1975
USDA FOREST SERVICE GENERAL TECHNICAL REPORT PNW-37

SILVICULTURAL USE of Herbicides in Pacific Northwest Forests

By H. Gratkowski

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND, OREGON

Abstract

After a brief description of silvicultural problems, the author tells how to prescribe herbicidal sprays for aerial, application in Pacific Northwest forests. The publication offers a detailed discussion of the five basic considerations: (1) selection of the best herbicide or herbicides, (2) amount of herbicide to be applied per acre, **(3)** carriers, (4) volume of spray per acre, and *(5)* seasons for application of aerial sprays.

Appendixes provide standard treatments for many common silvicultural problems in site preparation and to release young conifers from shrub and weed tree competition. Also included is a glossary of agricultural chemical terms and a list of abbreviations used in brush control literature.

This is a working manual for silviculturists based upon more than 20 years research and experience of Federal, State, and industrial foresters. It provides much information not generally available in the literature and tells how to use this knowledge in Pacific Northwest silviculture. Although designed primarily for the Pacific Northwest, the basic information should be useful in culture of coniferous forests far outside this region.

Keywords: Herbicide preparations, silvicultural control, management (forest).

ABBREVIATIONS OF TERMS USED IN WEED CONTROL LITERATURE

Abbreviation	*Definition*
A	acre(s)
ae	acid equivalent
aehg	acid equivalent per 100 gallons
ai	active ingredient
aihg	active ingredient per 100 gallons
cfs	cubic feet per second
diam	diameter
fpm	feet per minute
ft	foot or feet
g	gram(s)
gal	gallon(s)
gpa	gallons per acre
gpm	gallons per minute
ht	height
in	inch(es)
l	liter(s)
lb	pound(s)
mg	milligram(s)
μm	micrometer (formerly micron, one one-thousandth of a millimeter)
min	minute(s)
ml	milliliter(s)
mm	millimeter(s)
mph	miles per hour
oz	ounce(s)
ppmv	parts per million by volume
ppmw	parts per million by weight
psi	pounds per square inch
pt	pint(s)
qt	quart(s)
rpm	revolutions per minute
sp gr	specific gravity
T	ton(s)
tech	technical
temp	temperature
vmd	median diameter of droplets in spray
wt	weight
w/v	weight per volume. Do not use this abbreviation. Instead give specific units (examples: g/l or lb/gal).

Contents

Introduction

The Pacific Northwest contains a wide range of habitats that are reflected in the many different forest types on commercial forest lands. Dense Sitka spruce-western hemlock and Douglas-fir forests are found in the warm, rainy habitats along the coast; but Douglas-fir is predominant throughout most of the Coast Ranges and on the west slope of the Cascade Range. True fir and mountain hemlock forests occupy a limited area along the crest of the Cascade Range, and ponderosa pine and lodgepole pine are most abundant in the dry intermountain region. Mixed conifer types containing Douglas-fir, ponderosa pine, sugar pine, incense cedar, white fir, and Shasta red fir are prevalent in southwestern Oregon.

Brushfields are equally diverse. Broad-sclerophyll forests of tanoak, golden chinkapin, and Pacific madrone with an understory of evergreen shrubs are common in the wetter western end of the Siskiyou Mountains (fig. 1); while a chaparral of evergreen brush species occupies drier sites in the same area and in the relatively arid eastern end of the Siskiyou Mountains. Mixed evergreen and deciduous brushfields containing a high percentage of evergreen shrubs occupy large areas devastated by forest fires in the southern end of the Cascade Range. Northward in both the Coast and Cascade Ranges, deciduous brush species and weed trees increase in abundance in shrub communities.

'To safely achieve silvicultural objectives, foresters must select herbicidal treatments keyed to these variations in plant communities and environmental conditions. Although use of herbicides is complicated, research and experience during the past 20 years have shown that only a few herbicides are useful in Pacific Northwest silviculture. With modest effort, foresters can readily learn to consider the factors involved, prescribe treatments, and use these few herbicides safely and effectively.

Safety and economy demand that herbicidal chemicals be used as sparingly and infrequently as possible to accomplish our silvicultural objectives. Effective use requires that we apply minimal amounts of herbicides at the proper time of the year to obtain the maximum degree of control on undesirable species without damaging desirable tree species, wildlife browse, or esthetically desirable shrub species.

These objectives are best accomplished by early recognition and treatment of small shrubs and weed trees on burns and cuttings where brush problems threaten to develop. Better control of undesirable species can be accomplished with less herbicide, fewer treatments, and reduced contamination of the forest environment. Early recognition and treatment will also increase survival and growth rates of young conifers.

Figure 1. –This nonstocked brushfield of evergreen shrubs and weed trees occupied thousands of acres afterfire swept the area 36 yearsago.

Silvicultural Objectives

Two major objectives in application of herbicides on forest land are to release young conifers from brush and weed tree competition and to prepare sites for reforestation or interplanting with additional conifers.

The silvicultural objective in aerial spraying to release young conifers is not necessarily to kill all competitive vegetation, but to increase the amount of light reaching young conifers in the understory and decrease brush competition for soil moisture and nutrients. We need only obtain a high percentage of defoliation, a fair amount of topkill, and a minimum of resprouting. In fact, complete topkill may stimulate development of basal sprouts on many weed species and result in more rapid recovery and greater competition than if some of the original crown remains alive (fig. 2). Given **3** to 5 years of improved light and moisture, young conifers on most sites will outgrow the herbicide-damaged brush and be permanently released. Release spraying allows application of minimal amounts of herbicides,but requires careful choice of selective herbicides, carriers, and seasons of application.

For site preparation, much more'complete control is needed. **A** high percentage of competitive woody vegetation must be killed, and there must be a minimum of resprouting. On areas where no conifers are present, site preparation treatments allow use of broad-spectrum herbicides or higher rates of the selective herbicides used in release spraying. On nonstocked sites, herbicides are usually applied during the growing season in late spring, when plants are most susceptible to herbicides. Oil-in-water emulsion carriers are frequently used to obtain the greatest degree of shrub and weed tree control.

Site preparation may also call for saving scattered existing conifers on a site while controlling shrubs and weed trees enough to allow interplanting, survival, and growth of additional trees on the site. For such areas, treatments require more care. More selective herbicides such as low volatile esters of 2,4-D and/or 2,4,5-T are most frequently chosen for application. These herbicides are applied at minimal rates in carefully selected carriers during seasons when shrub and weed tree competition can be sufficiently reduced to allow survival and growth of newly planted small trees without damaging trees already present amid the shrubs. Budbreak, late foliar, or late summer applications of herbicides are usually preferred for such areas. The prime objectives are to increase light and available soil moisture. . . especially to the new trees.

Mechanical eradication is possible on some sites, but this method is expensive and often damages trees hidden within the shrubs. With either method, subsequent application of herbicides is usually required to kill new brush seedlings, retard growth of resprouting shrubs, and insure survival and dominance of the interplanted trees on most sites (fig. 3).

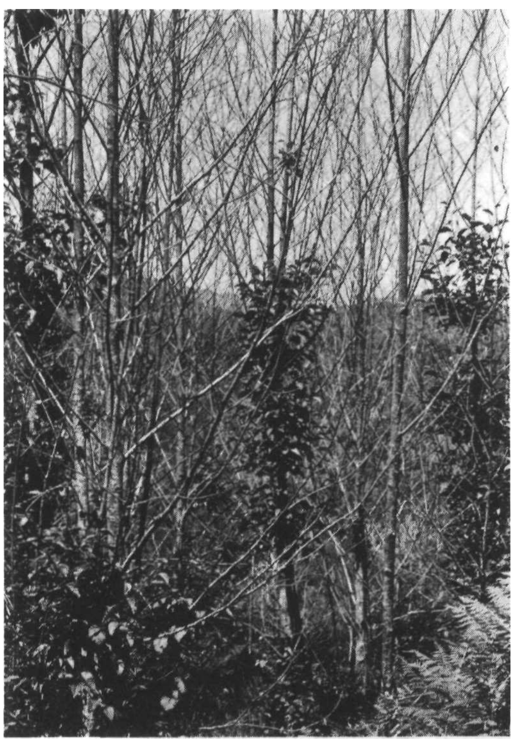


Figure 2.–Flagging–development of a limited amount of new foliage–along main stems and branches reduces production of basal sprouts on many shrubs and weed trees.

Figure 3.–Six years after mechanical eradication, growth of resprouting shrubs and weed trees threatened survival of young conifers planted on this site in the Cascade Range.

Herbicides are also used to kill and desiccate shrubs and weed trees on nonstocked sites, to prepare the areas for reforestation. Contact herbicides such as dinitro (4,6-dinitro-o-sec-butylphenol) and paraquat (1,1'-dimethyl-4,4'-bipyridium ion) in water carriers are sometimes applied as defoliants in late summer to prepare brush for burning. As contact herbicides, however, their prime effect is a rapid killing and drying of foliage. They produce little or no stem kill; therefore, areas to be burned should receive their major preburn treatment with a phenoxy herbicide, picloram, or other slower acting, systemic herbicide. The contact herbicide should only be applied a week or two before burning to kill any green foliage, add to the dry fuel, and allow penetration of sunlight to further desiccate litter and other fuel on the soil surface.

Factors in Herbicidal Treatments

Prescribing herbicidal treatments in silviculture is not as complicated, difficult, or mysterious as it may seem. It is a relatively simple process in which only five items must be specified. These are: (1) herbicide or herbicides to be used, (2) rate or amount of herbicide to be applied per acre, (3) carrier, (4) volume of spray per acre, and (5) season of application.

Other contract specifications are merely refinements of these basic considerations. Special application equipment and drift control agents may be required, especially during aerial spraying (fig. 4). These allow accurate placement of aerial sprays near ownership lines or insure that unsprayed buffer strips will be left along streams and waterways, around habitats of rare or endangered species, to preserve wildlife winter range, or to protect other ecologically sensitive areas. Forest practice laws and several publications spell out safety requirements for transport, mixing, and aerial application of herbicides in the field (Brazelton 1971, Gratkowski and Stewart 1973, Gratkowski 1974).

Figure 4.–Helicopter applying a foamed spray to reduce herbicidal drift.

Many techniques and restrictions have already been imposed by foresters to control drift and other spray losses, preserve buffer strips, and eliminate damage to other ownerships and ecologically sensitive areas. Volatilization is minimized by use of low volatile esters and by spraying only when air temperature is below 75°F and relative humidity above 50 percent. To minimize drift, aerial spraying is stopped when windspeed exceeds 6 miles per hour, when air temperatures rise above 70°F, producing convection currents that rise from heated slopes and prevent the spray from falling to the brush cover, or when other weather conditions are not suitable. Flying speed is limited to a maximum of 40 to 50 miles per hour, and flying height is generally 20 to 45 feet above the vegetation. With conventional spray booms, drift is also controlled by use of nozzles with an orifice size that will produce the largest droplets compatible with adequate coverage and desired effect upon the vegetation. Larger and heavier droplets fall more directly, strike the vegetation more quickly, and drift less than small droplets or mists.

In addition, invert emulsions, spray thickeners, foamed sprays, and special aerial spray equipment have been developed to minimize volatilization and insure more accurate application of aerial sprays. Such materials and equipment are already being used by a large percentage of silviculturists during aerial application of herbicides.

Herbicides and Formulations

For many years, a great number of different herbicidal formulations were used in forestry. Many were not specifically designated for silvicultural use but were applied as an extension of their registration for agricultural use. In recent years, however, Federal and State regulations have become more strict and specific. They now require that only herbicides labeled and registered for forest use be applied on forest lands. Questions concerning the registration of a particular formulation should be directed to the appropriate State Department of Agriculture, the Oregon State Board of Forestry, the Washington State Department of Natural Resources, or the Environmental Protection Agency which is now responsible for Federal registration of all pesticides. Many States also have laws that provide special regulations for specific herbicides and areas where they may be used. Federal foresters applying herbicides on forest lands can consult their appropriate regional pesticide coordinator to secure necessary approval for treatments.

Data on physical characteristics of herbicides are adequately covered in the Oregon Weed Control Handbook, the Washington Weed Control Handbook, the Washington Pest Control Handbook, and the Herbicide Handbook of the Weed Science Society of America. It would be redundant to repeat that information.

Neither will this publication attempt to discuss technical aspects of herbicidal formulation. Instead, it will offer some information that is not generally available in the literature. And since aerial spraying is most economical and most frequently used in applying herbicides on forest land, this publication will stress choice of treatments for aerial application (fig. 5).

Figure 5.–To reduce drift and evaporation and insure accurate application of herbicidal sprays, helicopters fly at minimum safe flying height over brushfields.

HERBICIDES

Many chemicals have herbicidal activity, but the way they are used and their effectiveness depend upon the physical characteristics of the chemical and the way it is formulated. Kirch (1967) stated that the two main objectives in formulating herbicides are to put the chemical in the best possible form for use in the field and to improve the herbicide's performance by increasing its penetration, translocation, and accumulation within the plants to be controlled. Most herbicidal compounds are initially produced as white crystalline acids or powders insoluble in water. In this form, they would be difficult to apply and relatively ineffective on woody plants (Kirch 1961). Therefore, the basic herbicidal compounds are chemically modified to increase their biological activity, allow small amounts to be spread over large areas, and ease handling and mixing in the field.

Research and experience over the past 20 years have shown that only a limited number of herbicides are useful in silviculture. Common and chemical names of these compounds are listed below. The phenoxy (or hormone) herbicides–especially low volatile esters of 2,4-D and 2,4,5-T–are especially important in silviculture. These chemicals are used on approximately 75 percent of the acreage treated annually, and they are the most important chemicals for controlling woody plants. The next most abundantly used chemical in Pacific Northwest forests is atrazine, followed by picloram, silvex, and amitrole-T.

Common name	Chemical name
2,4-D	(2,4-dichlorophenoxy) acetic acid
2,4,5-T	(2,4,5-trichlorophenoxy) acetic acid
amitrole-T	3-amino-s-triazole plus amnionium thiocyanate
silvex (2,4,5-TP)	2-(2,4,5-trichlorophenoxy) propionic acid
dichlorprop (2,4-DP)	2-(2,4-dichlorophenoxy) propionic acid
picloram	4-amino-3,5,6-trichloropicolinic acid
dicamba	3,6-dichloro-*o*-anisic acid
cacodylic acid	hydroxydimethylarsinic acid
atrazine	2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine
dalapon	2,2-dichloropropionic acid

The first eight herbicides are primarily used for woody plant control, but they are also effective on broadleaf weeds. Although atrazine and dalapon are mainly used for grass control, some broadleaf weeds may also be killed with these chemicals.

With a proper choice of rate, carrier, and season of application, 2,4-D, 2,4,5-T, silvex, atrazine, dalapon, and amitrole-T can all be used to release young conifers from competitive vegetation. All of these plus picloram and dicamba can also be used for site preparation. Picloram and dicamba, however, can't be used to release conifers; they are not selective and damage young trees.

In selecting a herbicidal treatment for a particular site, the choice is usually dictated by two to four species that are predominant in the brushfield. The actual choice among suitable chemicals is based upon silvicultural objectives to be achieved. Many publications are available to guide foresters in choosing the most effective herbicides for our major brush species and conifers in Pacific Northwest forests (see literature cited on pages 26 to 28). These recommendations are based upon intensive research by Federal, State, and industrial organizations and experience of silviculturists over the past 25 years. Results are presented in numerous piiblications that offer information like that shown in table 1.

For example, the data in table 1 show that both 2,4-D and 2,4,5-T are almost equally effective on manzanitas . . . with a slight edge in favor of 2,4-D. And since 2,4-D is only half as expensive as 2,4,5-T, it is most economical to use 2,4-D to control manzanita.

But mountain whitethorn is more susceptible to 2,4,5-T. Both 2,4-D and 2,4,5-T completely killed the tops of mountain whitethorn, but 2,4-D only killed 5 percent of the plants while 2,4,5-T killed 20 percent. Obviously, 2,4,5-T is the best herbicide to control mountain whitethorn.

These differences in effectiveness become even more pronounced with repeated applications of foliar sprays applied on shrubs during the period of active growth (tables 2 and 3). On mountain whitethorn, for example, three applications of 2,4-D and 2,4,5-T gave quite different results. Shrub kill with 2,4-D was only 5 percent after the first spray, 20 percent after a second treatment, and only 55 percent after the third spray. With 2,4,5-T, however, initial kill was 20 percent, then went to 65 percent, and then to 90 percent. In contrast, scrub tanoak is equally susceptible to both 2,4-D and 2,4,5-T.

Table 1.--*Degree of control achieved with foliar applications of 2,4,5-T and other herbicides in Pacific Northwest forests*[1]

Species	Herbicide				
	2,4-D	2,4,5-T	Silvex	Dichlorprop	Amitrole-T

[1] Data from Gratkowski (1959) and Stewart (1974b).

Table 2.--*Cumulative percentage*[1] *of shrubs killed by repeated foliar sprays of herbicides on mature (1955) and resprouting (1957 and 1959) brush species in southwestern Oregon*[2]

Species and herbicide	Concentration	Carrier	1955	1957	1959
	Lb aehg[3]	- - Percentage of shrubs killed - -			
Hairy manzanita					
2,4-D	1	Water	100	([4])	([4])
2,4,5-T	1	Water	90	([4])	([4])
2,4,5-T	2	Water	100	([4])	([4])
Hoary manzanita					
2,4-D	1	Water	100	([4])	([4])
2,4,5-T	1	Water	85	([4])	([4])
2,4,5-T	2	Water	100	([4])	([4])
Howell manzanita					
2,4-D	2	Water	95	([4])	([4])
2,4-D	2	Emulsion	100	([4])	([4])
2,4,5-T	2	Water	85	([4])	([4])
Deerbrush ceanothus					
2,4-D	2	Water	90	([4])	([4])
2,4-D	2	Emulsion	80	([4])	([4])
2,4,5-T	2	Water	85	([4])	([4])
Snowbrush ceanothus					
2,4-D	2	Emulsion	20	65	([4])
2,4,5-T	2	Emulsion	30	80	([4])
2,4,5-T	4	Emulsion	40	95	([4])
2,4,5-T + amitrole	2	Water	70	90	([4])
Varnishleaf ceanothus					
2,4-D	2	Emulsion	45	60	([4])
2,4,5-T	2	Emulsion	65	95	([4])
2,4,5-T	4	Emulsion	85	100	([4])
Mountain whitethorn					
2,4-D	2	Water	5	20	55
2,4,5-T	2	Water	20	65	90
Greenleaf manzanita					
2,4-D	2	Water	15	45	90
2,4-D	2	Emulsion	20	30	80
Golden chinkapin					
2,4-D	2	Emulsion	0	15	25
2,4,5-T	2	Emulsion	0	25	55
Amitrole	4	Water	0	20	60
2,4-DP + amitrole	2	Water	10	30	50
Golden evergreenchinkapin					
2,4-D	2	Emulsion	0	20	30
2,4,5-T	2	Emulsion	0	15	55
Amitrole	4	Water	0	40	60
Scrub tanoak					
2,4-D	2	Emulsion	0	35	55
2,4,5-T	2	Emulsion	0	20	60
Serviceberry					
2,4-D	1/2	Water	0	40	50
2,4-D	2	Water	0	40	60
Canyon live oak					
2,4-D	2	Emulsion	0	0	5
2,4-D	4	Emulsion	0	0	5

[1] 1955 and 1957 sprays were rated just before the next respray was applied. The 1959 treatments were rated in autumn, 1960.

[2] From Gratkowski (1968).

[3] Pounds acid equivalent per 100 gallons. For amitrole, read aihg (active ingredient per 100 gallons).

[4] No respray.

Table 3.--*Cumulative percentage of shrubs killed by repeated foliar sprays on mature (1970) and resprouting (1972) brush species in the Oregon Coast Ranges* 1/

Species and herbicide	Concen-tration	Carrier	Early foliar spray, 1970 2/	Early foliar respray, 1972 2/
	Lb aehg 3/		- - Percentage of shrubs killed - -	
Salmonberry				
2,4,5-T	3	Emulsion	50	90
Amitrole-T	1	Water	70	70
	3	Water	80	80
Picloram	1	Water	70	90
Western thimbleberry				
2,4,5-T	3	Emulsion	50	90
Amitrole-T	1	Water	10	20
	3	Water	20	50
Picloram	1	Water	70	100
Vine maple				
2,4,5-T	1	Water	0	20
	3	Water	40	80
Silvex	1	Water	10	30
	3	Water	30	50
Picloram	1	Water	40	80
California hazel				
2,4,5-T	1	Water	20	80
	3	Water	60	100
Silvex	1	Water	40	70
	3	Water	10	70
Picloram	1	Water	80	100

1/ From Stewart (1974c).

2/ When 3/4 of the leaves were fully developed.

3/ Pounds acid equivalent per 100 gallons. For amitrole, read aihg (active ingredient per 100 gallons).

Tables such as these provide very helpful information in selecting the most effective herbicide or herbicides to control individual species or combinations of brush species.

Application of the most effective herbicide will allow use of minimal amounts of chemical per acre, generally reduce costs, and minimize contamination of the forest environment. In release sprays, however, choice of herbicide may necessarily be modified in order to minimize damage to young conifers.

Phenoxy Herbicides

The phenoxy herbicides, especially 2,4-D and 2,4,5-T, are by far the most useful herbicides in silviculture. A major advantage of these herbicides is the great range of selective activity that can be obtained by changing carriers and by varying rates and seasons of application (Gratkowski 1961b, Sutton 1967). None of the other herbicides allow such selective control. This versatility makes 2,4-D and 2,4,5-T invaluable in silviculture.

Other phenoxy herbicides such as silvex and dichlorprop control certain species but are not as effective as 2,4-D and 2,4,5-T on the broad spectrum of native shrubs and weed trees found on Pacific Northwest forest lands.

2,4-D and 2,4,5-T are often combined in a "brushkiller" mixture. Such mixtures are especially useful if a half dozen or more species are abundant in the plant communities to be treated (fig. 6). They are less useful, however, if only three or four species are predominant and most are susceptible to one of the herbicides while only a minor component of the shrub cover **Is** susceptible to the other. Since most commercial brushkiller mixtures usually contain a 1:1 mixture of 2,4-D and 2,4,5-T, they will not provide the maximum degree of control on the more abundant species in such plant communities unless an excessive amount of herbicide is used. However, at least one company produces a series of brushkiller mixtures in which the proportions of 2,4-D and 2,4,5-T are varied. If species composition varies considerably from area to area, it is wise to purchase such commercial formulations to meet your need. If they are not available, however, you can prepare your own brushkiller mixture in the field. It should contain a higher percentage of the herbicide that will be most effective on the more abundant shrub species in the brushfield. Such mixtures can be prepared in the nurse tank truck just before application.

However, in preparing brushkiller mixtures in the field, similar esters of both herbicides should be obtained from the same manufacturer to assure compatibility of the two formulations in the spray mixture. Products from two different manufacturers may be formulated in different systems of oils, emulsifiers, wetting agents, and penetrants that may not be compatible. This is not as important when using oil carriers as when using water or oil-in-water emulsion carriers. Since esters are soluble in oil and are formulated in oil, all can be dissolved in diesel oil or in No. 2 fuel oil carriers for budbreak sprays.

Also, in preparing field-mixed brushkiller mixtures for use in water carriers or in oil-in-water emulsions, a formulation designated only for oil carriers should not be mixed with another designated for water carriers or for oil-in-water emulsions. The resultant mixture may not contain enough emulsifier to produce a stable emulsion.

In such cases, the spray mixture may break down and the oil-and-herbicide solution will rise to the surface of the water phase in the nurse tank. Even with compatible formulations, a continual, mild agitation of emulsion and water sprays in the nurse tank is 'advisable to prevent separation.

Figure 6.—Two aerial applications of phenoxy herbicides in emulsion carriers released suppressed Douglas-firs from 30- to 40-foot-tall evergreen weed trees and a dense brush understory.

Amitrole-T

Amitrole-T has been most frequently used to control salmonberry, and it may still be the most effective chemical for controlling salmonberry during early spring. However, there is a change in susceptibility of salmonberry as the season progresses. By late spring, 2,4,5-T is at least as effective as amitrole-T. By midsummer, 2,4,5-T in an oil-in-water emulsion carrier is far more effective than amitrole-T on salmonberry and also provides a fair degree of control on thimbleberry as well (Gratkowski 1971, Stewart 1974b). Since thimbleberry is commonly associated with salmonberry and frequently takes over sites where salmonberry has been controlled, use of 2,4,5-T rather than amitrole-T is recommended for release spraying or site preparation where salmonberry and western thimbleberry are intermixed and abundant in the brush community. Both species are controlled with one application of 2,4,5-T. Properly used, 2,4,5-T is also less damaging to conifers.

Amitrole-T is no longer registered for use on pastures and other land subject to grazing of domestic animals.

Picloram

Picloram is a nonselective herbicide. It seriously damages young conifers when applied as a broadcast aerial spray and is not suitable for releasing conifers from brush competition. Combined with phenoxy herbicides, however, picloram is an excellent chemical for site preparation. West of the crest of the Cascade Range, picloram does not appear to persist in damaging concentrations in the soil for unreasonably long periods, especially in soils with high organic matter content. Sites can be planted with Douglas-firs within 8 months to 1 year after application of up to 1 lb of picloram plus 4 lb ae of 2,4-D per acre (Finnis and Sund 1970). Stewart (1974b) is also evaluating aerial spray tests of picloram in combination with 2,4-D and 2,4,5-T for preburn desiccation of vegetation in site preparation. He reports that initial results indicate use. of picloram may reduce resprouting of shrubs after burning.

Dicamba

Dicamba is another relatively nonselective herbicide that produced extensive defoliation and topkill of conifers in both late spring and early summer sprays (Stewart 1974b). Dicamba should not be used alone or in combination with phenoxy herbicides to release young conifers from brush competition. It is useful only for site preparation.

Cacodylic acid

Cacodylic acid has been used to some extent as a silvicide injected into trees during thinning and weeding operations. Care should be exercised to prevent dermal contact with this herbicide. Those using cacodylic acid should be provided protective clothing including rubber gloves.

Atrazine

Extensive testing and experience has shown that atrazine is by far the most effective herbicide for grass control in Pacific Northwest forests. Unfortunately, it is registered for use only on forest lands west of the crest of the Cascade Range. It cannot be used in eastern Oregon and Washington. Effective rates of application on the west side are 4 lb active ingredient per acre applied in a water carrier during February or March. Sufficient rain must fall after application to leach atrazine into the soil, where it can be absorbed through root systems of susceptible grass species. Atrazine provides very little control of broadleaf weeds, which often increase markedly in abundance and may reduce release achieved by grass control. Grass control achieved with atrazine is very pronounced during the first summer after application; regrowth begins with the onset of autumn rains.

Atrazine is sometimes combined with 2,4-D or 3 to 5 lb active ingredient of dalapon per acre in an attempt to control broadleaf weeds as well as grass. These mixtures have been used for some time to release young Douglas-firs from grass competition. In at least one area in southwestern Oregon, however, a combination of atrazine and dalapon resulted in complete defoliation of well-established ponderosa pines 8 to 15 feet tall. Such damage is extremely undesirable and indicates a synergistic effect of these two chemicals which increases their activity and effect upon conifers. The author does not consider use of atrazine-dalapon mixtures advisable on ponderosa pines.

Dalapon

Dalapon is the only herbicide registered for grass control on forest lands east of the Cascade Range in Washington and Oregon. In preplanting applications, dalapon must be applied at least 2 weeks before planting conifers. However, results of tests run by Stewart and Beebe (1974) on the Wenatchee National Forest indicate that 5 lb of dalapon per acre will provide adequate grass control without damaging ponderosa pine seedlings planted immediately after spraying.

FORMULATIONS

Most silvicultural herbicides are formulated as esters, emulsifiable acids, water- or oil-soluble amines, or wettable powders. These basic formulations may be further modified for application as liquid sprays in oil, water, oil-in-water emulsions, as invert emulsions or thickened sprays, or in dry form as granules or pellets (fig. 7).

Figure 7.–Granular herbicides are especially useful for site preparation in multistoried communities of shrubs and weed trees. Red alder in this stand, however, is near merchantable size and should not be killed but grown and harvested later in type conversion.

Esters

Low volatile esters of the phenoxy herbicides 2,4-D and 2,4,5-T are by far the most widely used formulations on forest lands. These are liquid formulations with the esters dissolved in oil. They are easily transported and mixed in the field. In addition, they are readily absorbed into leaves and stems, are biologically active at very low rates, and a variety of formulations are available that provide stable spray mixtures in the several different carriers required for selective silvicultural use.

Esters are formed by the reaction of a parent acid such as 2,4-D with an alcohol and are generally named for the alcohol from which they are made (Kirch 1967). Only low volatile ester formulations should be used in forestry. These are formed from alcohols that have more than five carbon atoms in the chain such as propyleneglycolbutyl ethers, butoxy ethanol or isooctyl alcohols.[1] Foresters should remember, however, that even low volatile esters will begin to vaporize during application when air temperatures approach 90°F. Soil, bark, and leaf surfaces may reach this temperature when air temperature is considerably lower than 90°F. As a result, contract specifications usually require that aerial spraying must cease when air temperature exceeds 70°F.

Most esters, like the parent acids, are not soluble in water. In commercial formulations, therefore, esters are dissolved in oil with other additives to improve mixing, penetration, and biological activity in the field. In addition to the herbicide and oil, a good commercial formulation may contain filming or wetting agents, emulsion stabilizers, penetrants, solvents, coupling agents, and in some cases an antifreeze compound. Since esters are formulated in oil, they are soluble in and may be applied in oil carriers. If they are to be used in water or oil-in-water emulsions, however, the formulation must contain an emulsifier to form a stable emulsion in the mixing tank.

Amine and Metallic Salts

Water-soluble amines of phenoxy herbicides are probably the next most widely used formulations in forestry. Amine salts are formed by neutralizing the organic acid with an amine to form a salt. Water-soluble amines are especially useful in cut surface treatments, where the chemical is placed in direct contact with water- and nutrient-conducting elements of phloem and xylem. Since both food and nutrients move in aqueous solutions in phloem and xylem, water-soluble amine formulations are also readily dissolved and translocated with these materials throughout shrubs and weed trees. Water-soluble amines, however, are relatively ineffective as foliage sprays, except in the case of highly phytotoxic herbicides such as picloram.

Oil-soluble amines have been manufactured in an effort to provide relatively nonvolatile herbicides for foliage sprays. In theory, the amine in oil phase would pass through the cuticle into the leaf and then move in the water phase of the plant. Kirch (1967) indicated oil-soluble amines might equal low volatile esters in performance if applied at high volumes, but believed their main advantage is decreased volatility.

Initially, alkali metal salts were also manufactured using sodium, ammonium, potassium, magnesium, and other salts; but these have largely been discarded. Their greatest value was in broadleaf weed control, and they were of limited value in forestry.

---

[1]Paul M. Ritty. Some aspects of the formulation of herbicides. Agricultural Chemicals Development, Dow Chemical Company, Midland, Michigan. 4 p, mimeo., 1960.

Emulsifiable Acids

Parent acids of the phenoxy herbicides can be solubilized in special formulations so that they may be applied in water carriers. These formulations are sometimes referred to as free acid formulations but evidently contain some low volatile esters as well. They are relatively low in volatility and have proved useful on some hard-to-kill perennial weeds and woody plants (Kirch 1967). However, low volatile ester formulations are far more useful in silviculture.

Powders

Some herbicides such as atrazine for grass control are manufactured as wettable powders by mixing the herbicide with an inert carrier. With wetting and dispersing agents added in the commercial formulations, powders can be mixed to form a fine suspension for application in water carriers. Such formulations are generally very low in volatility but most useful for herbicides to be leached into the soil and absorbed through root systems. Soil sterilants are frequently formulated as wettable powders.

Dalapon, another grass control chemical, is formulated as a water-soluble powder. Water-soluble powders are much easier formulations to mix and apply in the field.

Granules and Pellets

Granular or pelleted nonselective, soil-active herbicides are especially useful in multistoried stands of shrubs and weed trees, for they can be distributed by aircraft and drop through all levels of the plant canopy to the soil surface (fig. 7). There, they are leached into the soil by rainfall and absorbed by roots of all species. The chemicals must be effective on a broad range of woody plants and have no undesirable effects on water and soil or other life forms of the forest ecosystem. After killing undesirable plants, the herbicide also must degrade or decompose quickly to permit reforestation. Other plant life must be able to reoccupy the site in order to minimize soil erosion and maintain high quality of water from the treated area.

Rates of Application

Rates of application per acre depend upon silvicultural objectives, and some information has already been provided in the preceding sections. Proper rates are necessary not only to achieve a desired degree of brush control but to minimize damage to conifers in release spraying as well. Too high a rate in some seasons and on certain species may result in as little brush control as using too little herbicide.

Movement of phenoxy herbicides is associated with translocation of carbohydrates in plants. With deciduous species, especially during spring, high concentrations of herbicides may kill leaves too quickly, reduce absorption of the chemicals, stop or reduce photosynthesis, minimize production and translocation of sugars, and thus reduce intake and movement of phenoxy herbicides into stems and roots. **As** a result, the degree of brush control achieved may be drastically reduced as well.

For release sprays, 20 years' experience has shown that phenoxy herbicides are most effective when applied at rates of 1 to 3 pounds acid equivalent (averaging 2 lb ae) per acre. In contrast, atrazine to release young conifers from a grass cover requires application of 4 pounds active ingredient (4 lb ai) per acre. Rates of application for these and other herbicides on a number of common silvicultural problems are suggested in appendix 1A.

In site preparation, however, less selective herbicides can be used; and some herbicides can be applied at higher rates than those used in release sprays. Rates of application for phenoxy herbicides, for example, may be as high as 4 lb ae per acre. Beyond a critical minimum dosage, however, adding additional herbicide is not likely to do much good. It is better to increase the total volume of spray and improve spray coverage by increasing the amount of carrier—which usually costs less and results in better control.

Volume of Spray

Volume of spray applied per acre is primarily dependent upon height and density of brush species and weed trees. The greater the density or the taller the height, the larger the volume of spray required to obtain adequate coverage.

Volume of aerial spray in most cases has been standardized at 10 gallons per acre. This can be varied, however, depending upon height and density of the brush cover. Small scattered shrubs may be satisfactorily killed with as little as 5 gallons per acre; while tall, dense stands of weed trees and brush species may require 10 or even 15 gallons of spray per acre. When D8 or similar nozzles are used on helicopters, 10 gallons of spray allows cross-flying or double flying the area to insure uniform application with a minimum of skips and misses (fig. 8).

F'igure 8.–Helicopter applying 5 gallons of herbicidal spray per acre; the second 5 gallons per acre will be applied at right angles to the initial lines of flight.

Carriers

For aerial application, herbicides are diluted in one of three carriers: (1) oil, (2) water, or **(3)** oil-in-water emulsions. The carriers may be considered biologically inactive and form 80 to 95 percent of the spray volume, improve spray coverage, and allow uniform distribution of the small amount of active ingredient over a large area in herbicidal sprays. Another prime function of the carrier is to insure that a maximum amount of herbicide enters the plant.

Choice of carrier depends primarily upon species and season of application. Oil is used as the carrier in early spring at the beginning of the growing season, when herbicides must be absorbed through the bark of leafless stems and branches of deciduous species. Oil remains the preferred carrier during this season, even where some evergreen species are present in plant communities primarily composed of deciduous shrubs and weed trees. Water is the preferred carrier for herbicides to be absorbed from soil through roots or from foliage sprays on tender, immature leaves of deciduous species early in the growing season. Oil-in-water emulsions are used for foliage sprays that must be absorbed through heavily cutinized leaves of evergreen species or through hardened, mature leaves of deciduous species.

OIL CARRIERS

Esters, emulsifiable acids, and oil-soluble amines are applied in oil carriers when the major route of penetration is through the bark of stems and branches. Diesel oil or No. 2 fuel oil is the preferred carrier for early spring budbreak sprays on thin-barked deciduous species such as red alder and vine maple. Oil carriers penetrate the bark much more readily than water carriers. Since esters and other formulations named above are soluble in oil, they are carried through bark with the oil solute.

Oil carriers should not be applied on tender, new leaves during early spring. The leaves die too rapidly, minimizing absorption and translocation of the herbicide and reducing effectiveness of the spray treatment. Water carriers should be used in spring foliage sprays on deciduous species until almost all leaves are fully developed and hardened.

Mixing herbicides in the field is a relatively simple process, for almost all labels of commercial formulations bear specific instructions on how to mix the formulation with compatible carriers. **A** generally recommended procedure for mixing oil-soluble herbicides with oil carriers is:

1. Place one-fourth to one-third of the required volume of oil in the nurse tank on the truck.
2. Begin agitating and add the desired amount of oil-soluble herbicide to the oil in the nurse tank.
3. With continued agitation, add sufficient oil to obtain necessary volume of spray containing the desired ratio of herbicide:oil in the spray solution.

WATER CARRIERS

Esters, emulsifiable acids, and water-soluble amines should be applied in water carriers for foliage sprays on tender new leaves of deciduous species during the growing season. Since conifers are **also** highly susceptible to herbicides during this period, especially if oil is present in the carrier, water carriers are especially necessary if young conifers are to be released without damage. Water carriers are also specified for late summer sprays to release ponderosa pines from brush competition.

Use of water carriers may also be required because of physical characteristics of certain herbicidal formulations. Wettable powders such as atrazine and other soil-active herbicides that enter plants through root systems must be applied in water carriers during early spring, when sufficient rain will fall after application to leach the herbicides into the soil.

Procedures for field-mixing water-soluble herbicides or wettable powders in water carriers are exactly the same as those described for mixing oil-soluble herbicides in oil carriers. The only difference is that water is used instead of oil.

Low-volatile esters of phenoxy herbicide may also be applied in water carriers. Mixing procedures are exactly the same as for oil-soluble herbicides. However, esters are dissolved in special oils in commercial formulations, and they form a light, milky emulsion rather than a true solution when mixed with water. This does not affect either mixing procedures or aerial application in the field.

OIL-IN-WATER EMULSION CARRIERS

Esters of phenoxy herbicides may also be applied in oil-in-water emulsions, but the commercial formulation must contain an emulsifying agent to produce a stable emulsion. Oil-in-water emulsions are especially effective carriers on evergreen shrub and tree species (fig. 9), for even dormant season and early spring budbreak sprays are intercepted as foliage sprays (van Overbeek and Blondeau 1954, Gratkowski 1959). Emulsions are also used in late foliar and late summer applications on deciduous species, after leaves are fully developed and hardened. Since the herbicide must enter through a thick waxy cuticle, oil aids in wetting and penetration. However, if ponderosa pines are present or if other conifers are exposed and actively growing, water carriers must be used. Oil in the carrier would seriously damage the conifers (Gratkowski 1961**b).**

Oil-in-water emulsions with esters of phenoxy herbicides for aerial application usually contain ½ to I gallon of black diesel oil or No. 2 fuel oil in 10 gallons of spray per acre. Mixing procedure is as follows:

1. Fill the spray tank with about one-third the desired amount of water.
2. In a separate container(s), measure out the required amount of oil. Add the commercial formulation of esters to the oil and mix thoroughly.
3. Start agitation in the nurse tank and slowly add the oil-and-herbicide mixture to the vigorously agitating water in the nurse tank.

4. Continuing vigorous agitation, add the remainder of the water to obtain the required volume of spray mixture.

   Note: If commercial formulations contain an adequate amount of a good emulsifier, it may be possible to add the oil after the ester is mixed with the water in step 2. Continued vigorous agitation is necessary if this procedure is followed.

5. Continue agitation in the nurse tank for 15 to 20 minutes after step 4 before removing any spray for application. Also agitate the remaining spray in the nurse tank periodically to maintain a stable emulsion. With poor formulations or inadequate emulsifiers, the oil-herbicide droplets will tend to coalesce and rise to the surface—the emulsion breaks down and the oil-and-herbicide phase rises to the top of the water phase of the spray mixture in the nurse tank. Results obtained with separated spray mixtures will not be uniform or satisfactory.

Figure 9.*—*Young Douglas-fir released from evergreen shrubs and weed trees by one aerial spray of 2,4-D plus 2,4,5-T in an emulsion carrier.

Seasons of Application

Stage of plant growth and season of application are especially important in prescribing herbicidal treatments. Chemicals should be applied when undesirable plants are most susceptible and desirable species are relatively resistant or will sustain little damage. **All** plants exhibit seasonal changes in susceptibility to herbicides. Susceptibility of deciduous species is usually low during dormancy in late fall and winter, increases from time of budbreak throughout the growing season, and then decreases after growth has ceased. Conifers display similar but even more marked changes in susceptibility, with Douglas-fir, ponderosa pine, and sugar pine showing a rapid increase in resistance to phenoxy herbicides after cessation of growth and formation of new buds (Gratkowski 1970).

Correct timing in applying herbicidal sprays is especially necessary in releasing young conifers from brush competition without damaging the trees. Fortunately, phenological differences between hardwoods and conifers result in periods when brush species and weed trees are susceptible while conifers are resistant to herbicidal sprays. Successful release of young conifers from brush competition is based upon and exploits these differences in stages of growth and susceptibility to herbicides (fig. 10). Release sprays are applied when they will produce an acceptable kill of competing shrubs with minimum adverse effects on the trees.

Figure 10.– A single budbreak aerial application of 2,4,5-T will release this small Douglas-fir from the 15-foot-tall overstory of varnishleaf ceanothus without damaging the conifer.

Four periods are now recognized for silvicultural application of herbicides in Pacific Northwest forests. These are: budbreak, early foliar, late foliar, and late summer (table 4).

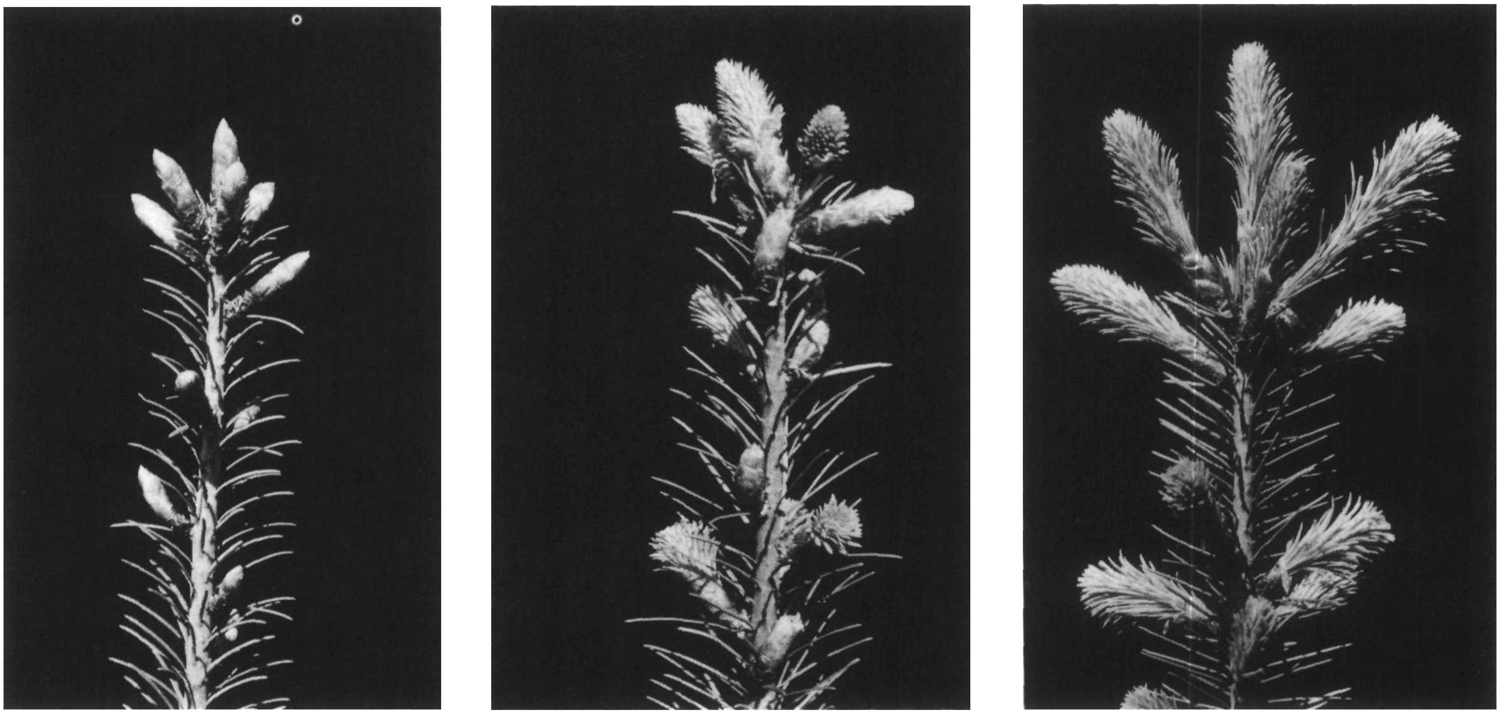
Season	Phenological description
EARLY FOLIAR	Period of active growth; approximately three-fourths of new leaves on shrubs and weed trees full size. Period of maximum susceptibility to herbicides.
LATE FOLIAR	During midsummer, usually mid-July to early August, after cessation of growth on conifers, brush species, and weed trees. All leaves full size and hardened. New terminal buds well developed on both conifers and brush species.
LATE SUMMER	Usually late August to early September, long after cessation of spring flush of growth. Primarily a season for release of pines. DO NOT SPRAY IF LATE SUMMER GROWTH IS IN PROGRESS ON CONIFERS.

BUDBREAK SPRAYS

Luckily, early spring phenology of brush species and weed trees do not completely coincide with those of commercially important conifers in Pacific Northwest forests. Weed species generally begin growth and are susceptible to herbicides before budbreak on the conifers.

Budbreak sprays to release Douglas-fir, western hemlock, and other conifers are usually applied in late winter or early spring after brush species and weed trees begin growth, just before or during bud burst of the conifers. During this period, new leaves are beginning to form on the weed species–especially deciduous species–but absorption of herbicides is primarily through the bark of stems and branches. Most brush species and weed trees are susceptible to herbicides in oil carriers immediately after budbreak, while conifers are relatively resistant. As a result, budbreak sprays are one of the most effective treatments to release conifers from brush competition. To prevent damaging conifers, budbreak spraying should cease when new growth on Douglas-firs reaches 1 inch in length (fig. 11).

Figure 11. – Development of Douglas-fir buds allows accurate timing of budbreak sprays.



Aerial spraying in progress. . . *. . . cease spraying* *. . . too late for aerial spraying*

If **DECIDUOUS SPECIES** are predominant or important components of the brushfield, a diesel oil carrier is used at this time of the year. The reason is that budbreak sprays are primarily intercepted by stems and trunks of deciduous species and the herbicide must penetrate and enter the plant through the bark of leafless stems and branches. Diesel oil is much more effective than either water or oil-in-water emulsion carriers in carrying esters of phenoxy herbicides through bark.

However, if brush or weed tree **EVERGREEN SPECIES** are predominant, an oil-in-water emulsion is just as effective; for the herbicides will be intercepted as foliage sprays and can enter the plant much more readily. An oil carrier is not necessary on evergreen species.

Release of ponderosa pines is an exception; pines cannot be released with budbreak sprays even in water carriers. In the Cascade Range in southwestern Oregon, young ponderosa pines became susceptible to damage from 2,4-D and 2,4,5-T in mid-February, 2% months before bud elongation signalled the beginning of the spring flush of growth.[2]

---

[2] H. Gratkowski, unpublished data.

EARLY FOLIAR SPRAYS

Early foliar sprays are applied in late spring after approximately three-fourths of the new leaves on brush species and weed trees are fully developed. All plant species are highly susceptible to herbicides during active growth, and this is one of the most effective periods for application of herbicides for site preparation. A light oil-in-water emulsion is frequently used as the carrier to obtain maximum effect of the herbicides.

This is a poor period for releasing conifers from brush and weed trees, for conifers also are most susceptible to herbicides during active growth. If any conifers are to be saved, minimum amounts of herbicide and water carriers must be used. In addition, the trees must be small and fully protected from the spray beneath the foliage of the shrub and weed tree overstory.

LATE FOLIAR SPRAYS

These are midsummer sprays applied after brush species have ceased active growth. All leaves are fully developed and hardened, and new terminal buds have been formed. During this period, most brush species are still photosynthetically active and accumulating food reserves, some of which are translocated to root systems for storage. Since phenoxy herbicides move in conjunction with carbohydrates in shrubs, there can be effective translocation of herbicides to the root systems as well.

Water carriers are generally used during this season. Emulsion carriers containing no more than ½ gallon of diesel oil per acre may be considered, but only if the trees will be protected from the spray by the brush canopy.

Although late foliar sprays are not as effective on shrubs as those applied during the growing season, this can be an effective season for releasing conifers from brush competition without damaging the trees. Conifer resistance to herbicides increases rapidly after cessation of growth and formation of new buds (Gratkowski 1970). Care must be exercised, however, on wet sites or if rain has fallen shortly before spraying or rainfall is imminent. Conifers may then experience a second flush of growth, again become susceptible to herbicides and be damaged by late foliar sprays.

LATE SUMMER SPRAYS

Late summer sprays are applied in late August or very early September, long after brush species and conifers have ceased growth, but at least 1 month before leaf abscission on deciduous species. This is one of the least effective periods for controlling brush species and weed trees with herbicides, but control of many species is still sufficient to allow safe and effective release of ponderosa and other pines.

Late summer has proved the only period when ponderosa and sugar pines can be safely released from brush competition with phenoxy herbicides (Gratkowski 1972). Both ponderosa and sugar pines are more sensitive than Douglas-firs to phenoxy herbicides. Since pines are damaged less by 2,4,5-T than by 2,4-D, late summer sprays of 2,4,5-T in water carriers are used to release ponderosa pines from brush competition in southwestern Oregon.

This discussion of seasons for application of herbicides is meant to stress the point that seasons and stages of plant growth are an important key to safe and effective silvicultural use of herbicides. Also—as stated earlier—stages of growth of our conifers do not exactly coincide with those of our brush species and weed trees. The conifers do not begin growth as early as most brush species in spring and show a much more rapid increase in resistance to herbicides after cessation of growth.

Except for pines, two periods—budbreak in early spring and late foliar during midsummer—allow maximum safety in releasing conifers from brush and weed tree competition. Good kills can be achieved on brush species and weed trees with little or no damage to the conifers. For pines, late summer is the only safe period for release with aerial sprays.

Prescribing Herbicidal Treatment

A vital decision in prescribing any herbicidal treatment is selection of a herbicide or combination of herbicides that will adequately control the most abundant species on the area to be treated. That choice will usually be dictated by two to four species that provide 75 percent or more of the cover. Although controlling these species would be sufficient for release or even for site preparation on most areas, many minor species will also be affected by the same herbicides—providing an even greater degree of control.

During the past 25 years, a great number of studies have been conducted to determine the most effective herbicides to control native shrubs, weed trees, and grasses. Many publications provide results of this research and are available to guide selection of effective chemicals. Those considered most useful for silviculturists are listed in Literature Cited on pages 26 to 28. Publications are available for shrubs of central Oregon (3,4,7,9,11,16), for western Oregon and Washington (5,6,7,14,16,25, 26,27,30,31,32,33,34,35,36) and for southwestern Oregon (7,8,9,10,11,12,13,16, 18,20,25,26,27). Effects of herbicides on conifers are described in publications 3,9, 10,14,21,23,25,31,33, and 34. Information on grass control in western Oregon is available in publications 28,29, and 36.

Cooperative research and field trials based upon such data have produced effective herbicidal treatments for many silvicultural problems on Pacific Northwest forest lands. Many are described in the literature (6,10,11,15,16,17,18,20,24,25,29, 32,33,34,37).

Aerial application of herbicides is often combined with prescribed burning or mechanical eradication for site preparation. Aerial spraying followed by prescribed burning has been discussed in other articles (1,8,16,20) and aerial spraying combined with mechanical eradication (1,16,17,32).

Herbicidal treatments for many common silvicultural problems are provided in appendix 1A of this paper. Others may be found in some of the publications listed in Literature Cited. Tentative treatments for special problems not covered in either source may be developed by considering the factors described earlier and modifying the basic treatments provided in appendix 1A.

literature Cited

1 Bently, J. R.
1967. Brushfield reclamation in California. *In* Symp. Proc.: Herbicides in vegetation management, p. 186-195. Sch. For., Oreg. State Univ., Corvallis, Oreg.

2 Brazelton, Robert W.
1971. Control of chemical drift. Univ. Calif. Agric. Ext. Serv. OSA #n5, 2 p.

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

4 Dahms, Walter G., and George A. James.
1955. Brush control on forest lands. USDA For. Serv. Pac. Northwest For. & Range Exp. Stn. Res. Pap. 13, 81 p. Portland, Oreg.

5 Finnis, J. M.
1964. Chemical control of salmonberry. (Abstr.) *In* .West. Weed Control Conf., Res. Prog. Rep., p. 48.

6 Finnis, J. M., and Jimmie D. Sund.
1970. Planting of Douglas-fir seedlings following aerial application of Tordon 101 herbicide. Down to Earth 26(1): 10-11.

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

8 Gratkowski, H.
1961a. Brush seedlings after controlled burning of brushlands in southwestern Oregon. J. For. 59(12): 885-888, illus.

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

10 Gratkowski, H.
1961c. Use of herbicides on forest lands in eastern and southwestern Oregon. *In* Symp. Proc.: Herbicides and their use in forestry, p. 65-81. Sch. For., Oreg. State Univ., Cowallis, Oreg.

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

12 Gratkowski, H.
1970. Seasonal effects of herbicides on northwestern conifers and brush species. *In* West. Soc. Weed Sci. Proc., p. 46.

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

14 Gratkowski, H.
1972. Annual variation in susceptibility of ponderosa pines to phenoxy herbicides. (Abstr.) *In* West. Soc. Weed Sci., Res. Prog. Rep., p. 20.

15 Gratkowski, H.
1974. Herbicidal drift control. USDA For. Serv. Gen. Tech. Rep. PNW-14, 12 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

16 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. & Range Exp. Stn., Portland, Oreg.

17 Gratkowski, H., D. Hopkins, and P. Lauterbach.
1973. The Pacific coast and northern Rocky Mountain region. J. For. 71(3): 138-143, illus.

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

19 Gratkowski, H., and R. Stewart.
1973. Aerial spray adjuvants for herbicidal drift control. USDA For. Serv. Gen. Tech. Rep. PNW-3, 18 p. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

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

21 Kirch, J. H.
1961. Formulation and effectiveness of herbicides. *In* Symp. Proc.: Herbicides and their use in forestry, p. 33-40. Sch. For., Oreg. State Univ., Corvallis, Oreg.

22 Kirch, J. H.
1967. The formulation and application of herbicides. *In* Symp. Proc.: Herbicides and vegetation management, p. 67-71. Sch. For., Oreg. State Univ., Corvallis, Oreg.

23 Krygier, James T., and Robert A. Ruth.
1961. Effect of herbicides on salmonberry and on Sitka spruce and western hemlock seedlings. Weeds 9(3): 416-422.

24 Lauterbach, P. G.
1961. Herbicides and their use in forest management in west side forests. *In* Symp. Proc.: Herbicides and their use in forestry, p. 57-63. Sch. For., Oreg. State Univ., Corvallis, Oreg.

25 Lauterbach, P. G.
1967. Chemical weeding and release of conifers in western Oregon and Washington. *In* Symp. Proc.: Herbicides and vegetation management, p. 148-151. Sch. For., Oreg. State Univ., Corvallis, Oreg.

26 Leonard, **O. A.**
1961. Tables of reaction of woody plants to herbicides. *In* West. Weed Control Conf., Res. Prog. Rep., p. 27-37.

27 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.

28 Newton, Michael.
1967. Control of grasses and other vegetation in plantations. *In* Symp. Proc.: Herbicides and vegetation management, p. 141-147. Sch. For., Oreg. State Univ., Corvallis, Oreg.

29 Newton, Michael.
1969. Herbicides and the tending of forests. *In* Woodland handbook for the Pacific Northwest, 2d ed., p. 58-78. Coop. Ext. Serv., Oreg. State Univ., Corvallis, Oreg.

30 Rediske, **J.** H.
1961. Chemical selectivity on woody plants. *In* Symp. Proc.: Herbicides and their use in forestry, p. 23-32. Sch. For., Oreg. State Univ., Corvallis, Oreg.

31 Rediske, **J.** H., and George R. Staebler.
1962. Herbicidal selectivity of chlorophenoxybutyrics on Douglas-fir. For. Sci. 8(4): 353-359.

32 Schubert, Gilbert H., and Ronald **S.** Adams.
1971. Reforestation practices for conifers in California. 359 p., illus. Div. For., Calif. Dept. Conserv., Sacramento, Calif.

33 Stewart, R. E.
1974a. Budbreak sprays for site preparation and release from six coastal brush species. USDA For. Serv. Res. Pap. PNW-176, 20 **p.,** illus. Pac. Northwest For. & Range Exp. Stn., Portland, Oreg.

34 Stewart, R. E.
1974b. 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. & Range Exp. Stn., Portland, Oreg.

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

36 Stewart, R. E., and T. Beebe.
1974. Survival of ponderosa pine seedlings following control of competing grasses. *In* Proc. West. Soc. Weed Sci. 27: 55-58, illus.

37 Sutton, R. F.
1967. Selectivity of herbicides. For. Chron. 43(3): 265-268.

38 Theisen, **P.** A.
1967. Chemical weeding and release of conifers in southwestern Oregon. *In* Symp. Proc.: Herbicides and vegetation management, p. 152-160. Sch. For., Oreg. State Univ., Corvallis, Oreg.

39 van Overbeek, J., and Rene Blondeau.
1954. Mode of action of phytotoxic oils. Weeds 3(1): 55-65, illus.

Appendix 1

A. Aerial Spray Treatments to Release Conifers and Control Brush in Pacific Northwest Forests

This section offers herbicidal prescriptions for some common silvicultural problems encountered on Pacific Northwest forest lands. These prescriptions are considered the best that have been developed for the species and brush types specified based upon extensive research by Federal, State, and industrial forestry organizations. Some were modified or developed by practicing foresters for particular combinations of species, vegetation, and site conditions. All have been tested, developed, and modified in silvicultural application during the past 20 years.

As stated earlier, a herbicidal treatment for any given site must be keyed to species composition and designed to achieve the desired silvicultural objective. The Pacific Northwest presents an unusually large variety of topographic, geographic, and climatic conditions; and this great diversity in habitats is reflected in the vegetation of our forests. **As** a result of this diversity, silviculturists are faced with many different problems. Although the number of suggested treatments in this section may seem excessive, a half dozen manual-type prescriptions cannot be expected to meet all needs. Even those presented will not provide answers for a number of important silvicultural problems.

Douglas-fir, Hemlock, and Spruce Release

All treatments in this section are on a “per acre” basis to release Douglas-firs, hemlock, and Sitka spruce.

VINE MAPLE. Acceptable kill to release Douglas-firs from vine maple has been obtained only with early spring aerial application of low volatile esters of 2,4,5-T in diesel oil. The spray is applied just before or during bud burst of Douglas-firs. An oil carrier is a necessity, for vine maple is leafless at this time and the herbicide is actually applied as a stem spray that must enter through the bark. Foliage spraying in late spring through summer is relatively ineffective on vine maple. Treatment per acre consists of the following:

2,4,5-T	2 lb ae
Diesel oil	9½ gal of black diesel or No. 2 fuel oil

RED ALDER. Two types of treatment may be designated to release Douglas-firs from red alder. The choice depends upon height of the alder when treated. If alder is 15 feet or less in height, a single budbreak spray will usually be sufficient. If alder exceeds 15 feet in height, two sprays may be needed: (1) a budbreak spray in an oil carrier, and (2) a late foliar spray in a water carrier. The treatments are designated below:

1. Alder 15 feet or less in height:

   Dormant spray

2,4-D	1 lb ae	(Use a commercial brushkiller formulation)
2,4,5-T	1 lb ae	
Diesel oil	9%gal	

   Season: Apply just before or as Douglas-firs burst their buds in early spring. Diesel oil carrier needed to carry herbicide through bark of stems and trunk, since alder is leafless at this time of year. Cease spraying when new growth on Douglas-firs reaches 1 inch in length.

   Note: The Weyerhaeuser Company sometimes uses an early foliar spray of 1 lb of 2,4-D **plus** 1 lb of 2,4,5-T in a water carrier, but stops spraying when new leader growth on the Douglas-firs exceeds 2 inches in length. I would recommend, however, that an early foliar spray such as this should not be used unless the conifers are well shielded from the spray by alder foliage. If conifers are exposed, they may sustain damage. Foresters should consider the fact that any dead tissue on conifers is undesirable and may serve as an entry court for disease.

2. Alder more than 15 feet fall: two sprays required.

   Dormant spray

2,4-D	1 lb ae	(Use a commercial brushkiller formulation)
2,4,5-T	1 lb ae	
Diesel oil	9½ gal	

   Season: Apply just before or as Douglas-firs burst their buds in early spring. Diesel oil carrier needed to carry herbicide through bark of stems and trunk, since alder is leafless at this time of year.

   *Late **foliar** spray*

2,4-D	*2* lb ae
Water	to make 10 gal of spray per acre

   Season: Apply in July after alder has ceased active growth, all leaves are full size and hardened, and terminal buds have been formed. Do not use oil in the carrier unless the conifers will be protected from the respray by foliage of the alder overstory.

   Note: This late foliar respray should be applied 1 to 2 years after the initial spray. Respray when alder has enough foliage to intercept most of the foliar spray.

RHODODENDRON. This species is more difficult to control, but the following treatment is sometimes used where density of the shrubs is sufficient to require control in order to release young Douglas-firs. It should also be considered for site preparation on such areas when conifers are to be interplanted to increase stocking. Treatment per acre:

2,4-D	2 lb ae	(Use a commercial brushkiller formulation
2,4,5-T	2 lb ae	of 2,4-D and 2,4,5-T)
Diesel oil	½ gal	
Water,	to make 10 gal spray per acre	

Note: If using a 6 lb/gal commercial formulation **(3** lb of 2,4-D plus **3** lb of 2,4,5-T), add 1 **pt** of Multi-film X-77 surfactant to each 100 gal of spray.

Season: Apply as a budbreak spray during early spring, just before or as vegetative buds burst on Douglas-firs. Retreatment will be necessary.

SNOWBRUSH, BLUEBLOSSOM, VARNISHLEAF, AND MOUNTAIN WHITE-THORN CEANOTHUS. These species respond well to low volatile esters of 2,4,5-T applied from early spring throughout the growing season. In release projects, carriers are varied to fit physiological condition of the conifers and their degree of protection from spray beneath the shrub canopy. Ceanothus species should be treated before the shrubs exceed 4 to 5 feet in height. This will minimize damage to conifers among the shrubs when the shrubs break off and fall.

1. Ceanothus shrubs 5 feet or less in height:

2,4,5-T	2 lb ae
Diesel oil	3/4 gal
Water	to make 8 to 10 gal of spray per acre

Note: If using a 6 lb ae/gal commercial formulation of 2,4,5-T, add 1 pt of Multi-film X-77 surfactant per 100 gal of spray.

Season: Apply during budbreak, just before conifers burst buds or even while buds are swelling. Can also be used during late spring and summer, if conifers are overtopped and well shielded from the spray by ceanothus foliage. If an appreciable number of conifers will be exposed, the budbreak spray is preferred. If a water carrier (no diesel oil) must be used during the growing season, cease spraying when new growth on the conifers reaches 1 inch in length.

In dormant (bud burst) spraying, low volatile esters of 2,4,5-T can also be applied in a straight diesel oil carrier rather than in the oil-in-water emulsion given below. This would consist of:

2,4,5-T	2 lb ae per acre
Diesel oil	to make 10 gal of spray per acre

This treatment is especially useful in a mixture of deciduous species such as vine maple or alder with evergreen brush species. An oil carrier is necessary to get the herbicide through the bark of stems on leafless deciduous species at this time of year. And vine maple ***must*** be sprayed at this time of the year.

2. Taller ceanothus, with Douglas-firs and other conifers intertwined with the ceanothus stems. If ceanothus shrubs like this are killed, they will usually rot at the root crown and break off and fall as a clump, carrying many of the intertwined conifers with them. These trees will not recover unless manually released from the fallen brush within the first year after the shrubs break down.

   To minimize damage to conifers intertwined with tall ceanothus shrubs, a very light dosage of herbicide is advised. Its objective is to obtain a high percentage of defoliation, to kill back the stems one-third or one-half of their length, but to maintain life in the lower portion of the stems and especially the root crown. The purpose is to prevent the root crown from rotting and having the entire shrub fall, carrying the intertwined trees with them. If new foliage develops on the living portions of the stem, it can be desirable. It may reduce basal sprouting and slow regrowth of the shrubs. The recommended treatment per acre for tall ceanothus is as follows:

2,4,5-T	3/4 lb ae
Diesel oil and	3/4 gal
Water	to make 10 gal of spray per acre

CHINKAPIN. This species resprouts abundantly after initial treatment of mature shrubs, and repeated treatments are needed to get a high percentage of kill. However, this treatment (with followup spraying where observation indicates necessity) is used to release Douglas-firs:

2,4,5-T	2 lb ae
Diesel oil	1 gal
Water	to make 10 gal of spray per acre

Season: Apply when buds are swelling or bursting on Douglas-firs during early spring.

Note: Again, if using a 6 lb ae/gal commercial formulation of 2,4,5-T, add 1 pt of Multi-film X-77 or similar surfactant.

SALMONBERRY. To release Douglas-fir, hemlock, or Sitka spruce, three treatments are available. One involves use of amitrole-T; the pther two involve use of 2,4,5-T. All are applied as foliage sprays.

1. *Late foliar spray.* These sprays are usually applied .during the latter half of July. This is the preferred treatment, especially since thimbleberry usually is found with salmonberry. A late foliar spray with 2,4,5-T will also provide good control of thimbleberry and prevent its occupying areas where the

salmonberry has been eliminated. Care should be taken not to apply the treatment on any area where conifers still show active growth.

2,4,5-T	**3** lb ae
Diesel oil	½ gal
Water	to make 10 gal of spray per acre

Season: Late foliar.

2. *Early foliar spray.*

Amitrole-T	2 lb (1 gal) per acre
Water	to make 10 gal of spray per acre

Season: Apply while salmonberry is growing. Good results obtained on the Siuslaw National Forest when applied in mid-June. May cause some damage in foliage of exposed conifers.

3. *Early foliar spray.* Use only if the young conifers are well shielded from direct application of the spray by salmonberry foliage. Do not apply after new growth on the conifers exceeds 1 inch in length.

2,4,5-T	2 lb ae
Water	to make 10 gal of spray per acre

Season: Early foliar.

TANOAK, MADRONE, CANYON LIVE OAK, AND MANZANITA.

To release: Douglas-fir, hemlock, Sitka spruce, or grand fir

2,4-D	**3** lb ae
Diesel oil	3 qt
Water	to make 10 gal of spray per acre

Season: Budbreak; apply just before or during budbreak on Douglas-firs.

ALDER, VARNISHLEAF CEANOTHUS, CHINKAPIN, AND VINE MAPLE (Southwest Oregon Coast Ranges).

To release: Douglas-fir, Sitka spruce, and hemlock

2,4,5-T	2 lb ae
Diesel oil	to make 10 gal of spray per acre

Season: Budbreak; apply just prior to or at time of bud burst on Douglas-firs during early spring.

DECIDUOUS OAKS (Oregon white and California black oaks).

To release: Douglas-fir

2,4,5-T	2 lb ae
Diesel oil	2 qt
Water	to make 10 gal of spray per acre

Season: Early foliar, after at least three-fourths of the oak leaves are full size. Conifers should be well shielded from the spray by oak foliage; exposed conifers are apt to be damaged. If many conifers are exposed, do not spray after new growth exceeds 1 inch in length.

Cut surface treatment: To release fir or pine. Hack-squirt oaks with 2,4-D amine with cuts spaced no more than 1% inches apart. Apply 1 to 2 ml of amine per cut. Best results if treated during growing season.

DECIDUOUS BRUSH AND TREES (especially willow, cherry, and elderberry).

To release: Douglas-fir, Sitka spruce, and hemlock

2,4-D	1 lb ae
2,4,5-T	1 lb ae
Water	to make 10 gal of spray per acre

Season: Early foliar during spring, after most new leaves are fully developed. Cease spraying when new growth on conifers reaches 1 inch in length. If conifers will not be shielded from the spray by foliage of the deciduous overstory, use a late foliar spray in midsummer.

Pine Release

MIXED DECIDUOUS BRUSH.

To release: ponderosa pines

2,4,5-T	1% lb ae
Water	to make 8 to 10 gal of spray per acre

Season: Late August to early September

BROADLEAF EVERGREEN BRUSH AND WEED TREES (except manzanitas).

To release: ponderosa pines

2,4,5-T	2 lb ae
Water	to make 10 gal of spray per acre

Season: Late August to mid-September

CEANOTHUS (deciduous and evergreen species).

To release: ponderosa pines

2,4,5-T	2 lb ae
Water	to make 10 gal of spray per acre

Season: Late August to mid-September

DECIDUOUS OAKS (Oregon white and California black oaks).

To release: ponderosa pines

2,4,5-T	2 lb ae
Water	to make 10 gal of spray per acre

Season: Late summer spray during late August to early September

POISONOAK, PACIFIC. Usually Douglas-firs and ponderosa pines are found intermixed with poisonoak only at low elevations or on dry sites.

To release: Douglas-firs. Two treatments are possible.

1. The preferred treatment would be:

2,4,5-T	2 lb ae
Water	to make 8 gal spray per acre

Season: Late foliar

Note: A small amount (1 to 2 qt) of diesel oil may be added, if the trees will be shielded from the spray by the brush overstory.

2. Less desirable would be:

Amitrole-T	1 gal
Water	to make 8 gal spray per acre

Season: Early foliar. 'May cause some yellowing and defoliation of Douglas-fir.

To release: ponderosa pines

2,4,5-T	2 lb
Water	to make 8 gal spray per acre

Season: Late summer foliage spray, at least 1 month before abscission begins.

B. Site Preparation Treatments for Brush Control on Nonstocked Sites

Timing is not as critical in spraying nonstocked sites as when spraying for conifer release. These treatments may be applied at any time from bud burst on the brush species and weed trees through late June. The brush species will be physiologically active during this period, and herbicidal sprays will be most effective throughout that season.

ALDER. Two types of treatments are possible depending upon height of alder to be treated. If alder is 15 feet or less in height, a single budbreak spray will usually be sufficient. **If** alder exceeds 15 feet in height, two sprays will probably be required: (1) a budbreak spray in an oil carrier, and (2) a late foliar spray in a water carrier after the area has been planted. These treatments are designated below:

1. Alder 15 feet or less in height:

   Dormant spray

2,4-D	1 lb ae	(Use a commercial brushkiller formulation)
2,4,5-T	1 lb ae	
Diesel oil	9% gal	

   Season: Budbreak; new alder leaves beginning to uncurl, but few full-sized, tender, new leaves.

2. Alder more than 15 feet fall. Two sprays are required.

   Dormant spray (plant area as soon as possible after applying this initial treatment).

2,4-D	1 lb ae	(Use a commercial brushkiller formulation)
2,4,5-T	1 lb ae	
Diesel oil	9% gal	

   Season: Budbreak; new alder leaves beginning to uncurl, but few full-sized, tender, new leaves.

   Late foliar respray

2,4-D	*2* lb ae
Water	to make 10 gal of spray per acre

   Season: Apply in July after alder has ceased active growth, when all leaves are full sized and hardened and terminal buds have been formed. Do not use oil in the carrier. This late foliar respray should be applied 1 or 2 years after the initial spray. The alder should have enough foliage to intercept sufficient spray to increase alder kill to the point where no additional sprays will be needed.

   Note: If salmonberry and thimbleberry have grown rapidly after the initial spray and have developed a dense canopy over the newly planted conifers, use the following spray treatment:

2,4,5-T	**3** lb ae
Diesel oil	½ gal
Water	to make 10 gal of spray per acre

   Season: Late foliar. Apply in July after alder has ceased active growth, all leaves are full size and hardened, and terminal buds have been formed. This treatment should not only control the alder, it should release the young conifers from salmonberry and thimbleberry as well.

DECIDUOUS HARDWOODS (mixed brush and/or trees). Apply during late spring, after most new leaves are full size, but during period of active growth on all species. Amount of herbicide and the carrier may be varied depending upon species, height, and density of the stand. Low, open stands should get less herbicide.

2,4-D	1% lb ae
2,4,5-T	1% lb ae
Diesel oil[1]	½ gal
Water	to make 10 gal of spray per acre

CEANOTHUS (all species). Most susceptible during active growth from early spring to early July.

2,4,5-T	2 lb ae
Diesel oil	3 qt
Water	to make 10 gal of spray per acre

Season: Early foliar, during active growth.

DECIDUOUS, EVERGREEN, OR MIXED DECIDUOUS AND EVERGREEN. For brushfields or mixed brush and weed trees. Dow Chemical Company reports its Esteron 245 label registered with the Environmental Protection Agency allows use of the following combination.[2] It should be used *only for site preparation.*

Picloram	2 gal Tordon 101
2,4,5-T	4 lb ae (1 gal Esteron 245)
Water	to make 10 gal spray per acre

Season: Early foliar

Note: I consider this an excessive dosage per acre of both herbicides. Efforts are being made to obtain registrations that will allow use of lower rates of these herbicides in combination for site preparation.

BROAD-SCLEROPHYLL CHAPARRAL AND BROAD-SCLEROPHYLL FORESTS. In these types in southwestern Oregon, the spray treatments suggested for release of Douglas-fir can also be used for site preparation. In the extensive tanoak, madrone, canyon live oak, and manzanita brush type, the treatment listed for releasing Douglas-firs, etc., is as good as any that can be suggested.

---

[1]Diesel oil should be used only on tall, dense stands or late in the season, after most leaves have hardened.

[2]This claim was checked with and verified by the Environmental Protection Agency.

Appendix 2
List of Trees and Shrubs

TREES

Scientific name	Common name
Abies concolor	fir, white
Abies magnifica var. *shastensis*	fir, Shasta red
Alnus rubra	alder, red
Arbutus menziesii	madrone, Pacific
Castanopsis chrysophylla	chinkapin, golden
Libocedrus decurrens	incense-cedar
Lithocarpus densiflorus	tanoak
Picea sitchensis	spruce, Sitka
Pinus contorta	pine, lodgepole
Pinus lambertiana	pine, sugar
Pinus ponderosa	pine, ponderosa
Pseudotsuga menziesii	Douglas-fir
Tsuga heterophylla	hemlock, western
Tsuga mertensiana	hemlock, mountain

SHRUBS

Acer circinatum	maple, vine
Amelanchier alnifolia	serviceberry, Saskatoon
Arctostaphylos canescens	manzanita, hoary
Arctostaphylos columbiana	manzanita, hairy
Arctostaphylos hispidula	manzanita, Howell
Arctostaphylos patula	manzanita, greenleaf
Castanopsis chrysophylla var. *minor*	chinkapin, goldenevergreen
Castanopsis sempervirens	evergreenchinkapin, Sierra
Ceanothus cordulatus	ceanothus, mountain whitethorn
Ceanothus integerrimus	ceanothus, deerbrush
Ceanothus thyrsiflorus	ceanothus, blueblossom
Ceanothus velutinus	ceanothus, snowbrush
Ceanothus velutinus var. *laevigatus*	ceanothus, varnishleaf
Corylus cornuta var. *californica*	hazel, California
Lithocarpus densiflora var. *echinoides*	tanoak, scrub
Quercus chrysolepis	oak, canyon live

Rhododendron macrophyllum	rhododendron, Pacific
Rhus diversiloba	poisonoak, Pacific
Rubus parviflorus	thimbleberry
Rubus spectabilis	salmonberry
Salix spp.	willow
Sambucus cerulea	elderberry, blue
Sambucus racemosa	elderberry, red

Appendix 3
Glossary of Agricultural Chemical Terms

Acid equivalent – Amount of active ingredient expressed in terms of the parent acid.

Active ingredient – An ingredient which provides stimulating or killing action. In herbicides, this is equivalent to the amount of technical material with herbicidal action in a formulation.

Adjuvants – Additional compounds added to the herbicide. These act as wetting or spreading agents, stickers, penetrants, emulsifiers, etc., changing physical characteristics of the toxic materials to make them easier to handle, mix, and apply in the field.

Aerial spray – Broadcast aerial application of a herbicide as a solution, emulsion, or wettable powder as a spray applied from helicopters or fixed-wing aircraft.

Annual – A plant that completes its life cycle in 1 year.

Aromatics – Oil or oil-like materials that burn tops of weeds. Sometimes used in formulating herbicides.

Basal spray – Application of a coarse-droplet spray at low pressure on the basal portion of stems to a height of 12 to 18 inches above the soil surface. Spray is applied until an excess runs off onto the soil surface at the base of the stem.

Broadcast spray – Application over an entire area rather than in bands or strips. All exposed stems and foliage visible from above receive treatment.

Broadleaf plants – Usually refers to herbaceous plants with broad, flat leaves as opposed to grasslike plants with very narrow leaves.

Brush control – Control of woody plants.

Carrier – A liquid or solid material added to a herbicidal chemical or formulation to allow easier mixing, storage, shipment, and application in the field. In this publication, the term refers especially to oil, water, or both added to the commercial formulation to increase its volume and allow application of small amounts of active ingredient over a large area. (Also see "Diluent.")

Compatible – Two or more compounds or products that can be mixed without detrimentally affecting their performance.

Concentration – Refers to the amount of active material in a given weight of a mixture or volume of a solution. Recommendations and specifications for concentration of agricultural chemicals are frequently given in terms of pounds acid equivalent or active ingredient per unit volume of spray mixture or solution.

Conifer – A tree or shrub of the order Gymnospermae, mostly evergreens bearing true cones (hence, conifers) and needle-shaped or scalelike leaves. In forestry, generally tree species producing timber known as softwood.

Contact herbicide – One that kills primarily by contact with plant tissue rather than as a result of translocation. Only that portion of a plant contacted is directly affected. Young seedlings are killed, but perennials may recover from the uninjured parts below the soil surface. On woody plants, contact herbicides usually kill only the leaves and very tender stem tips without damaging the main portion of the living stems.

Cuticle – A nonliving outer waxy layer covering all or part of a leaf.

Deciduous – Plants which normally lose their leaves during the winter.

Defoliant – A material that causes the leaves or foliage to fall from plants.

Delayed action – As opposed to immediate effect. With some herbicidal chemicals (i.e., 2,4-D; 2,4,5-T; MCP; or dalapon) delayed response is expected. Considerable time may elapse before maximum effects are observed. Usually treated plants stop developing soon after treatment, then gradually die.

Desiccant – A plant drying agent. Usually the foliage is killed quickly by contact action, but this category of herbicides may include slower acting chemicals such as the phenoxy herbicides.

Detergent – Any liquid or solid material that will remove residues from application equipment, such as a dishwashing or laundry detergent.

Diluent – Any liquid or solid material used to dilute the technical toxicant or herbicide to field strength for mixing and dilution to allow adequate plant coverage. (See also "Carrier.")

Dinitro (=dinoseb) – A common designation for dinitro-phenols. These materials are used as contact herbicides to cause rapid defoliation.

Dissolve – Usually refers to getting solids into solutions in a solvent; requires the breaking apart of solids into molecules, ions, or other fractions of the solid molecules in the solvent.

Dormancy – The term describing the temporary suspension of visible growth.

Dormant spray – Application of chemical in winter or very early spring before treated plants show any evidence of active growth.

Drift – Movement of airborne particles as dust, fine droplets, mists, aerosols, or vapors from the intended target area to other areas.

Emulsifying agent – A material which helps to suspend globules of one liquid in another, i.e., oil-in-water.

Emulsion – A mixture in which one liquid is suspended as minute globules in another liquid. Example: butterfat globules in milk, or a suspension of oil droplets in water.

Epinasty – Twisting or curling of leaves and stems caused by uneven growth of plant cells. This is a characteristic. reaction from treatment with 2,4-D and other growth regulator herbicides.

Eradication – Complete elimination of a living organism from a specified area.

Flagging – Production of a reduced number of new leaves (often small and deformed) on partially killed stems and crowns of shrubs and weed trees treated with herbicides.

Formulation – **A** mixture of an active herbicidal chemical with carriers, diluents, or other materials; usually to facilitate handling, mixing, effectiveness, and application in the field.

Granules – A type of forniulation in which the active ingredient is usually mixed and pressed with an inert carrier to form a small pellet.

Growth regulator – A chemical or herbicide, which, when applied in small amounts to leaves, stems, or roots, alters the normal growth and form of the plant. Phenoxy herbicides are classified as growth regulators.

Herbaceous – **A** plant that remains soft or succulent and does not develop woody tissue.

Herbicide – A phytotoxic chemical used for killing or inhibiting (stunting) the normal growth and development of a plant.

Hormone – A growth regulating substance occurring naturally in plants that controls growth or other physiological processes. Also refers to certain manmade or synthetic chemicals which regulate growth activity. Such manmade chemicals, however, are more correctly called synthetic regulators; they are not true plant hormones.

Humidity – Refers to moisture or dampness in the air. Weed killers are often more effective under moderately humid conditions. In areas or at times when humidity is very low, high herbicidal rates or high volumes of carrier may be required because sprays dry more quickly and absorption is poor.

Hydrocarbons – Compounds that contain carbon and hydrogen only.

Inert ingredient – Any ingredient in a formulation which has been added for other than its pesticidal action.

Invert emulsion – One in which the water is dispersed in oil rather than oil in water. Oil forms the continuous phase with water dispersed throughout the oil. Usually this produces a thick, mayonnaiselike mixture.

Label – All written, printed, or graphic matter on or attached to the herbicide container as required by law.

Leach – Usually refers to the movement of chemicals through a soil by or with an amount of water that is in excess of the soil's moisture-holding capacity. May also refer to movement of herbicide out of leaves, stems, or roots into the air or soil.

Miscible – Capable of being mixed, usually with another liquid. Example: water and alcohol.

Necrosis – The death of tissue, such as all or part of a plant.

Nonselective herbicide – Formulations of herbicides that destroy or prevent plant life in general without regard to species. Soil sterilants are classified as nonselective herbicides, although one or more species on an area may not be controlled even by such herbicides.

Noxious weed – A weed arbitrarily defined by law as being especially undesirable, troublesome, or difficult to control.

Oils – Usually refers to aromatic or paraffinic oils used as diluents in formulating products, as diluents or carriers for herbicides, or for direct use as herbicides. (Also see "Aromatics.")

Oral toxicity – Toxicity of a compound when it is ingested.

Organic compounds – Chemical compounds with molecules containing several carbon atoms.

Perennial – A plant that lives for many years. The tops may die back in winter or in severe drought, but the roots or rhizomes persist.

Persistence – Refers to the length of time that a herbicide remains active and phytotoxic in a plant or soil.

Pesticide – Any substance or mixture of substances intended for controlling insects, rodents, fungi, weeds, and other forms of plant or animal life that are considered to be pests. A broad classification including herbicides.

Pesticide tolerance – The amount of pesticide residue which may legally remain in or on a food crop. Federal residue tolerances are established by the Environmental Protection Agency.

Photosynthesis – The manufacture of simple sugars by green plants utilizing light as the energy source.

Phytotoxic – Poisonous or injurious to plants.

Postemergence treatment – Treatments made after plants emerge above the soil. Generally refers to weed control procedures in reference to time of application of a herbicide.

Preemergence treatment – Treatment made before weed species emerge above the soil surface.

Rate or dosage – These terms are synonymous. "Rate" is the preferred term. Rate usually refers to the amount of active ingredient of a herbicide (such as 2,4-D acid equivalent) applied to a unit (such as 1 acre) regardless of percentage of chemical in the carrier.

Registered – Pesticides that have been approved for use by the Environmental Protection Agency or by a State Department of Agriculture.

Residual – To have a continued killing effect over a period of time.

Residue – That amount of active pesticide that is on or in plants, animals, or other life forms, or in water or soil at the time a sample is taken and analyzed.

Residue tolerance – The amount of pesticide residue which may legally remain in or on a food crop.

Resistance – The ability of an organism to withstand, reduce, or suppress the injurious effects of a pesticide.

Selective herbicide – One which is more toxic to some species of plants than others. Thus, weeds may often be controlled without significant damage to trees or other plants by selective herbicidal action.

Sensitivity – Susceptibility of a species to effects of a toxicant at low dosage; not capable of withstanding effects. For example, many broadleaved plants are sensitive to 2,4-D.

Silvicide – **A** herbicide used to control trees.

Soil sterilant – **A** herbicide, which when present in or on the soil prevents the growth of plants. Sterilization may be temporary or relatively permanent.

Solubility – The amount of a substance which will dissolve in a given amount of a specified liquid.

Solution – Should be used only to describe a formulation in which the ingredients are dispersed throughout the solvent in an ionic or molecular state.

Solvent – **A** liquid which will dissolve a substance forming a true solution (generally a molecular or ionic dispersion in the liquid solvent).

Species – **A** group of individuals similar in structure and physiology capable of interbreeding and producing fertile offspring which are like their parents.

Spot treatment – Application of herbicides as sprays, granules, or powders to a restricted area or individual plants as differentiated from overall, broadcast, or complete coverage.

Spreading agent – A substance used to improve the wetting, spreading, or possibly the adhesive properties of a spray.

Stem – Those parts of a plant which support leaves, flowers, or roots. The main plant framework.

Sterilant – **A** chemical used to render the soil barren of all plants for **a** certain length of time.

Surface tension – Due to molecular forces at the surface, a drop of liquid forms an apparent membrane that causes it to ball up rather than to spread as film. This molecular force or attraction is termed surface tension.

Surfactant – A material used in herbicidal formulations to impart emulsifiability, spreading, wetting, dispersibility, or other surface-modifying properties to the formulation.

Suspension – Particulate matter dispersed and suspended in a liquid as contrasted to a true solution, e.g., diuron, atrazine, or simazine wettable powders in water and slurries.

Synergism – **A** cooperative action of different chemicals so that their total activity, in this case control effectiveness, is greater than the sum of their individual effects on the plant.

Systemic – Any chemical that, when absorbed into one part of a plant or other organism, becomes distributed throughout the organism; for example, phenoxy herbicides.

Tolerance – (pesticide) – The amount of pesticidal chemical allowed by law to be in or on plant or animal products sold for consumption. (See also "Residue tolerance.")

Tolerant – Capable of withstanding the effects of herbicides. For example, grass is tolerant of 2,4-D to an extent that allows this herbicide to be used selectively to control broadleaved weeds without killing the grass.

Toxic – Poisonous or injurious to animals and plants through contact or systemic action.

Toxicity – Degree to which something is poisonous to a life form.

Translocation – Transfer of food or other materials, such as 2,4-D, from one part of a plant to another. (See also "Systemic.")

Volatile – A compound is said to be volatile when it evaporates or is vaporized (changes from a liquid or solid to a gas) at ordinary temperatures on exposure to air.

Weed – Any plant growing where not wanted.

Wettable powder – A powder that will readily form a suspension in water.

Wetting agent – A compound added to a spray formulation to cause the spray droplets to spread and more thoroughly and uniformly wet plant surfaces.

Woody plants – Plants that develop woody stems.

GPO 994-472

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 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: 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

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.

The U.S. Department of Agriculture is an Equal Opportunity Employer. Applicants for all Department programs will be given equal consideration without regard to race, color, sex or national origin.