to control varnishleaf ceanothus (table 10). A 4 lb aehg solution in an emulsion carrier killed all aerial parts of the exceptionally large shrubs, and 70 percent of the plants treated with this formulation did not produce basal sprouts. Two years after treatment, 85 percent of the shrubs were dead (fig. 7), and only a few sprouts were found on the remaining 15 percent. No other herbicide was as effective as 2,4,5-T on varnishleaf ceanothus.

Table 10--*Effects of herbicides on varnishleaf ceanothus at the end of the second growing season after treatment*

Treatment: Herbicide	Treatment: Concentration	Treatment: Carrier	Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
	aehg[1]		Number	Percent	Number[2]	Inches	- - - Percent	- - -	
2,4-D	2	5% DO[3]	20	55	F	7	74	45	Gratkowski (1959)
2,4-D	4	5% DO	20	80	F	15	88	40	
2,4,5-T	2	5% DO	20	40	F	21	93	65	
2,4,5-T	4	5% DO	20	30	F	14	100	85	
dichlorprop	2	5% DO	10	60	F	8	60	30	
silvex	2	5% DO	10	40	F	19	88	60	
amitrole	8	Water	10	70	F	7	32	0	
dichlorprop plus amitrole	2 } 4	Water	10	50	F	7	72	50	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution; for amitrol, read aihg (active ingredient per 100 gallons).

2/ F = number of basal sprouts less than original number of stems originating at ground level.

3/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

Figure 7.--Varnishleaf ceanothus shrub killed with one foliar spray of 2,4,5-T in an emulsion carrier.

Despite its large and formidable appearance, varnishleaf ceanothus sprouted far less vigorously than snowbrush after treatment with herbicides.

Seasonal susceptibility.--Exceptionally large varnishleaf ceanothus shrubs in the Coast Ranges were sprayed on nine dates between July 1 and September 16, 1960 (Gratkowski 1977). Stages of growth ranged from active growth on July 1 to no stem growth and 80 percent of the seeds disseminated on September 16. On each date, five large mature shrubs were foliage sprayed to drip point with a 2 lb aehg formulation of low volatile esters of 2,4,5-T in a 1-percent diesel oil emulsion carrier.

Varnishleaf ceanothus proved highly susceptible to 2,4,5-T throughout the entire summer season (table 11). The unusually low degree of control on July 1 may have been due to inadequate coverage of the large shrubs on the first spray date. Experience has shown that varnishleaf is as susceptible from budbreak through spring as it was throughout the summer season in this experiment.

Table 11--*Seasonal effect of low volatile esters of 2,4,5-T applied as foliage sprays to drip point on mature varnishleaf ceanothus shrubs in the Cascade Range*[1]

Treatment			Total plants sprayed	Basal sprouts per plant, by average number and average height[2]		Top-kill	Complete plant killed
Date of treatment	Concentration	Carrier					
	aehg[3]		Number	Number	Inches	- - - Percent - - -	
July 1	2	1% DO[4]	5	--	--	49	0
July 8	2	1% DO	5	--	--	96	60
July 15	2	1% DO	5	--	--	96	80
July 22	2	1% DO	5	--	--	85	60
July 29	2	1% DO	5	--	--	79	60
Aug. 10	2	1% DO	5	--	--	90	60
Aug. 20	2	1% DO	5	--	--	97	80
Aug. 30	2	1% DO	5	--	--	91	60
Sept. 16	2	1% DO	5	0	0	100	100

1/ From Gratkowski (1977), For. Sci. 23:2-12.

2/ Many of the original stems remained alive on surviving shrubs sprayed on July 1 through August 30. These expressed apical dominance and suppressed production of basal sprouts. For the September 16 sprays, no sprouts were produced because all shrubs died.

3/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution.

4/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 1 gallon per 100 gallons of spray mixture.

MOUNTAIN WHITETHORN (Moderately susceptible)

Mountain whitethorn is found in the Coast and Cascade Ranges from southern Douglas County, Oregon, southward beyond Mount Shasta in the Sierra Nevada and in the Coast Ranges to southern California. In Oregon, mountain whitethorn is common in brushfields at elevations of 3,500 feet and higher in the Siskiyou Mountains and the Coast and Cascade Ranges of southwestern Oregon (fig. 8).

Small groups of spreading, low to procumbent shrubs are typical in evergreen brushfields of the Siskiyou Mountains; extensive, relatively pure stands of taller, more erect shrubs that exceed 8 feet in height are typical on burns and cuttings in the Cascade Range. The seeds of mountain whitethorn germinate abundantly after fire (Gratkowski 1974), and relatively pure stands of this small-leaved, spiny shrub are common in broadcast-burned clearcuts on pumice soil near Diamond Lake in the Cascade Range. Mountain whitethorn produces a spreading, dense mat of roots near the soil surface and sprouts prolifically from the entire root system when the tops are cut off or killed with herbicides. This dense mat of roots probably provides seedling conifers with intense competition for soil moisture during the dry summer season.

Figure 8.--This dense stand of mountain whitethorn occupied a cutting in a Douglas-fir forest on pumice soil near the crest of the Cascade Range in southwestern Oregon.

Four herbicides were tested on mature mountain whitethorn shrubs on pumice soil in the Cascade Range. When sprayed during early August, a few late flowers were blooming on the shrubs, seed capsules were developing, and stems were growing in length on all plants.

2,4,5-T was the most effective herbicide tested on mountain whitethorn, but root kill after one application was poor even with this chemical (table 12). Basal sprouts were abundant and vigorous in all treatments. An emulsion seemed no more effective than water as a carrier for low volatile esters of 2,4-D applied as foliage sprays on this species. As with other species, however, mountain whitethorn seedlings and sprouts are more susceptible to herbicides than are vigorous, mature shrubs. Two resprays of 2,4,5-T following the initial application resulted in death of 90 percent of the shrubs (Gratkowski 1968).

When the 1955 screening tests were installed, a series of 1/100th-acre plots were also sprayed with each of the four herbicides in water at a rate of 2 pounds acid equivalent per acre (table 13). In addition, two more plots were sprayed with 2,4-D and 2,4,5-T in diesel oil emulsions. There was no replication of treatments.

Table 12--*Effects of herbicides on mountain whitethorn ceanothus at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1/]		Number	Percent	Number[2/]	Inches	Percent	Percent	
2,4-D	1	Water	20	100	M	27	100	0	Gratkowski (1959)
2,4-D	2	Water	20	95	M	28	100	5	
2,4-D	1	5% DO[3/]	20	100	M	26	100	0	
2,4,5-T	2	Water	20	80	M	27	100	20	
amitrole	4	Water	19	100	M	15	88	0	
dichlorprop	2	Water	10	100	M	28	100	0	
2,4-D plus amitrole	1 } 1	Water	10	100	M	26	99	0	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution; for amitrol, read aihg (active ingredient per 100 gallons).

2/ M = number of basal sprouts equal to or more than the original number of stems.

3/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

Table 13--*Effects of herbicides on mountain whitethorn ceanothus in 1/100th-acre plots*[1/]

Treatment			Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed
Herbicide	Pounds per acre	Carrier					
	ae[2/]		Percent	Number[3/]	Inches	Percent	Percent
2,4-D	2	Water	100	M	29	100	0
2,4-D	2	5% DO[4/]	100	M	28	100	0
2,4,5-T	2	Water	100	M	24	98	0
2,4,5-T	2	5% DO	90	M	23	100	10
dichlorprop	2	Water	100	M	23	98	0
amitrole	4	Water	--	-	--	5/	0

1/ The herbicides were applied as foliage sprays in August 1955. Results were determined by examining 10 plants on each plot in October 1956.

2/ Acid equivalent; for amitrole, read active ingredient.

3/ M = number of basal sprouts equal to or more than the original number of stems.

4/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

5/ Little or no effect.

Results of the small plot tests verified the results of the individual plant tests. 2,4,5-T again proved more effective than the other chemicals, but sprouting occurred in all treatments. As in the tests on individual shrubs, a diesel oil emulsion was no more effective than water as a carrier for 2,4-D. The emulsion appeared slightly more effective than water as a carrier for 2,4,5-T, however.

For aerial application, low volatile esters of 2,4,5-T are recommended to control mountain whitethorn, since repeated sprays also proved 2,4,5-T more effective than 2,4-D on this species (Gratkowski 1968). Esters of 2,4-D can be used if necessary but will usually require additional applications and a higher dosage per acre to achieve the same degree of control. In an aerial application on mature shrubs in Siskiyou Mountain brushfields, however, 3 lb ae of 2,4-D per acre (table 14) resulted in top-kill of mountain whitethorn that equalled that obtained with a brushkiller mixture of 2 lb ae of 2,4-D and 2 lb ae of 2,4,5-T (Gratkowski and Philbrick 1965).

Table 14--*Mortality after a midsummer aerial application of herbicides on mature mountain whitethorn ceanothus in the Siskiyou Mountains*[1/]

Treatment			Number of shrubs sampled	Plants with basal sprouts	Top-kill	Complete shrub killed
Herbicide	Pounds per acre	Carrier				
	ae[2/]			- - - - - Percent	- - - - -	
2,4-D	3	Emulsion	20	100	84	0
2,4-D plus 2,4,5-T	2 2	Emulsion	20	100	72	0
2,4-D plus 2,4,5-T	4 4	Emulsion	20	100	98	0

1/ From Gratkowski and Philbrick (1965), J. For. 63:922.

2/ Acid equivalent.

PACIFIC MADRONE (Moderately susceptible)

Pacific madrone has a range that extends from Baja, California (Abrams 1951), to western British Columbia in the Coast Ranges, and from central California northward through the Sierra Nevada and Cascade Range to western Oregon. In southwest Oregon, Pacific madrone is a major component of broad sclerophyll forests and brushfields in the Siskiyou Mountains, on the eastern slope of the Coast Ranges, in the interior valleys, and at low elevations in the Cascade Range. Broad-leaved evergreen species such as tanoak, canyon live oak, chinkapin, ceanothus, and manzanita are generally found with madrone in the Siskiyou Mountains and Coast Ranges. Deciduous species such as Oregon white oak, California black oak, and poison oak are common associates at lower elevations in the dry interior valleys and in the foothills of the Cascade Range.

Esters of 2,4-D were compared with similar formulations of 2,4,5-T on tall, well-established sprouts of Pacific madrone that had developed from stumps and roots after a severe wildfire had swept the test area (Gratkowski 1977). When treated, the sprouts were 10 to 25 feet tall (fig. 9). Both herbicides were applied in water carriers as foliage sprays to drip point.

Pacific madrone appears equally susceptible to low volatile esters of 2,4-D and 2,4,5-T (table 15). **Low volatile esters of 2,4-D are recommended for foliage sprays to control madrone.** This is in agreement with Leonard and Harvey (1965), who recommend a 4 aehg formulation of 2,4-D in an oil-in-water emulsion carrier for high-volume foliage sprays to control individual plants of Pacific madrone.

Figure 9.--A clump of Pacific madrone sprouts being sprayed during a herbicide screening test.

Table 15--*Effects of herbicides on Pacific madrone at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1/]		Number	Percent	Number[2/]	Inches	- - - Percent	- - -	
2,4-D	2	Water	10	20	M	10	100	80	Gratkowski
2,4,5-T	2	Water	10	20	M	14	100	80	(1977)

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution.

2/ M = number of basal sprouts equal to or more than the original number of stems.

These limited tests allowed no comparison of water vs. oil-in-water emulsion carriers, since excellent top-kill was obtained with either herbicide in a water carrier in this trial. Experience, however, indicates that oil-in-water emulsions would be more effective as a carrier for phenoxy herbicides applied as foliage sprays on thick, leathery leaves such as these, especially in low-volume aerial sprays. The added oil spreads the herbicide over the leaf surface, improves coverage, and increases penetration of herbicide through the waxy cuticle.

Seasonal susceptibility tests were also conducted to detect any change in effectiveness of esters of 2,4,5-T from the end of the growing season in late June throughout the summer until mid-September. Madrone maintained a high level of susceptibility to 2,4,5-T throughout the entire period (table 16).

Although the data from high volume spray tests (table 16) seems to indicate an increase in susceptibility and percentage of plants killed by late summer sprays, experience has shown this is not true with low-volume aerial sprays. In fact, control with low-volume, late summer aerial sprays is erratic, and many Pacific madrone trees become resistant to phenoxy herbicides during early autumn. Response varies from tree to tree, possibly a result of genetic variation controlling changes in dormancy of individual trees. Trees that become dormant sooner would be more resistant and show less effect from late summer--early autumn sprays (Gratkowski 1977).

Table 16--*Seasonal effect of low volatile esters of 2,4,5-T applied as foliage sprays to drip point on large, well-established clumps of Pacific madrone sprouts in the Rogue River Valley*[1/]

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed
Date of treatment	Concentration	Carrier						
	aehg[2/]		Number	Percent	Number[3/]	Inches	- - - Percent	- - -
June 29	2	Water	10	60	M	13	96	40
July 7	2	Water	10	60	M	12	98	40
July 13	2	Water	10	70	M	16	85	30
July 21	2	Water	10	70	M	13	97	30
July 28	2	Water	10	50	M	12	99	50
Aug. 9	2	Water	10	20	M	25	99	80
Aug. 18	2	Water	10	20	M	14	100	80
Aug. 30	2	Water	10	40	M	11	89	60
Sept. 15	2	Water	10	20	M	13	100	80

1/ This seasonal variation in response is presented graphically in For. Sci. 23:2-12 (Gratkowski 1977).

2/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution.

3/ M = number of basal sprouts equal to or more than the original number of stems.

Based on trials and experience, application of **3 lb ae per acre of low volatile esters of 2,4-D in an oil-in-water emulsion carrier is recommended for aerial sprays on relatively pure stands of Pacific madrone. Such sprays should be applied before the shrubs and trees exceed 20 feet in height.**

Reduced control must be expected in dense stands or on large trees of Pacific madrone. As with other shrubs and weed trees (Gratkowski 1968), sprays are more effective on young plants or 2- to 3-year-old sprouts of Pacific madrone than on mature trees. **In a dense stand of trees about 20 to 35 feet tall, a mixture of 2 lb ae of 2,4-D plus 1 lb ae of 2,4,5-T proved highly effective;** crowns and trunks of almost all Pacific madrone trees were killed, although many resprouted from root crowns. A repeated treatment is usually necessary on such tall trees.

SALMONBERRY (Moderately susceptible)

Salmonberry is one of the most abundant and troublesome brush species on forest land in the Coast Ranges and coastal areas of Oregon and Washington (fig. 10, A and B). Its natural range, however, is far more extensive. It occurs from Mendocino County, California, north along the coast to Alaska, and eastward in the Rocky Mountains to Idaho and Montana. Salmonberry presents special silvicultural problems at low to medium elevations on the wet coastal slopes of the Coast Ranges in Oregon and Washington and inland through the Willapa Hills to the foothills on the west slope of the Cascade Range in Washington. Dense, vigorous stands quickly occupy forest sites after logging or wildfire.

Figure 10A.--Salmonberry...

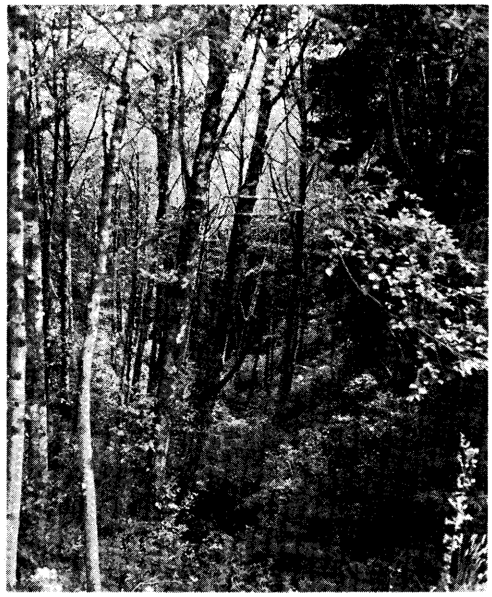

Figure 10B.--...often forms a deep, dense understory beneath red alder in the Coast Ranges.

On July 22-23, 1966, two experimental formulations of picloram (M-2951 and M-3083) were applied as foliage sprays on 1/100-acre plots of salmonberry in the Oregon Coast Ranges near Coos Bay, Oregon (Gratkowski 1971). M-2951 contained ½ lb ae of picloram plus 2 lb ae of 2,4,5-T per gallon, and M-3083 contained 1 lb each of picloram, 2,4-D, and 2,4,5-T per gallon in the form of triisopropanolamine salts. Amitrole-T and low volatile propylene glycol butyl ether esters of 2,4,5-T were applied on separate adjacent plots for comparison. A 2-percent diesel oil-in-water emulsion was used as the carrier for 2,4,5-T; the other herbicides were applied in water carriers.

In the 1966 trials, the spray solution containing 1½ lb each of triisopropanolamine salts of picloram, 2,4-D, and 2,4,5-T (M-3083) produced better control of salmonberry than any of the other treatments (table 17). Stewart (1974b) states that a single application of picloram alone may be adequate for site preparation on areas occupied by salmonberry. Picloram, however, is nonselective and damages conifers; it cannot be used to release young conifers from salmonberry.

Table 17--*Effect of 1966 midsummer foliage sprays on salmonberry*[1/]

Herbicide	Treatment		Degree of control[2/]
	Pounds per acre	Carrier	
	aehg[3/]		
amitrole-T	2	Water	2.4
amitrole-T	2	Water	2.4
picloram 2,4,5-T	1/2 2	Water	2.8
2,4,5-T	3	Emulsion	3.5
picloram 2,4-D 2,4,5-T	1 1 1	Water	3.5
picloram 2,4-D 2,4,5-T	1-1/2 1-1/2 1-1/2	Water	4.1

1/ From Gratkowski (1971), USDA For. Serv. Res. Note PNW-171, 5 p.

2/ A rating of 1.0 indicates little or no effect; a rating of 5.0 indicates complete kill with no resprouting.

3/ Acid equivalent per 100 gallons of spray mixture or spray solution; for amitrole-T, read aihg (active ingredient per 100 gallons).

Stewart (1974a) reported amitrole-T was more effective than 2,4,5-T in both early foliar and late foliar sprays on salmonberry, but it does not control western thimbleberry. Since most stands of salmonberry also contain thimbleberry, use of amitrole-T frequently releases thimbleberry and converts the stand to relatively pure thimbleberry. **A late foliar spray of low volatile esters of 2,4,5-T applied in an emulsion carrier controls both salmonberry and thimbleberry** (Gratkowski 1971, Stewart 1974b) and is a better choice for site preparation in plant communities where both species are important components of the shrub cover.

A late foliar aerial application of 3 lb ae of low volatile esters of 2,4,5-T is also recommended to release well established young conifers from salmonberry (Gratkowski 1971, 1975; Stewart 1974b). To release small conifers or for site preparation followed by interplanting, a second treatment with 2,4,5-T in a water carrier may be necessary to control resprouting brush and insure adequate light and soil moisture for greatest survival and height growth of the conifers.

In late July 1974, another test was installed on salmonberry to compare effects of foliage sprays of triclopyr and Krenite with effects of similar sprays of picloram and 2,4,5-T. Picloram was in the form of a potassium salt; 2,4,5-T was a low volatile ester. Krenite was a water-soluble liquid formulation of the active ingredient; triclopyr formulations were a triethylamine salt and an ethylene glycol butyl ether ester. As in the earlier test, all herbicides were applied as fine droplet foliage sprays to drip point.

Both Krenite and triclopyr (when registered) deserve consideration as foliage sprays for site preparation in relatively pure stands of salmonberry. Although both required 3-lb aehg spray solutions to produce a degree of control equal to that obtained with a 1-lb aehg spray of picloram (table 18), each chemical has some advantages over picloram.

Table 18--*Effect of 1970 midsummer foliage sprays on salmonberry at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier					
	aehg[1/]		Number	- - - - - -	Percent	- - - - -	
2,4,5-T	3	3% DO[2/]	10	30	99	[3/]40	Stewart (1974a)
amitrole-T	3	Water	10	20	58	[3/]70	
picloram	1	Water	10	0	100	[3/]100	
2,4,5-T	3	2% DO[4/]	20	75	94	25	Gratkowski et al. (1978)
picloram	1	Water	20	15	94	85	
triclopyr ester	1	Water	20	67	99	33	
triclopyr amine	1	Water	20	68	90	32	
triclopyr amine	3	Water	20	5	100	95	
Krenite TM	1	Water	20	80	71	20	
Krenite	3	Water	20	25	98	75	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution; for amitrole-T and Krenite, read aihg (active ingredient per 100 gallons).

2/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 3 gallons per 100 gallons of spray mixture.

3/ Plants sprayed July 1970; examined June 1972.

4/ Oil-in-water emulsion carrier containing DO equivalent to 2 gallons per 100 gallons of spray mixture.

Like picloram, triclopyr damages conifers and should only be used for site preparation. Triclopyr, however, controls both deciduous and evergreen brush species; picloram is much less effective on evergreen shrubs. In addition, triclopyr is less persistent in the soil and may allow planting of conifers sooner after application.

Krenite does not control evergreen brush, but it is effective on deciduous shrubs and weed trees. Krenite is registered for site preparation on forest land and now has SLN[5/] labels for conifer release in Oregon and Washington. This herbicide should prove useful for releasing young conifers from competition of deciduous shrubs and weed trees--especially where the eye-catching "brown-out" of dead foliage characteristic of 2,4-D and 2,4,5-T is undesirable. A more complete discussion of these tests is available in a publication by Gratkowski et al. (1978).

WESTERN THIMBLEBERRY (Moderately susceptible)

Western thimbleberry may be found from southern California northward to Alaska at elevations ranging from sea level to 9,000 feet. From the west coast, its range extends eastward to New Mexico, Colorado, and Michigan. It also occupies a wide range of habitats from open to wooded, and moist to dry sites throughout Oregon and Washington. Western thimbleberry is an especially common associate of salmonberry in dense brushfields following logging, wildfire, or soil disturbance on the western slopes of the Coast Ranges in Oregon and Washington (fig. 11, A and B).

On July 22-23, 1966, two experimental formulations of picloram (M-2951 and M-3083) were applied as foliage sprays on 1/100-acre plots of thimbleberry in the Oregon Coast Ranges near Coos Bay, Oregon. M-2951 contained ½ lb ae of picloram plus 2 lb ae of 2,4,5-T per gallon, and M-3083 contained 1 lb each of picloram, 2,4-D, and 2,4,5-T per gallon. All herbicides were in the form of triisopropanolamine salts. Amitrole-T and low volatile propylene glycol butyl ether esters of 2,4,5-T were applied on separate adjacent plots for comparison.

5/ "State and Local Need" labels issued by the respective State Departments of Agriculture as authorized by the U.S. Department of Environmental Quality.

Figure 11A.--Western thimbleberry...

Figure 11B.--...formed a dense brush cover intermixed with salmonberry on a logged area in the Oregon Coast Ranges.

Tordon 10K pellets, 10 percent ae picloram as a potassium salt, were also tested on thimbleberry at rates of 10 and 30 lb of pellets per acre. Pellets were distributed by hand; a 2-percent diesel oil-in-water emulsion was used as the carrier for 2,4,5-T; the other herbicides were applied in water carriers.

As on salmonberry, 1½ gallons of M-3083 containing 1½ lb each of picloram, 2,4-D, and 2,4,5-T per acre was more effective than any other herbicide or mixture of herbicides in the 1966 tests on western thimbleberry (table 19). Although this mixture is not registered or available, it is possible that ½ gallon per acre of Tordon 155 (½ lb ae picloram plus 2 lb ae of 2,4,5-T, both in the form of isooctyl esters) may be equally effective for site preparation in western thimbleberry. Since picloram damages conifers, Tordon 155 is not suitable for releasing young conifers overtopped by thimbleberry.

Foliage sprays of the potassium salt of picloram alone controls thimbleberry as well as salmonberry (Stewart 1974a), but it damages conifers and is used only for site preparation. Amitrole-T is relatively ineffective on western thimbleberry (Gratkowski 1971; Stewart 1974a, 1974b).

Low volatile esters of 2,4,5-T are preferred for western thimbleberry. For site preparation, control of thimbleberry by an early foliar application of 3 lb ae of 2,4,5-T in an emulsion carrier is almost equal to that obtained with a similar spray of 1 lb picloram (Stewart 1974b). In addition, esters of 2,4,5-T can be used safely for conifer release.

Table 19--*Effect of midsummer foliage sprays and picloram pellets on western thimbleberry*[1]

Herbicide	Treatment		Degree of control[2]
	Pounds per acre	Carrier	
	aehg[3]		
amitrole-T	3	Water	2
picloram pellets[4]	10	None	2
picloram pellets[4]	30	None	2
picloram 2,4,5-T	3/4 3	Water	2
2,4,5-T	3	Emulsion	4
picloram 2,4-D 2,4,5-T	1-1/2 1-1/2 1-1/2	Water	4.5

[1] From Gratkowski (1971), USDA For. Serv. Res. Note PNW-171, 5 p.

[2] A rating of 1.0 indicates little or no effect; a rating of 5.0 indicates all shrubs on the plot are dead.

[3] Acid equivalent per 100 gallons of spray mixture or spray solution; for amitrole-T, read aihg (active ingredient per 100 gallons).

[4] Picloram pellets containing 10 percent active ingredient were distributed on the soil surface throughout each plot.

As on salmonberry, **a late foliar spray of 3 lb ae of low volatile esters of 2,4,5-T in an emulsion carrier is considered the best treatment to release Douglas-fir and Sitka spruce from western thimbleberry.** The trees, however, should be protected from the spray by foliage of the brush overstory. If the trees are exposed, a water carrier should be used even though the degree of brush control will be reduced. An aerial respray may be needed 1 or 2 years later to control thimbleberry sprouts and maintain dominance of the conifers.

GOLDEN CHINKAPIN (Resistant)

Golden chinkapin is found on the west slope of the Cascade Range from the vicinity of the Columbia River southward to California and across the Cascade Range into south-central Oregon. It is abundant on the Rogue-Umpqua Divide, throughout the Siskiyou Mountains, the southern end of the Oregon Coast Ranges, and southward in the California Coast Ranges to Mendocino County.

Golden chinkapin varies greatly in habit and is often found both as a shrub and a tree in the same area (fig. 12). It is often present as understory brush in stands of conifers in the Cascade Range, where it assumes a habit intermediate between a shrub and a tree. In the understory, it grows in a clumpwise fashion similar to vine maple; each clump may develop one or more main stems resembling individual trees. Smaller stems develop on roots near the main stems to produce the clumps. Golden chinkapin trees of good form are found on many sites in both the Cascade Range and the Siskiyou Mountains.

Figure 12.--Golden chinkapin is found both as a shrub and a tree in western Oregon forests.

Eight formulations of herbicides were tested on clumps of golden chinkapin in the Cascade Range during 1955. When the shrubs were sprayed in late July, stems were still growing in length; but most of the new leaves were full size.

Sixteen months after spraying, response to all treatments was similar (table 20). All treatments affected the aerial parts to some

Table 20--*Effects of herbicides on golden chinkapin at the end of the second growing season after treatment*

Treatment: Herbicide	Treatment: Concentration	Treatment: Carrier	Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
	aehg[1]		Number	Percent	Number[2]	Inches	- - - Percent	- - -	
2,4-D	2	5% DO[3]	20	80	M	13	38	0	Gratkowski (1959)
2,4-D	4	5% DO	20	100	M	13	54	0	
2,4,5-T	2	5% DO	20	100	M	12	61	0	
2,4,5-T	4	5% DO	20	100	M	12	61	0	
dichlorprop	2	5% DO	10	90	M	11	51	0	
silvex	2	5% DO	10	90	M	14	58	0	
amitrole	8	Water	10	40	M	6	42	0	
dichlorprop plus amitrole	2 } 4 }	Water	10	80	M	9	77	10	

[1] Pounds acid equivalent per 100 gallons of spray mixture or spray solution; for amitrole, read aihg (active ingredient per 100 gallons).

[2] M = number of basal sprouts equal to or more than the original number of stems at ground level.

[3] Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

extent, but none were especially effective in killing roots of the sprayed plants. Great variation in top-kill within treatments indicates that there were no important differences between treatments. A few comments, however, concerning the relative effectiveness of the chemicals may be of value.

The most effective herbicide for golden chinkapin is 2,4,5-T; a conclusion verified in repeated applications on this species (Gratkowski 1968). A 2 lb aehg formulation in an emulsion carrier is recommended for foliage sprays on individual plants. In initial sprays on mature shrubs, increasing the concentration of 2,4,5-T from 2 lb aehg to 4 lb aehg did not increase its effect (table 20); evidently the 2 lb aehg dosage of 2,4,5-T was near its effective practical maximum when foliage was sprayed to drip point.

Amitrole in mixture with dichlorprop showed promise; a mixture of amitrole and dichlorprop was the most effective formulation tested. At present, however, amitrole in combination with other chemicals is not recommended for widespread use on golden chinkapin. Extensive stands of golden chinkapin do not seem to develop on forest land; it is usually intermixed with other shrubs and weed trees. Since most native shrubs and weed trees are much more susceptible to phenoxy herbicides than to amitrole, brushkiller mixtures of 2,4-D and 2,4,5-T are far more useful for controlling golden chinkapin in mixed brushfields on commercial forest land.

Aerial application of 2 lb ae of 2,4,5-T in an emulsion carrier per acre is recommended for budbreak sprays to release young conifers (except pines) from golden chinkapin. In emulsion carriers, 3/4 gallon of black diesel or No. 2 fuel oil is added in a spray volume of 10 gallons per acre. This treatment produced 81-percent top-kill, and 8 percent of the shrubs were dead in a 1973 aerial spray in the Cascade Range (Gratkowski and Stewart 1976). For specified silvicultural purposes, seasonal changes in carriers are recommended in USDA Forest Service General Technical Report PNW-37 (Gratkowski 1975).

GOLDEN EVERGREENCHINKAPIN (Resistant)

Golden evergreenchinkapin, a shrubby variety of golden chinkapin, is abundant in evergreen brushfields of the Siskiyou Mountains and sparsely distributed on the west slope of the Sierra Nevada in Eldorado County, California (fig. 13, A and B). The shrub form is generally found at higher elevations and on drier sites than golden chinkapin (McMinn 1951). It is an important component of the evergreen chaparral in southwest Oregon, and relatively pure stands are found as an open cover on many dry sites in the mountains of western Josephine County. The shrubs sprout from stumps and root crowns after fire, cutting, or treatment with herbicides.

Figure 13A.--Golden evergreen-chinkapin, a shrubby variety of golden chinkapin, is easily identified...

Figure 13B.--...by its trough-shaped leaves formed by upward folding of the blade on each side of the midrib.

Potentially useful herbicides were tested on vigorous, 5- to 15-foot-tall shrubs of golden evergreenchinkapin in three separate screening tests during 1955, 1956, 1963, and 1974. All herbicides were applied as high-volume foliage sprays during active growth, and results are presented in table 21. For comparison, effects of a single midsummer aerial spray of 2,4-D and of brushkiller mixtures of 2,4-D and 2,4,5-T on golden evergreenchinkapin in three brushfields in the Siskiyou Mountains are shown in table 22.

No herbicide killed an acceptable number of golden evergreenchinkapin shrubs after only one application as a foliage spray on well established, vigorous plants. Although some foliage, stems, and branches were killed by all herbicides, only triclopyr killed an appreciable number of golden evergreenchinkapin shrubs with one application. Amine and ester formulations of triclopyr at the highest rate (3 lb aehg) killed 25 and 45 percent of the shrubs, respectively, when applied as high volume foliage sprays. If triclopyr is later registered by EPA for forest use, it should prove useful for site preparation in mixed brushfields of evergreen and deciduous species (Gratkowski et al. 1978). Since it is nonselective and damages conifers, however, triclopyr will not be safe for conifer release.

Table 21--*Effects of herbicides on golden evergreenchinkapin at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg 1/		Number	Percent	Number 2/	Inches	Percent	Percent	
2,4-D	2	5% DO 3/	20	100	M	12	58	0	Gratkowski (1959)
2,4-D	4	5% DO	20	100	M	11	70	0	
2,4,5-T	2	5% DO	20	100	M	10	67	0	
2,4,5-T	4	5% DO	20	100	M	10	68	0	
dichlorprop	2	5% DO	10	100	M	8	62	0	
silvex	2	5% DO	10	80	M	7	44	0	
amitrole	8	Water	10	40	F	3	61	0	
dichlorprop plus amitrole	2 / 4	Water	10	100	M	11	27	0	
2,4-DB	2	Water	20	20	M	5	2	0	Previously unpublished data
2,3,6-TBA	2	Water	20	60	F	6	9	0	
AMS	20	4% DO 4/	20	55	M	5	11	0	
AMS	40	4% DO	20	90	M	6	36	0	
picloram 5/	.5	Water	20	100	F	6	13	0	
picloram	1.0	Water	20	100	M	7	37	0	
picloram	1.5	Water	20	85	M	6	47	15	
2,4,5-T 5/	1.5	Water	20	100	M	7	59	0	
2,4,5-T	3	2% DO 6/	20	100	M	8	81	0	Gratkowski et al. (1978)
picloram	1	Water	20	100	F	11	24	0	
triclopyr amine	1	Water	20	95	F	5	95	5	
triclopyr amine	3	Water	20	75	F	7	96	25	
triclopyr ester	3	Water	20	55	F	8	99	45	
Krenite TM	1	Water	20	7/	--	--	7/	0	
Krenite	3	Water	20	7/	--	--	7/	0	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution; for amitrole, AMS, and Krenite, read aihg (active ingredient per 100 gallons).

2/ M = number of basal sprouts equal to or more than original number of stems. F = number of basal sprouts less than original number of stems at ground level.

3/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

4/ Oil-in-water emulsion carrier containing DO equivalent to 4 gallons per 100 gallons of spray mixture.

5/ Picloram as potassium salt; 2,4,5-T as low volatile ester.

6/ Oil-in-water emulsion carrier containing DO equivalent to 2 gallons per 100 gallons of spray mixture.

7/ Top-kill too slight to induce basal sprouting.

Low volatile esters of 2,4,5-T are still the most reliable herbicide for silvicultural use on golden evergreenchinkapin. Since this species usually occurs with other shrubs and weed trees, 2,4,5-T is the most effective herbicide to release conifers from mixtures of golden evergreenchinkapin and other brush species. It is also effective for chemical site preparation to be followed by interplanting in understocked stands of young conifers intermixed with brush species. Treatment with 2,4,5-T will release the existing conifers, while selectively controlling and reducing competition of shrubs and weed trees to prepare the site for planting additional trees.

Table 22--*Mortality after a midsummer aerial application of herbicides on mature golden evergreenchinkapin in the Siskiyou Mountains*[1]

Treatment			Number of shrubs sampled	Plants with basal sprouts	Top-kill	Complete shrub killed
Herbicide	Pounds per acre	Carrier				
	ae[2]			- - - - - - Percent - - - - - -		
2,4-D	3	Emulsion	20	100	43	0
2,4-D plus 2,4,5-T	2 2	Emulsion	20	100	34	0
2,4-D plus 2,4,5-T	4 4	Emulsion	20	100	37	0

1/ From Gratkowski and Philbrick (1965), J. For. 63:919-923.

2/ Acid equivalent.

Increasing the concentration of 2,4,5-T beyond 2 lb aehg in an emulsion carrier did not increase either top- or root-kill of golden evergreenchinkapin (table 21). As on golden chinkapin in the Cascade Range, the 2 lb aehg dosage of 2,4,5-T in an emulsion carrier was evidently near an effective maximum for foliage sprays.

Although not as effective as triclopyr or 2,4,5-T, amitrole also controls golden evergreenchinkapin. Three applications of 4 lb aihg formulations of amitrole as foliage sprays killed 60 percent of the shrubs--a degree of control equal to that achieved with 2 lb aehg formulations of 2,4,5-T. Amitrole-T should be equally effective. Water carriers are used with either amitrole or amitrole-T. Both amitrole and amitrole-T, however, are less selective than 2,4,5-T and may damage foliage on young conifers. Therefore, amitrole-T is less desirable than 2,4,5-T for releasing young conifers from brush competition.

The mixture of amitrole and dichlorprop which looked promising on golden chinkapin in the Cascade Range was ineffective on this shrubby variety in the Siskiyou Mountains.

Oil-in-water emulsion carriers are preferred for use with phenoxy herbicides in both budbreak and late foliar sprays for site preparation and for releasing young conifers from golden evergreenchinkapin. Pines, however, are sensitive to phenoxy herbicides, especially in emulsion carriers. Water carriers should be used in late summer sprays of 2,4,5-T to release pines in southwest Oregon.

A budbreak aerial application of 3 lb ae of 2,4-D per acre in an emulsion carrier resulted in a 30-percent top-kill with 11 percent of the shrubs completely dead at the end of the second summer (Gratkowski and Stewart 1976). Young Douglas-firs were not damaged by this treatment. As with other resistant species, however, repeated aerial applications of phenoxy herbicides are required to kill more than 50 percent of the golden evergreenchinkapin shrubs in a brushfield (Gratkowski 1968).

In two separate screening tests during 1963 and 1974, 1 lb aehg solutions of potassium salts of picloram in water applied as foliage sprays were less effective than similar treatments with low volatile esters of 2,4-D or 2,4,5-T in emulsion carriers. Picloram is not recommended for foliage sprays to control golden evergreenchinkapin.

SASKATOON SERVICEBERRY (Resistant)

Serviceberry probably has a greater range than any other shrub listed in this publication. Its range extends from Alaska southward through the Coast and Cascade Ranges to central California, thence eastward to the Dakotas, Colorado, and New Mexico. Elevational range is also great; from near sea level to subalpine areas.

Serviceberry does not form extensive, dense stands in western Oregon. Instead, it usually occurs in small clumps or scattered shrubs as a component of sparse brush understories in open stands of conifers. In dense brushfields on burns and cuttings, serviceberry shrubs are scattered throughout the stand of shrubs and weed trees. It is a substantial element of the dense 10,000-acre brushfield on the Cat Hill burn near Mount McLoughlin at the crest of the Cascade Range in southwestern Oregon.

Saskatoon serviceberry can be a severe competitor for young conifers. It produces a tangled mat of roots that fully occupy the surface layer of soil beneath dense clumps of serviceberry stems that can exceed 15 feet in height. Thick stands of sprouts develop from these root systems after fire or cutting or when the crowns are killed with herbicide.

Large clumps of serviceberry were sprayed during early August high on the west slope of the Cascade Range (fig. 14). When treated, twig growth had ceased and new buds had been formed. Most leaves were fully developed, and many of the fruits were ripe.

None of the herbicides produced a satisfactory degree of control with one treatment when applied as foliage sprays (table 23). Foliage died quickly and branches died back a limited amount, but all sprayed plants were still alive 2 years after treatment. Since all plants produced numerous stem and basal sprouts, a temporary reduction of crown size was the only result of the initial spraying. Three successive applications of phenoxy herbicides as foliage sprays were required to kill more than 50 percent of the shrubs (Gratkowski 1968).

2,4-D is recommended for use as a foliage spray to control saskatoon serviceberry. After the initial application, 2,4,5-T seemed slightly more effective than 2,4-D as a high volume foliage spray on this species. Within the

Figure 14.--The clump of serviceberry being sampled was last sprayed with 2,4-D 19 years ago. Note its greatly reduced vigor in comparison with the unsprayed shrub on right side of photo.

Table 23--*Effects of herbicides on saskatoon serviceberry at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1]		Number	Percent	Number[2]	Inches	Percent	Percent	
2,4-D	1/2	Water	20	100	M	14	33	0	Gratkowski (1959)
2,4-D	2	Water	20	100	M	11	50	0	
2,4-D	4	Water	20	100	M	14	44	0	
2,4,5-T	1/2	Water	10	100	M	15	33	0	
2,4,5-T	2	Water	10	100	M	12	68	0	
amitrole	4	Water	10	--	--	--	[3]	0	
2,3,6-TBA	1	Water	10	--	--	--	[3]	0	
2,4-D plus amitrole	1/2 + 1	Water	10	100	M	10	43	0	
2,3,6-TBA plus amitrole	1/2 + 1	Water	10	--	--	--	[3]	0	
2,4-DB	1	Water	20	100	M	12	54	0	Previously unpublished data
2,4-DB	2	Water	20	100	M	17	68	0	
AMS	10	Water	20	100	M	11	67	0	

[1] Pounds acid equivalent per 100 gallons of spray mixture or spray solution; for amitrole and AMS, read aihg (active ingredient per 100 gallons).

[2] M = number of basal sprouts equal to or more than original number of stems.

[3] Little noticeable effect.

range of treatments tested, however, the difference was too small to be of practical value. Use of the more expensive 2,4,5-T does not seem warranted for the slight increase in top-kill.

None of the other chemicals and combinations of chemicals tested are considered more useful than 2,4-D or 2,4,5-T on serviceberry. None were more effective than the phenoxy herbicides, and all have one or more less favorable characteristics. 2,4-DB, for example, is not effective on as wide a range of species, and AMS is less selective and corrodes spray equipment.

Probably the most important result of the tests on this species is the indication that very low concentrations of 2,4-D or 2,4,5-T may be useful for releasing conifer reproduction from competition of serviceberry. Although neither tops nor roots were entirely killed, increased light as a result of the great reduction in crown size and foliage should be beneficial to conifer reproduction. The reduction in serviceberry foliage and crown size should also increase the amount of soil moisture available to young conifers during the dry summer period.

SCRUB TANOAK (Resistant)

Scrub tanoak is another of the many undesirable evergreen shrubs on forest land in southwestern Oregon and northern California. This shrub (fig. 15) is a variety (*montanus*) of *Lithocarpus densiflorus*, one of the better hardwood trees in the Pacific Northwest. Both the tree

Figure 15.--Scrub tanoak is a common shrub in the Siskiyou Mountains of southwestern Oregon and northern California.

species and the shrubby variety are major components of brushfields in the Siskiyou Mountains and the interior of the Oregon Coast Ranges. In the Siskiyou Mountains near Grants Pass, scrub tanoak appears to be quite tolerant and is prevalent as an understory shrub in open stands of forest trees or in the moderate shade of partially cut stands.

One hundred and twenty plants were sprayed in the Siskiyou Mountains during mid-July 1955. The shrubs were growing, and many new leaves had attained full size. The pubescent new foliage was difficult to wet with water sprays; emulsion carriers wetted the foliage much more readily.

Scrub tanoak proved resistant to both 2,4-D and 2,4,5-T applied as foliage sprays in mid-July (table 24). Although the aerial parts died back halfway to the ground, stem sprouts developed on the living lower parts of the stems; and basal sprouts were almost invariably produced by the treated plants.

Within the range of concentrations tested, **2,4-D was as effective as 2,4,5-T.** Increasing the concentration of the chemicals from 2 to 4 lb aehg in emulsion carriers did not appreciably change extent of top-kill. Evidently dosages of both 2,4-D and 2,4,5-T were already near their effective maximum when 2 lb aehg solutions were applied to drip point. The relative effectiveness of 2,4-D vs. 2,4,5-T was verified in cut surface treatments of tanoak and Pacific madrone trees in northern California

Table 24--*Effects of herbicides on scrub tanoak at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1/]		Number	Percent	Number[2/]	Inches	Percent	Percent	
2,4-D	2	Water	20	95	M	10	40	0	Gratkowski (1959)
2,4-D	2	5% DO[3/]	20	100	M	11	66	0	
2,4-D	4	5% DO	20	100	M	14	55	0	
2,4,5-T	2	Water	20	95	M	12	43	0	
2,4,5-T	2	5% DO	20	100	M	12	58	0	
2,4,5-T	4	5% DO	20	100	M	12	63	0	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution.

2/ M = number of basal sprouts equal to or more than original number of stems at ground level.

3/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

(Radosevich et al. 1976). Amines of 2,4-D killed 87 percent and 2,4,5-T killed 79 percent of injected trees.

Diesel oil emulsions were more effective than water carriers for both 2,4-D and 2,4,5-T on scrub tanoak. Top-kill with a 2 lb aehg concentration of 2,4-D was about 65 percent greater in an emulsion carrier than in a water carrier; the effectiveness of a similar concentration of 2,4,5-T was increased almost 35 percent.

A budbreak aerial spray of 3 lb ae of 2,4-D esters in an emulsion carrier per acre killed only 3 percent of the scrub tanoak shrubs in three brushfields in the Siskiyou Mountains (Gratkowski and Stewart 1976). Top-kill on the remaining live shrubs averaged 50 percent. For comparison, foliar sprays of 2 lb and 4 lb aehg formulations of 2,4-D in emulsion carriers applied to drip point produced top-kills of 66 and 55 percent, respectively, but none of the shrubs were dead. This comparison indicates that effects of the high-volume foliage sprays shown in table 24 are reliable indicators of effects that may be expected when phenoxy herbicides are applied as low-volume aerial sprays.

Twenty years' experience with aerial sprays on scrub tanoak has verified this observation. It has also shown that repeated aerial sprays like repeated high-volume foliage sprays (Gratkowski 1968) are necessary to kill a moderately high percentage of scrub tanoak shrubs. Observation of numerous aerial spray projects also indicates that a brushkiller mixture of 2 lb ae of 2,4-D plus 1 lb ae of 2,4,5-T in an emulsion carrier is generally more effective than 3 lb ae of 2,4-D in a similar carrier on tanoak trees that have attained heights of 20 feet or more.

CANYON LIVE OAK (Resistant)

Canyon live oak, a broad-leaved evergreen shrub or tree, is a major component of brushfields in the Siskiyou Mountains and in the interior of the Coast Ranges south of the Rogue River. Low, shrubby forms of this oak are abundant in Siskiyou Mountain brushfields at elevations of 3,000 feet and above. At lower elevations, especially in canyons near Galice, it maintains its many-stemmed, shrubby characteristic but attains heights of 15 to 20 feet. The tree form is usually found in river bottoms as far north as Little River, a tributary of the North Umpqua River, east of Roseburg. From the Siskiyou Mountains, the range of canyon live oak extends southward in the Sierra Nevada to central California and in the Coast Ranges to southern California.

The low, shrubby form of canyon live oak was sprayed during mid-July in a brushfield in the Siskiyou Mountains. The shrubs averaged 4 feet in height when sprayed; twig growth had ceased, and terminal buds were forming. New leaves were similar to those of the previous year in size and appearance.

When applied as foliage sprays, neither 2,4-D nor 2,4,5-T provided an acceptable degree of control with one treatment (table 25). Although all sprayed plants were completely defoliated, top-kill was limited and every treated plant sprouted from the base (fig. 16). Stem sprouts also developed on most of the plants, but these appeared to be too few and too small to maintain life in more than a small part of the original crown.

Table 25--*Effects of herbicides on canyon live oak at the end of the second growing season after treatment*

Treatment			Total plants sprayed	Plants with basal sprouts	Basal sprouts per plant, by average number and average height		Top-kill	Complete plant killed	Reference cited
Herbicide	Concentration	Carrier							
	aehg[1/]		Number	Percent	Number[2/]	Inches	Percent	Percent	
2,4-D	2	Water	20	100	M	9	25	0	Gratkowski (1959)
2,4-D	2	5% DO[3/]	20	100	M	7	44	0	
2,4-D	4	5% DO	20	100	M	11	54	0	
2,4,5-T	2	Water	20	100	F	6	21	0	
2,4,5-T	2	5% DO	20	100	F	5	32	0	
2,4,5-T	4	5% DO	20	100	M	8	37	0	
AMS	20	4% DO[4/]	20	95	M	5	65	0	Previously unpublished data
AMS	40	4% DO	20	100	M	5	79	0	
8726-M	2	Water	20	5/	(Only slight tip-kill, little defoliation; ineffective)				
2,4-D	3	2% DO[6/]	20	65	F	5	76	0	Gratkowski et al. (1978)
picloram	1	Water	20	30	F	5	30	0	
triclopyr amine	1	Water	20	25	F	4	64	0	
triclopyr amine	3	Water	20	25	F	4	73	0	
triclopyr ester	3	Water	20	25	F	4	78	0	
Krenite™	1	Water	20	5/	--	--	0	0	
Krenite	3	Water	20	5/	--	--	18	0	

1/ Pounds acid equivalent per 100 gallons of spray mixture or spray solution; for AMS and Krenite, read aihg (active ingredient per 100 gallons).

2/ M = number of basal sprouts equal to or more than original number of stems. F = number of basal sprouts less than original number of stems at ground level.

3/ Oil-in-water emulsion carrier containing diesel oil (DO) equivalent to 5 gallons per 100 gallons of spray mixture.

4/ Oil-in-water emulsion carrier containing DO equivalent to 4 gallons per 100 gallons of spray mixture.

5/ Top-kill too slight to induce basal sprouting.

6/ Oil-in-water emulsion carrier containing DO equivalent to 2 gallons per 100 gallons of spray mixture.

2,4-D was more effective than 2,4,5-T for killing foliage and stems of canyon live oak, but neither chemical completely killed the tops. Both chemicals were slightly more effective in the stronger (4 lb aehg) formulations than in the weaker (2 lb aehg) formulations. The increase in top-kill was so slight, however, that it did not indicate that appreciably increased control might be obtained by adding more herbicide to the spray solution; any slight increase in top-kill would not be worth the additional cost. **For high volume foliage sprays on mature canyon live oak shrubs, 3 lb aehg of 2,4-D should produce near maximum top-kill.**

A diesel oil emulsion proved more effective than a water carrier for both herbicides. With the 2 lb aehg concentration of 2,4-D, top-kill with the emulsion carrier was approximately 76 percent greater than that obtained with the water carrier. With a similar concentration of 2,4,5-T, top-kill was about 50 percent greater with the emulsion carrier.

Figure 16.--Canyon live oak sprouts on site aerial sprayed, burned, and then resprayed with a mixture of phenoxyacetic herbicides 23, 22, and 20 years before, respectively. Initially, this area was covered by a dense brushfield of evergreen shrubs.

Sprayed-and-burned shrubs of this type in Siskiyou Mountain brushfields developed broad, dense clumps of healthy sprouts from roots and root crowns that survived both the phenoxy herbicides and the fire (Gratkowski and Philbrick 1965). In many cases, these clumps contained hundreds of sprouts to replace one or two dozen stems of the original mature shrubs. It appeared impossible that any young conifer could compete and survive within the sprout clumps. Neither two additional high-volume foliage sprays on individual shrubs (Gratkowski 1968) nor two aerial resprays (table 26), however, were sufficient to kill even 50 percent of resprouting canyon live oak shrubs.

Table 26--*Mortality after a midsummer aerial application of herbicides on mature canyon live oak in the Siskiyou Mountains*[1]

Treatment			Number of shrubs sampled	Plants with basal sprouts	Top-kill	Complete shrub killed
Herbicide	Pounds per acre	Carrier				
	ae[2]			Percent		
2,4-D	3	Emulsion	20	100	25	0
2,4-D plus 2,4,5-T	2 2	Emulsion	20	100	17	0
2,4-D plus 2,4,5-T	4 4	Emulsion	20	100	18	0

[1] From Gratkowski and Philbrick (1965), J. For. 63:919-923.

[2] Acid equivalent.

Of all chemicals tested as high-volume foliage sprays, only 3 aehg rates of triclopyr equaled the effect of low volatile esters of 2,4-D. When registered for forest use, both ester and amine formulations of triclopyr may prove useful for site preparation (Gratkowski et al. 1978). Triclopyr, however, damages conifers and cannot be considered a replacement for 2,4-D in release sprays.

Conclusion

None of the author's screening tests of herbicides on shrubs and weed trees during the past 24 years have revealed any chemical as versatile and effective as low volatile esters of either 2,4-D or 2,4,5-T. This conclusion is in agreement with that of many others who have compared 2,4-D and 2,4,5-T with silvex, dichlorprop, dicamba, picloram, and other herbicidal chemicals on woody plants (Schubert 1962; Leonard and Harvey 1965; Stewart 1974a, 1974b). The two phenoxyacetic herbicides are effective on most shrubs and weed trees that are silvicultural problems on Pacific Northwest forest land. It must also be stressed that 2,4-D is not a suitable replacement for 2,4,5-T; nor is 2,4,5-T an acceptable replacement for 2,4-D. Although there is some overlap in effect on many brush species, the two herbicides complement rather than replace each other in silviculture.

For site preparation on areas occupied by deciduous woody plants, picloram can be a satisfactory substitute for either 2,4-D or 2,4,5-T in the forest ecosystem. Picloram, however, is more persistent than the phenoxyacetic herbicides and is not as effective on evergreen species. Newer herbicides such as glyphosate, Krenite, and triclopyr should prove useful for controlling some species and for particular silvicultural problems as indicated in the text. Tests indicate, however, that none of these can completely replace either 2,4-D or 2,4,5-T in silviculture.

Literature Cited

Abrams, Leroy.
1951. Illustrated flora of the Pacific States. Vol. 3. Stanford Univ. Press, Stanford, Calif.

Dahms, Walter G.
1961. Chemical control of brush in ponderosa pine forests of central Oregon. USDA For. Serv. Pac. Northwest For. and Range Exp. Stn. Res. Pap. 39, 17 p. Portland, Oreg.

Gratkowski, H.
1959. Effects of herbicides on some important brush species in southwestern Oregon. USDA For. Serv. Pac. Northwest For. and Range Exp. Stn. Res. Pap. 31, 33 p., illus. Portland, Oreg.

Gratkowski, H.
1961. Toxicity of herbicides on three northwestern conifers. USDA For. Serv. Pac. Northwest For. and Range Exp. Stn. Res. Pap. 42, 24 p., illus. Portland, Oreg.

Gratkowski, H.
1968. Repeated spraying to control southwest Oregon brush species. USDA For. Serv. Res. Pap. PNW-59, 6 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Gratkowski, H.
1971. Midsummer foliage sprays on salmonberry and thimbleberry. USDA For. Serv. Res. Note PNW-171, 5 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Gratkowski, H.
1974. Origin of mountain whitethorn brushfields on burns and cuttings in Pacific Northwest forests. West. Soc. Weed Sci. Proc., p. 5-8, illus.

Gratkowski, H.
1975. Silvicultural use of herbicides in Pacific Northwest forests. USDA For. Serv. Gen. Tech. Rep. PNW-37, 44 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Gratkowski, H.
1976. Herbicides for grass and forb control in Douglas-fir plantations. USDA For. Serv. Res. Note PNW-285, 7 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Gratkowski, H. J.
1977. Seasonal effects of phenoxy herbicides on ponderosa pine and associated brush species. For. Sci. 23(1):2-12, illus.

Gratkowski, H., and Lyle Anderson.
1968. Reclamation of nonsprouting greenleaf manzanita brushfields in the Cascade Range. USDA For. Serv. Res. Pap. PNW-72, 8 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Gratkowski, H., and P. Lauterbach.
1974. Releasing Douglas-firs from varnishleaf ceanothus. J. For. 72(3):150-152, illus.

Gratkowski, H. J., and J. R. Philbrick.
1965. Repeated aerial spraying and burning to control sclerophyllous brush. J. For. 63(12): 919-923, illus.

Gratkowski, H., and R. Stewart.
1976. Aerial spray tests of drift control additives for herbicides in oil and oil-in-water carriers. West. Soc. Weed Sci. Proc. 29:107-124.

Gratkowski, H. J., R. E. Stewart, and H. G. Weatherly.
1978. Triclopyr and Krenite herbicides show promise for use in Pacific Northwest forests. Down To Earth 34(3): 28-31, illus. Dow Chem. U.S.A., Midland, Mich.

Kelsey, Harlan P., and William A. Dayton.
1942. Standardized plant names. 2d ed. 675 p. Harrisburg, Pa.

Leonard, O. A., and A. S. Crafts.
1956. III. Uptake and distribution of radioactive 2,4-D by brush species. Hilgardia 26: 366-416.

Leonard, O. A., and W. A. Harvey.
1965. Chemical control of woody plants. Univ. Calif. Agric. Exp. Stn. Bull. 812, 25 p., illus. Davis, Calif.

Little, Elbert L., Jr.
1953. Check list of native and naturalized trees of the United States (including Alaska). U.S. Dep. Agric., Agric. Handb. 41, 472 p.

McMinn, Howard E.
1951. An illustrated manual of California shrubs. 663 p., illus. Univ. Calif. Press, Berkeley.

Radosevich, S. R., P. C. Passof, and O. A. Leonard.
1976. Douglas-fir release from tanoak and Pacific madrone competition. Weed Sci. 24(1): 144-145.

Sampson, Arthur W., and Beryl S. Jespersen.
1963. California range brushlands and browse plants. Calif. Agric. Exp. Stn. Ext. Serv. Man. 33, 162 p., illus.

Schubert, Gilbert A.
1962. Chemicals for brush control in California reforestation. USDA For. Serv. Pac. Southwest For. and Range Exp. Stn. Misc. Pap. 73, 14 p. Berkeley, Calif.

Stewart, R. E.
1974a. Foliage sprays for site preparation and release from six coastal brush species. USDA For. Serv. Res. Pap. PNW-172, 18 p., illus. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Stewart, R. E.
1974b. Repeated spraying to control four coastal brush species. USDA For. Serv. Res. Note PNW-238, 5 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

GPO 986-182

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research are made available promptly. Project headquarters are at:

Fairbanks, Alaska	Portland, Oregon
Juneau, Alaska	Olympia, Washington
Bend, Oregon	Seattle, Washington
Corvallis, Oregon	Wenatchee, Washington
La Grande, Oregon	

Mailing address: *Pacific Northwest Forest and Range Experiment Station*
P.O. Box 3141
Portland, Oregon 97208

The FOREST SERVICE of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.