AN ABSTRACT OF THE THESIS OF

Edward A. Fredrickson for the degree of Master of Science in Forest Science presented on January 7, 1994.

Title: Efficiency of Forest Vegetation Control with Herbicides

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Abstract approved______________________________
Michael Newton

Selective suppression of crown and root sprouting of non-coniferous cover are the keys to effective forest vegetation management. This study 1) develops insight into mechanisms of controlling root suckering and top regrowth of bear clover (*Chamaebatia foliolosa*), and develops a broad data base for controlling broad groups of vegetation chemically. Finally, it develops a mangement guide for use of this technology to achieve certain management objectives.

Four herbicides were evaluated for their ability to control post-treatment resprouting of bear clover. Sprouting was evaluated above and below ground by creating trenches to expose the rhizome network. Soil moistures were also studied to determine if their were differences due to varying levels of efficacy. They were marginally responsive in the top 60 cm of soil. Plant moisture stress measurements were obtained on ponderosa pine (*Pinus ponderosa*), and were found considerably more responsive than surface soil water contents.

Several application parameters including volume, dose, surfactant, dropsize and product were studied to determine their influence on herbicide efficacy and efficiency on several Pacific Coast species of shrubs and grass. Sites included the Oregon Coast Range, the east side of the Oregon Cascade Range and the west side of the Sierra Nevada Mountains in California.

Growth regulator products were not suitable for long-term control. High levels of sprouting were observed above and below ground. Glyphosate led to control of above-ground sprouting as well as the rhizome system of bear clover. Sprouting was found to increase with increasing distance from healthy vegetation. Glyphosate was much less effective on other evergreen species.

Herbicide treatments in April were more selective between evergreen shrubs and ponderosa pine than those in June. Surfactant increased pine damage while decreasing selectivity. Drop size was related to pine damage in general but degree of effect varied with geographic location.

Dose was found to be the single most important factor contributing to response. Application parameters other than dose generally did not contribute to efficacy except that large drops enhanced growth regulator effects on manzanita on the east side of the Cascades, as indicated by a second order interaction between dose, surfactant and nozzle. The addition of surfactant to growth regulator products in April and to glyphosate in June also increased absolute efficacy on Sierran brush species.

Soil residual products did not respond in important ways to application technology. Salmonberry also did not respond to dropsize or surfactant.

The information obtained was incorporated into a management guide for efficient herbicide use.

Efficiency of Forest Vegetation Control with Herbicides

by

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Chapter 1

Evaluating Four Herbicides for Their Ability to Control Post-Treatment Resprouting of Bear Clover in the Sierra-Nevada Mountains of California

INTRODUCTION

Bear clover (*Chamaebatia foliolosa*) has been shown to be an extreme competitor for soil moisture with respect to planted conifers (Tappeiner and Radosevich, 1982) as well as causing substantial reductions in growth and survival. Bear clover is also known to be a prolific resprouter following a disturbance to the above ground portion of the plant (Potter, 1984). Therefore, for a conifer plantation to become established successfully in an area where bear clover is abundant, control of the competing shrub is a neccessity.

Mechanical treatments usually have little success, as do manual methods of control. Resprouting of bear clover may occur within a few weeks after treatment, fully reoccupying the site within a matter of months, to a year or more (Potter, 1984). Chemical treatments are more effective than manual or mechanical methods, but resprouting does still occur with some herbicides (McHenry et al., 1980).

For the control treatment to have a beneficial effect on plantation survival and growth, the method must provide control of bear clover for an extended period of time. This would reduce the need for repeat treatments as well as reduce the treatment costs.

The first objective of this study is to evaluate the ability of glyphosate, triclopyr, dichlorprop, and fluroxypyr to inhibit post-treatment resprouting above and below ground and to determine their potential for long term control. The second objective is to determine differences in soil moitures attributable to the degree to which sprouting was controlled. The final objective is to determine the influence of bear clover on ponderosa pine with respect to plant moisture stress.

LITERATURE REVIEW

BEAR CLOVER

Distribution

Bear clover (Chamaebatia foliolosa) is a low growing evergreen shrub common to the west side of the Sierra Nevada Mountains of California. It forms a dense ground cover from two to six decimeters in height with many leafy branches (Munz and Keck, 1959). It is known by many names such as bearmat, mountain misery, ket-ket-dizze, and tarweed. Its distribution extends from Kern County in the south to Shasta county in the north (Lanini, 1981) (Figure #). It ranges in elevation from 600 to 2100 meters (Tappeiner and Radosevich, 1982). Observations indicate it can occupy all aspects, all sites, and all soil types within its range (Potter, 1984). Bear clover is commonly associated with ponderosa pine (Pinus ponderosa) and mixed conifer forests (Tappeiner and Radosevich, 1982). It occurs in open areas as well as in the understory of somewhat open stands of mature timber.

Biology of Bear Clover

Bear clover has many attributes which make it a severe competitor for soil moisture. It has a very dense and fibrous root system which can extend to depths of six feet or more (Potter, 1984). The bulk of this root system occurs between depths of six to eighteen inches (Munns, 1922).

Tappeiner and Radosevich, 1982, have shown that the main effects of bear clover on soil moisture depletion occur at depths below 15 centimeters. Soil moisture below 15 cm reached 1.5 MPa of tension by August where bear clover was present. In areas where bear clover had been totally removed, soil moisture at these depths never exceeded four bars of tension all year. At depths from 0 to 7 centimeters, soil moisture was less for open areas with bear clover compared to areas in partial shade, open ares with full sun and squaw carpet, and areas in full shade (Tappeiner and Helms, 1971). These data are also consistent with the findings that pre-dawn, xylem sap tension of bear clover increased to greater than 3.0 MPa as season progressed from spring to summer (Lanini, 1981). This would indicate a rapid depletion of soil moisture.

Bear clover is a rhizomatous species in which the bulk of the rhizomes are between 10 to 40 centimeters below the soil surface. The plant will readily sprout from adventitious buds on the rhizomes following fire or soil disturbance (Tappeiner and Radosevich, 1982). Sprouting has been observed to be very rapid. Within a few weeks, sites from which the crowns of bear clover have been removed will be covered with new sprouts (Potter, 1984). Bear clover rhizomes have been shown to extend for distances of 90 feet or more, and are from .2 to .5 inch in diameter (Munns, 1922). The rhizomes produce a very high density of individual stems. Munns, 1922, counted as many as 104 individual stems per square foot. In addition to producing sprouts from above, the rhizomes also produce roots from below (Potter, 1984). It has also been shown that fragmented rhizomes will also readily sprout, this has been a problem with many types of mechanical site preparation treatments (Potter, 1984).

Mature bear clover produces an abundant seed crop every year, but seedlings on undisturbed sites are rare (Potter, 1984). Considerable seed loss from rodents has been observed. The lateral rate of spread is also very slow. Generally it appears to be around six inches per year or less (Potter, 1984, McHenry & Coombes, 1983). Therefore, sprouting from rhizomes appears to be the primary method of reproduction.

Bear clover is a severe competitor to conifer seedlings. It has been shown to inhibit regeneration and significantly reduce growth of established trees (Tappeiner & radosevich, 1982, Tappeiner & Helms, 1971, Fowells & Shubert, 1951, Munns, 1922). Early work by Munns, 1922, showed that ten years after a wildfire went through the study site, 99.6% of the natural reproduction that occurred was in areas where bear clover was not present or sparsely established. This amounted to roughly 30% of the total area. A further study showed that of seedlings which became established in areas where bear clover was present in the spring of 1921, only

43.5% survived by November, compared to 88% in areas where bear clover was not present (Munns, 1922).

Survival of newly germinated seedlings of white fir (Abies concolor) and Douglas-fir (Pseudotsuga menziesii) from May through October 1963 growing with bear clover in full sun was reported to be one and six percent respectively (Tappeiner & Helms, 1971). Water stress was the single largest contributor to seedling mortality. This was in contrast to areas in full sun with squaw carpet (Ceanothus prostratus) where seedlings had survival ratings of 94% and 80% respectively.

Planted ponderosa pine seedling survival was dramatically increased over a 19 year period when 100% of the bear clover had been removed with a combination of a herbicide application and hand clipping of fresh sprouts. When a trench was also constructed around the perimeter of the plot and lined with a polyethylene liner, invading rhizomes were excluded (Tappeiner and Radosevich, 1982). No bear clover reappeared over the course of the nineteen years. Survival of pine seedlings was 80% to 100% after nineteen years on three sites. Treatments consisting of a single herbicide application and no trenching resulted in survival rates of 52% to 88%. These lower rates were primarily due to heavy resprouting of bear clover. In treatments where bear clover had not been removed, survival ratings ranged from 6% to 12% after 19 years.

Height growth was also severely affected by competition from bear clover (Tappeiner & Radosevich, 1982). In the study mentioned above, height growth was two to four times greater where bear clover had been 100% excluded compared to the herbicide treated plot. This shows that a temporary reduction in bear clover may increase survival, but competition from sprouts severely decreases height growth. It has been estimated that competition from bear clover may reduce wood volume production at age 50 by 75% (Tappeiner & Radosevich, 1982). This coincides with work done by Fisk, 1984, where volume losses of 70% were predicted for an 85 year rotation in mixed conifer and west side pine stands growing in heavy bear clover. Fisk, (1984), also predicted control of bear clover would be needed for a minimum of two decades after seedling establishment to achieve Forest Service growth and yield objectives.

Height growth of natural regeneration is also significantly affected by competition from bear clover. After ten years of growing in direct competition from bear clover and other brush species, the few surviving pines averaged three feet in height. White fir and incense cedar averaged only one foot tall (Fowells & Schubert, 1951). Bear clover competition was also shown to increase the time required to reach 54 inches in height for sugar pine, ponderosa pine, incense cedar, and white fir by 112%, 112%, 52% and 42% respectively (Munns, 1922). Thus, bear clover reduces forest growth in two ways that are compounded.

Bear clover foliage is unique in that it has a very high amount of surface area. Leaves are 2 to 10 centimeters long, viscid, mostly thrice pinnate, with ultimate divisions, and are tipped with a stalked gland (Munz & Keck, 1963). The foliage produces a highly resinous, hydrophobic secretion, which is unpleasantly aromatic. Unpublished data by Newton & Fredrickson, 1991, has shown there to be roughly 140 pounds of such resin per acre in a medium stocked stand of bear clover. This residue may reduce the effects of some herbicide applications by reducing the penetration into the leaf.

Some positive aspects of bear clover are that it does potentially provide excellent road bank stabilization and erosion control due to the dense root system, abundant litter, and solid ground cover (Potter, 1984). Road cuts and fills not containing bear clover rhizome pieces would colonize slowly, however. It has also been reported that up to 67% of the winter diet of deer may consist of bear clover (Potter, 1984). Under certain soil conditions, bear clover has been shown to be a potential nitrogen fixer (Heisey et.al., 1980).

MANAGEMENT OF BEAR CLOVER

Site Preparation / Competition Release

Management of competing vegetation occurs at two stages during the regeneration period. Site preparation occurs prior to planting whereas release treatments occur after the trees have been established.

Site preparation entails the control of vegetation and formation of suitable microsites for establishing desired seedlings (Newton & Knight, 1981). The removal of vegetation by site preparation is accomplished by various mechanical methods, herbicides, hand removal, fire, or a combination of these methods (Lanini, 1981).

Competition release is the selective control of competing forest weeds in a stand of crop trees (Newton & Knight, 1981). Release may be achieved by any of several methods of applying herbicides, or by hand cutting, and includes both cleaning and liberation operations (Newton & Knight, 1981).

Due to the highly competitive nature of bear clover and its ability to resprout, both site preparation and release treatments are required to insure survival and adequate growth rates of planted conifers (Fisk, 1984, Potter, 1984). Therefore, a treatment which would adequately reduce the above ground portion of bear clover and substantially inhibit sprouting in the future would be the most efficient both biologically and economically.

Chemical Treatments

For treatment of bear clover, herbicides can be used for both site preparation and release. By the late 1970's, research indicated that the only long lasting effective method of controlling bear clover was with herbicides (Potter, 1984). Herbicide use also negates many negative aspects of mechanical treatments such as erosion, and the removal of valuable top soil (Jackson & Lemon, 1986). Herbicides are the most cost efficient method of bear clover treatment when compared to mechanical or hand cutting methods (Potter, 1984).

Many types of herbicides have been studied to control bear clover. The group includes growth regulator, systemic, and soil active products (Radosevich et. al.,1973, McHenry et. al. 1980, Lanini, 1981, Coombes & McHenry, 1983, Jackson & Lemon, 1987, Johnson, 1987). One problem associated with some herbicide applications is that they may provide a high degree of topkill, but they fail to control resprouting from the rhizomes (McHenry et. al., 1980). In many cases, as soon as one year after obtaining nearly 100% topkill, bear clover has fully resprouted to reoccupy the site (McHenry et.al., 1980), such was the case for spring application of triclopyr amine and 2,4-D l.v.e.. Tappeiner & Radosevich, (1982) also noted vigorous resprouting seven months after study plots were treated with 2,4,5-T. This necessitates repeat applications to maintain control of bear clover (Potter, 1984).

The phenoxy herbicides constituted much of the early work with bear clover. This group includes the herbicides 2,4,5-T, 2,4-D, and 2,4-DP. Early on, 2,4,5-T provided good results, yielding topkills of 80% to 100% when applied in mid June to mid July (Radosevich et. al., 1973). However, 2,4,5-T has since been banned for use in the United States. 2,4-D l.v.e. at 2 and 4 pounds active ingredient per acre and 2,4-DP at 4 pounds per acre have also been shown to give good results when applied in the spring (Lanini, 1981, McHenry et. al., 1980). However, 2,4-D fails to control resprouting (McHenry et.al., 1980). Fall treatments with 2,4-D and 2,4-DP have failed to provide acceptable control of bear clover (Coombes & McHenry, 1983, Lanini, 1981). Good initial topkill has been achieved with 2,4-D on scarified and undisturbed sites (Coombes & McHenry, 1983, McHenry et.al., 1980). Scarified sites seem to increase effectiveness (Potter, 1984).

Triclopyr, like the phenoxy group, is a synthetic growth regulator type herbicide (Newton & Knight, 1981). Good top kill of bear clover has been achieved with both the amine and ester formulations of triclopyr at 2 and 4 lbs a.i./acre in spring treatments (Lanini, 1981, McHenry et. al., 1980). Fall treatments are more inconsistent. Lanini, 1981 reported good control at 4 lbs a.i./acre with either the amine or ester formulation. However, results by Coombes & McHenry, 1983, and McHenry et. al., 1980, showed poor to moderate control for both formulations. Triclopyr ester has failed to control resprouting of bear clover at one a two lbs a.i./acre, and only marginal control at 4 lbs a.i./acre (McHenry et.al., 1980).

Glyphosate is a systemic herbicide which has shown much promise in the control of bear clover. Spring applications of glyphosate (Roundup-Monsanto) have been shown to exhibit some degree of control for up to five years after initial application (McHenry et.al., 1980). It has been suggested that applications with glyphosate may be more desirable than other herbicides because one application may provide acceptable results while two are usually necessary for other herbicides (Potter, 1984).

Acceptable control of bear clover has been achieved with spring treatments of glyphosate at rates from 2 to 8 lbs ai/acre (Lanini, 1981, McHenry et. al., 1980). Later in the summer, higher rates are required to obtain adequate control (Lanini, 1981). Glyphosate has also been shown to provide excellent results when used in directed spray treatments in 1% solution with .5% nonionic surfactant and 2% solution in water on undisturbed mature bear clover in spring treatments (Jackson & Lemon, 1986). Fall applications are more variable, Coombes & McHenry, 1983, found glyphosate gave excellent results at 4 lbs ai/acre while results at 2 lbs ai/acre were only somewhat less. However, other studies have indicated poor results with fall treatments of glyphosate (Mchenry et. al., 1980, Lanini, 1981).

Fluroxypyr is a pyridine carboxylic acid herbicide similar to picloram but with less soil residual activity (Rodney & Messersmith, 1991). It has been shown to adequately control bigleaf maple sprout clumps (Cole & Newton, 1990), as well as common sagewort (Artemesia campetris) (Whitson & Gade, 1991). Fluroxypyr has also been shown to control greenleaf manzanita (*Arctostaphylos patula*) (Cole & Newton, 1990). In recent trials, fluroxypyr has provided good initial topkill of bear clover, as well as being fairly selective on ponderosa pine (Newton & Fredrickson, 1993).

Mechanical Treatments

Many mechanical treatments have been used to try to control bear clover. Pressure from environmental groups to restrict the use of herbicides has led the Forest Service to rely heavily on these methods (Nelson, 1989). In general, most mechanical methods for control have proven ineffective (Potter, 1984). Many of the mechanical treatments tend to break up the rhizomes but fail to remove them from the soil. The rhizomes in turn tend to resprout vigorously from the smaller pieces (Potter, 1984). The cost of mechanical treatments are also considerably higher than the use of herbicides (Potter, 1984).

Terracing was an early method of mechanical site preparation that was somewhat effective in certain conditions. This method involved making a 2 to 4 foot cut in the soil profile along the land contour with a bulldozer, trees were then planted into the terrace (Potter, 1984). The idea was to plant trees under the zone of bear clover rhizomes. However, this method was limited to slopes between 15% and 40%. It also provided significant logging engineering problems for commercial thinnings and final harvests (Potter, 1984). Soil disturbance for this method was very high. Some degree of control was achieved, but results were variable. Costs of terracing in 1984, were $170.00/acre (Potter, 1984).

Making small terraces with dynamite was also attempted. However, with these attempts not enough bear clover was removed and rapid resprouting occurred. Costs of this method were extremely high at $500.00/acre (Potter, 1984).

Another technique involved ploughing with a single toothed agricultural plow. The idea was to create a furrow and plant the seedling in the bottom, hopefully below the bear clover rhizomes. However, vigorous resprouting occurred and the plantation failed within two years (Potter, 1984).

Disking is another method for site preparation. In this method, a heavy agricultural disc with six 18 inch discs was pulled behind a tractor (Potter, 1984). The theory was that if the rhizomes could be severed and mulched in the soil, they would desiccate and die (Potter, 1984). Results of one directional discing operations have provided poor results. Nelson, 1989, noted active sprouting only one month after treatment. Potter, 1984, noted rapid resprouting and a new vigorous stand of bear clover one year after treatment. Data for two way discing was not available. Current costs for disking are between $75 and $100/acre (Carr, personal communication).

An alternative approach taken was the "solar ban" method of bear clover control. In this approach, 4′ x 8′ sheets of durable materials such as heavy black plastic, or kraft paper with fiber glass and asphalt felt inside were layed out over bear clover. Seedlings were then planted in the center of the material (Potter, 1984). Hopefully the bear clover would die. The problems that occurred were that the materials would break down rapidly in sunlight, and bear clover would reoccupy the site. Animal damage was also a problem to the materials. This was a very labor intensive method of control. Costs ranged from $250-$400/acre depending on the terrain, number of trees, and the material used (Potter, 1984).

One promising method of mechanical site preparation is two-way ripping with a winged subsoiler. The winged subsoiler differs from a conventional ripper in that each shank has a winged shoe about 22 inches across that resembles a delta-winged plane (Nelson, 1989). The subsoiler provides excellent soil shatter and decreases soil bulk density (Nelson, 1989, Andrus & Froehlich, 1983). The subsoiler actually pulls large numbers of bear clover rhizomes from the ground. Nelson, 1989, reported superior control of bear clover was achieved with two way cross ripping in fine textured soils 15 months after treatment, slightly less control was achieved with one way ripping. In coarser textured rocky soils, control is not as good. The reason suspected is that rhizomes will tend to be held more firmly in the ground, and will tend to be cut, rather than ripped from the soil (Nelson, 1989). One advantage of two way ripping is that more ground can be covered by the treatment because maneuverability around obstacles is improved (Nelson, 1989). Cost of two way ripping is $100/acre, whereas one way is $75/acre (Carr, personal communication). Subsoiling alone will not control bear clover for extended periods, but it does provide for excellent survival and growth under certain conditions (Nelson, 1989).

Manual methods

Manual methods to remove bear clover have been ineffective. Hand grubbing bear clover around individual seedlings has been the predominant method (Potter, 1984). With hand grubbing, only the top portions of the plant are removed. As a result, vigorous resprouting occurs. Bear clover may fully reoccupy the grubbed areas in a matter of weeks (Potter, 1984). Hand grubbing is one of the more expensive methods at a cost of $300/acre (Carr, personal communication).

Fire

Although bear clover will readily sprout from rhizomes after being burned (Tappeiner & Radosevich, 1982), there are some implications that fire can be used for a management tool. Early thoughts on fire were that if bear clover could be burned at least three times in rapid succession, it would use up its carbohydrate reserves and die. However, research to date has not indicated this to be true (Potter, 1984). Some limited evidence suggests that season of burning related to shrub phenology may be an important factor in affecting its response to fire. Rundel et. al., (1981), have indicated that summer burns seem to inhibit regrowth for at least two years. However, work by Weatherspoon et. al., (1991), has indicated that bear clover response to a single growing season prescribed burn did not vary with date of burn. After a single season burn, Weatherspoon et.al. manually removed the tops of bear clover to simulate a second burn and found that the bear clover recovered much more slowly. This may suggest that repeated burns may reduce recovery rates of bear clover.

Costs of burning are high. Summer burns would cost approximately $200/acre, whereas burns in the wet seasons could be accomplished for around $75/acre (Carr, personal communication).

METHODS

In mid April, 1992, an experiment was established on the Placerville Ranger District of the El Dorado National Forest, California, to determine the ability of four herbicides to control post-treatment resprouting of bear clover, above and below ground. Herbicide effectiveness was evaluated above ground by the number of new sprouts produced, and below ground via sprouting of exposed rhizomes. A further objective was to evaluate differences in soil moisture at 0-30cm and 30-60 cm between areas of treated and untreated bear clover.

SITE SELECTION

The site selected for this study is a five year old clearcut in a stand of ponderosa pine, sugar pine (*Pinus lambertiana*), and incense cedar (*Calocedrus decurrens*) approximately 70 years old before harvest. A mature understory of bear clover was also present. It was since replanted with 1-0 ponderosa pine seedlings. There are currently starting their fifth growing season. This site is located approximately 15 miles southeast of Placerville, California in the SE 1/4 of section 28, R 13 E, T 9 N.

After logging, the slash was piled and burned and later the soil and vegetation was ripped. Bear clover, whiteleaf manzanita, annual grasses, thistles, and fireweed reoccupied the site after site preparation. Bear clover cover is approximately 15%, mostly in patches of solid cover. Slope is southeast, approximately 15%. Soils are a deep granitic derived yellow-red clay loam.

Approximately one acre in the east part of the unit had no site preparation treatment other than the piling of slash. The original understory of bear clover was left virtually intact and undisturbed. Bear clover cover was approximately 65%. This portion of the unit was utilized in this study (Figure 1.1).

EXPERIMENTAL DESIGN

The experiment consisted of a completely randomized design with each of eight treatments having two replications (Table 1.1). Plot size was 12′ x 36′ (.01 acre). The plots were layed out in areas where bear clover cover was continuous, either running north-south or east-west. No plot contained less than 50% bear clover. Plots were staked at either the north or west end with a three foot section of half inch PVC pipe labelled with plot numbers on an aluminum tags. The other ends of the plots were marked with numbered pin flags. Plots were installed as densely as cover permitted across the area where sufficient bear clover was present.

The herbicides used for this experiment were glyphosate, triclopyr, dichlorprop, and fluroxypyr. Each was applied at

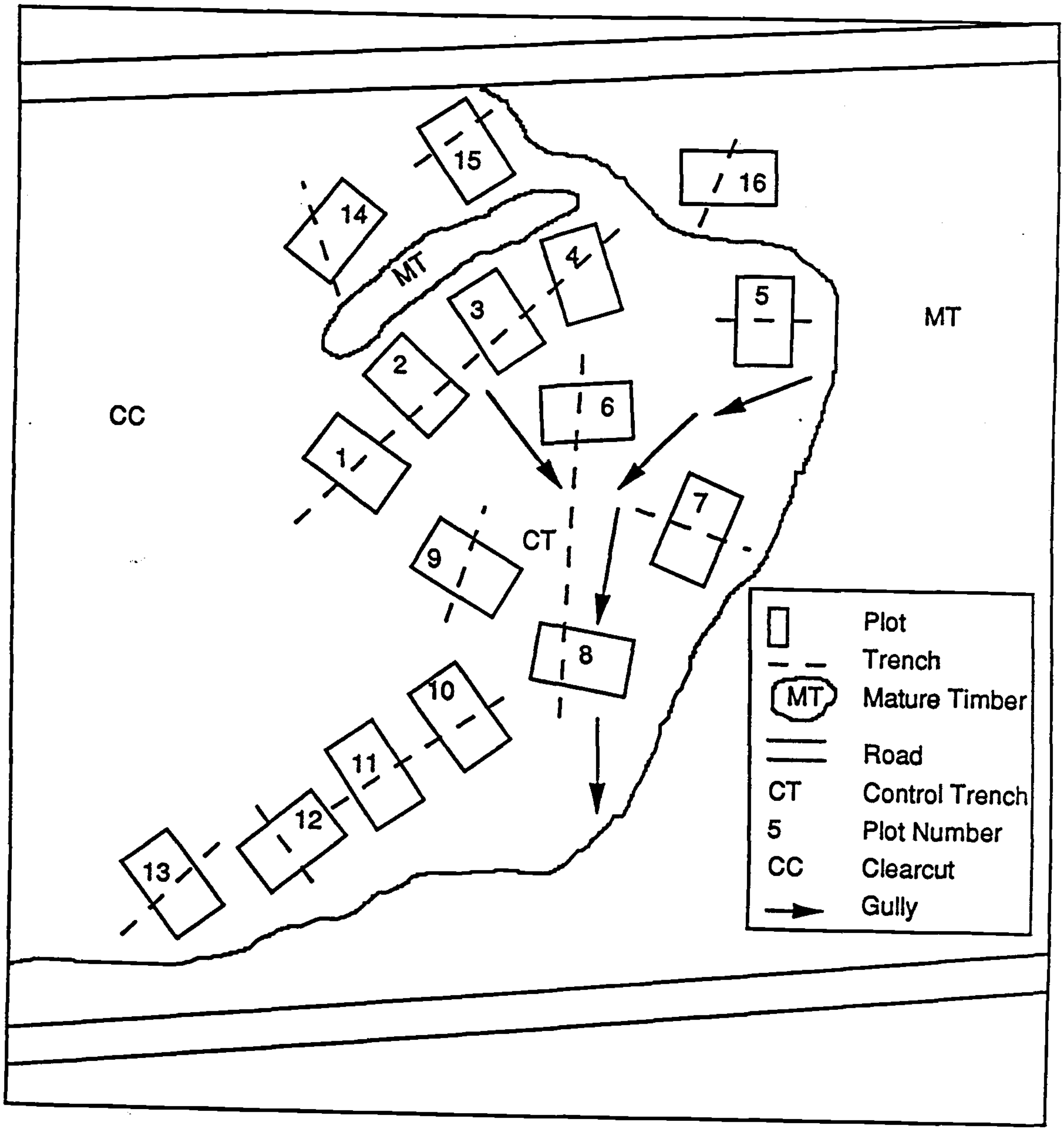

Figure 1.1 Plot and trench layout.

Table 1.1 Treatment list and plot randomization.

Herbicide	Dose a.i./ac *	Surfactant Type	Plot #'s
Glyphosate	1.5 lbs	L-77 (.15%)	7, 10
Glyphosate	3.0 lbs	L-77 (.15%)	12, 15
Triclopyr	0.9 lbs	Moract (5%)	3, 4
Triclopyr	1.5 lbs	Moract (5%)	11, 13
2,4-DP	2.0 lbs	Moract (5%)	5, 9
2,4-DP	4.0 lbs	Moract (5%)	1, 14
Fluroxypyr	0.5 lbs	Moract (5%)	2, 8
Fluroxypyr	1.0 lbs	Moract (5%)	6, 16

a

* a.i./ac = Active ingredient per acre.

high and low dose (Table 1.1). Surfactant was also added to improve coverage and performance. The surfactant Silwet® L-77 (Union Carbide) was included at .15% with glyphosate, due to its ability to significantly decrease spray droplet surface tension (Newton & Fredrickson, 1993). The other three herbicides were mixed with the surfactant Mor-act® (Wilbur-Ellis) at 5%. All treatments were sprayed at 10 gallons per acre. Plots were sprayed with a twelve-foot backpack boom sprayer. Pressure was constant at 30 psi. Each plot was sprayed with one timed pass. Timing of treatments was mid April, 1992. RD-6 nozzles, which produce relatively large drops (VMD ≅ 1,000 um) were used for all treatments.

CONTROL OF BEAR CLOVER

To determine the extent to which each herbicide initially controlled the above ground vegetation, ocular estimates of percent crown reduction and percent cover were used. Initial percent cover was estimated for each plot at the time of spraying in mid April. The first post-treatment evaluations took place in mid-July, two months after treatment. Percent crown reduction and percent cover were estimated on a plot by plot basis. Values were then averaged for individual treatments.

Second evaluations were made five months after treatment and final evaluations were made thirteen months after treatment. Percent cover was estimated to note any further effect obtained by the treatments, this is especially important for the slower acting systemic herbicides such as glyphosate.

ANALYSIS OF SPROUTING

Trenches

To obtain a better understanding of how each herbicide affects the resprouting potential of bear clover, it was necessary to determine their effect on the rhizome systems themselves. For herbicides to control resprouting adequately, they must be able to translocate through the rhizomes to suppress bud activity. To determine the herbicidal inhibitory effect on the rhizome system, a trench was constructed across each plot which produced a two dimensional view of the exposed rhizomes (Figure 1.2). Trenches were constructed on June 15, 1992, two months after spraying.

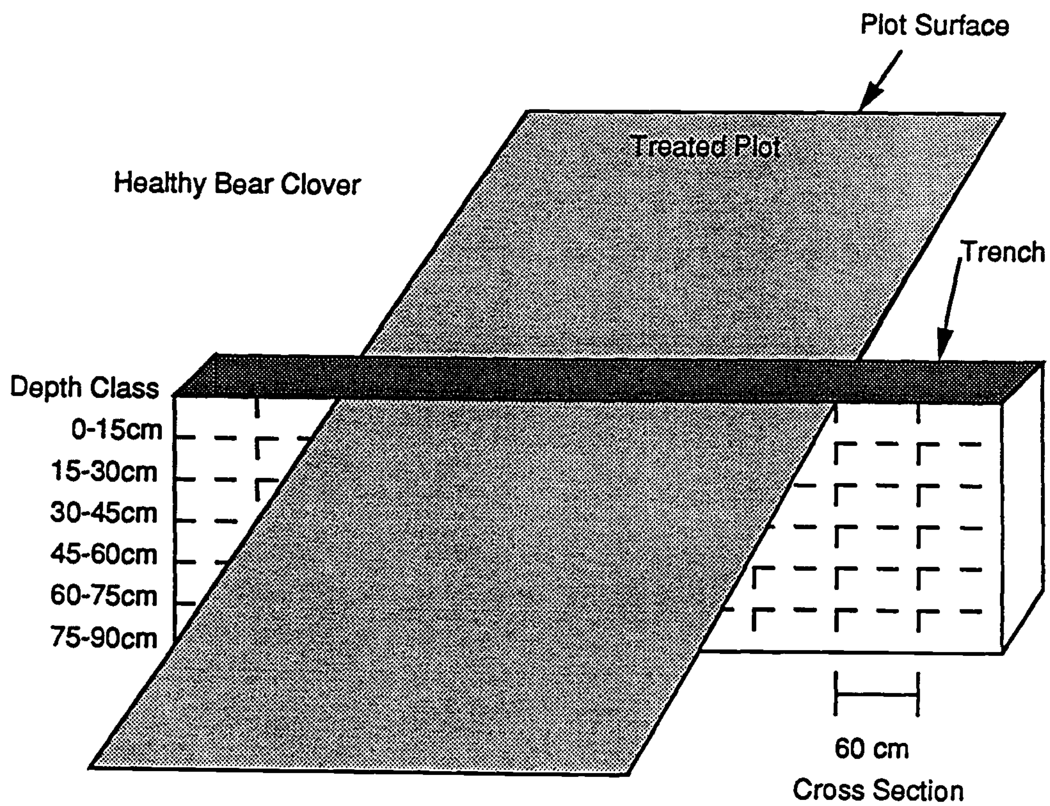

Figure 1.2 Plot and trench design for analysis of rhizome sprouting.

A mechanical trencher (ditchwitch) mounted on a small track-type tractor was used to construct the trenches. The trencher blade was 48 inches long by 6 inches wide, capable of producing trenches of the same dimensions.

The trenches were constructed transverse to the centers of each plot. The trenches extended at least four feet into the untreated bear clover adjacent to the plot to determine differences between rhizomes under treated and untreated bear clover, and to evaluate whether there was mobility from treated into untreated bear clover.

Evaluation of the trenches took place in early September. Only one wall of each trench was evaluated. Apart from time constraints, caving in often reduced the value of one side more than the other. Either the north or west side of the trench was evaluated depending on the direction of the plot. These were the aspects where the most sprouting could be observed. Trench walls were evaluated using a grid system, using 15 centimeter depth classes and 60 centimeter cross sections (Figure 1.2).

The evaluation consisted of counting the total number of rhizomes in each section, the number of sprouts, and the number of non-sprouting rhizomes. The number of non-sprouting rhizomes was then subtracted from the total number of rhizomes to obtain the number of rhizomes sprouting. Due to varying lengths of exposed rhizomes and varying numbers of buds per rhizome, treatment effects were evaluated on the basis of percent of rhizomes sprouting.

Statistical analysis of the data consisted of simple linear regression to determine gradients in the amount of sprouting as a function of distance from untreated cover. Analysis of variance was also used to determine significance of differences between sections within the plot adjacent to the edge and sections adjacent to the edge outside of the treated plot, i.e. the edge transition due to treatment. LSMEANS procedure in SAS was used calculate P-values for individual comparisons between treatments and factors therein. Orthogonal contrasts were used to compare herbicide treated plots with the controls.

Above Ground Sprouting

Evaluation of above ground sprouting also occurred in early September at the same time the trench evaluations took place. Evaluations consisted of three transects running across the narrow section of each plot (Figure 1.3). The transects extended four feet into untreated bear clover. Each transect was 30 centimeters wide and was divided into 60 centimeter sections. Where possible, transects were spaced approximately nine feet apart. When the trenches conflicted with the layout of a transect or where insufficient bear clover was present the transect was moved to the nearest area of bear clover. The total number of fresh green sprouts was counted for each section of the transect.

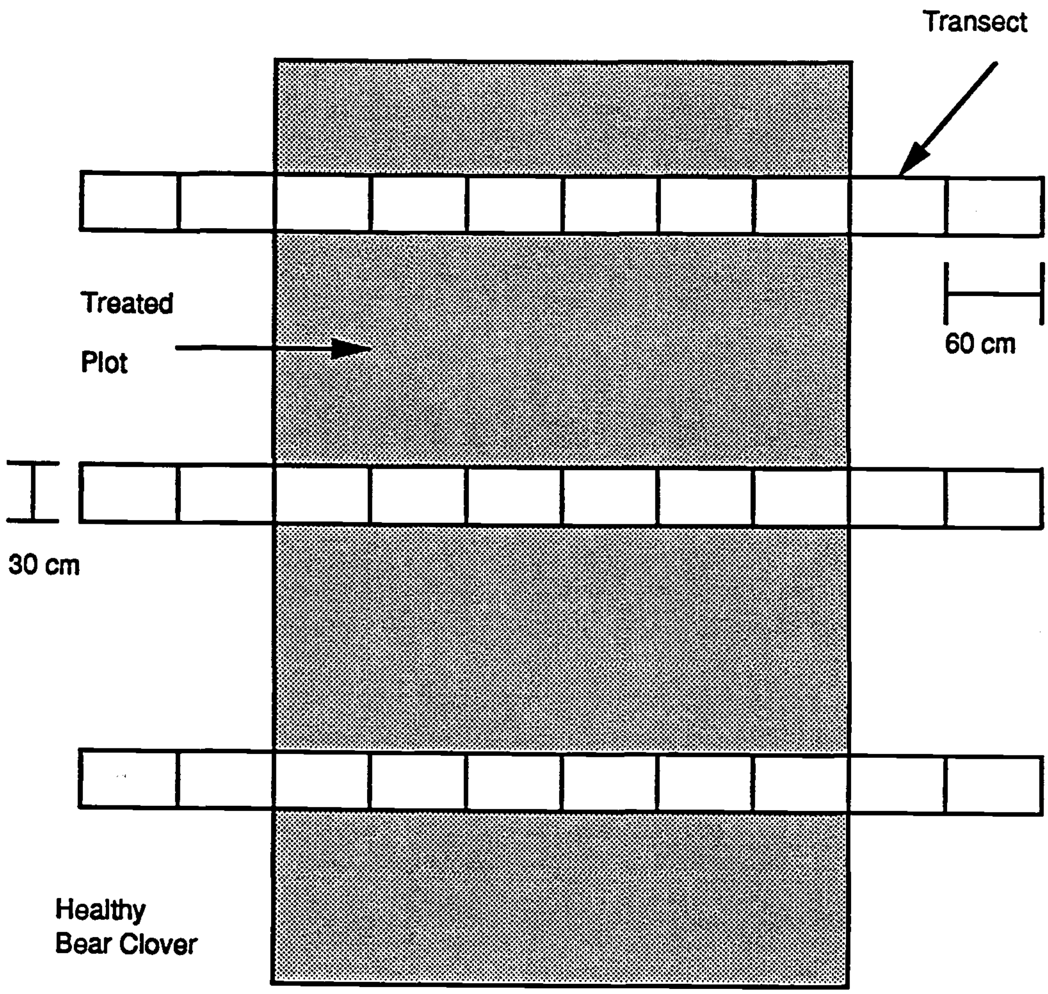

Figure 1.3 Plot and transect design for analysis of above ground sprouting.

Analysis of the data consisted of simple linear regression to identify gradients in the amount of sprouting across the plot. Analysis of variance was also used to determine significance of differences in sprouting between sections inside and outside of the treated zone on the plot edges. LSMEANS procedure in SAS was used to calculate P-values for comparisons of treatments and different factors. All statistics were run using the plot means.

SOIL MOISTURE

Soil moisture content was evaluated to determine differences between areas of treated and untreated bear clover at depths of 0-30 centimeters and 30-60 centimeters. A gravimetric soil sampler was used to take all samples.

Four samples were taken at each plot to obtain a reliable estimate and to possibly note any differences between treatments. Two samples were taken inside the treated plot, one at each end, half way between the trench and the plot end. Two other samples were also taken at least five feet away from the treated plot in areas of previously comparable bear clover cover. Samples were obtained in areas of comparable bear clover densities between plots to maintain as much similarity between samples as possible.

Each soil sample was drawn and immediately placed in a plastic zip-loc bag. A metal tag which was labeled with the plot number and sample location was placed in the bag along with sample. All soil samples were stored in a cooler with blue ice packs and transported back to Corvallis for analysis.

Soil samples were then placed in metal soil sample canisters with known tare weight. The canisters were then reweighed with the moist sample, and the original weight of the canister was subtracted to obtain the wet soil weight.

The samples were then dried in an oven at 103 degrees C. for 72 hours. At the end of the 72 hours, the samples were removed from the oven and immediately reweighed. The original canister weight was subtracted from the total weight to obtain the dry weight of the sample. The dry weight was then divided by the wet weight of the sample and subtracted from one to obtain the percent moisture content for the sample. Treatment averages were then obtained from all four replicates for each treatment.

The statistical analysis consisted of analysis of variance to determine the significance of differences in soil moisture between depths and treatments. LSMEANS procedure was used in SAS to compare individual treatments and factors therein.

PRE-DAWN MOISTURE STRESS

A series of plant moisture stress measurements were made on ponderosa pine seedlings growing in healthy bear clover and on seedlings growing in bear clover which had been treated with herbicides.

Table 1.2 Treatment list and bear clover percent cover (%Cov) and crown reduction (%CR) estimates for pre-dawn moisture stress measurements.

Plot	Herbicide	Dose*	Surf. Type**	Nozzle Type	%Cov	%CR
14	Tric.	0.6	None	80015	0.5	95
17	Tric.	0.6	None	11003	2.0	80
19	Control	****	****	****	60	0
23	Control	****	****	****	70	0
31	Tric.	0.6	None	80015	2.0	75
34	Control	****	****	****	55	0
42	Flur.	0.75	L-77***	80015	3.0	70
50	Dich.	4.0	None	80015	2.0	75
75	Flur.	1.0	None	80015	2.0	85
92	Dich.	2.0	None	80015	3.0	75
93	Flur.	0.75	None	80015	2.0	85
98	Gly.	3.0	None	80015	10.0	70
102	Gly.	3.0	None	80015	1.0	90

* Dosages are pounds active ingredient per acre.
** Surf. Type = Surfactant type.
*** L-77 was included in the mixture at 0.15%.

Due to high mortality of ponderosa pine seedlings on the thesis study plots, an alternative study site was used where adequate numbers of seedlings persisted in varying intensities of bear clover competition. The unit selected was a clearcut approximately four years old which was planted with ponderosa pine seedlings currently in their third growing season. The unit is approximately 15 miles northeast of the thesis study site. The site was the location of a series of herbicide application technology experiments conducted by Professor Michael Newton of Oregon State

University and myself. The study consisted of over 100 plots utilizing five herbicides, glyphosate, triclopyr, fluroxypyr, dichlorprop, or 2,4-D. The experiments were designed to study the effectiveness of herbicides in relation to varying drop sizes, surfactants, and doses on bear clover. Pine damage was also one of the factors evaluated.

Due to varying degrees of herbicide injury to the pine, only plots with very minimal but preferably no damage were selected for stress measurements. The treatments also had to have an acceptable level of bear clover control, preferably over 80% crown reduction. Therefore, the stress measurements were done on a wide array of treatments. The evaluation of the pine seedlings for herbicide damage was done in early September. Also three control plots already established on the site were selected to compare against seedlings from the treated plots. Each plot had at least three pine seedlings. Stress measurements were taken using a standard pressure bomb. In all, 13 treated plots were selected for stress measurements plus the three control plots. The Treatments for the selected plots are listed in Table 1.2 along with the percent crown reduction achieved and pine damage rating.

Predawn moisture measurements were made starting at 2:00 am and concluded around 4:30 am. Measurements were done on one twig from each of three trees per plot, resulting in three replications per treatment. The pressure bomb was set up in a centrally located area and all three samples from each plot were measured at the same time in the procedure described by the manufacturer (PMS Instruments, Corvallis, Or.). The steps in preparing the twigs were to cut the twigs, bring them back to the pressure bomb, trim the bark around the base of the twig, make an even cut at the end of the twig with a razor, and place in the pressure bomb. Measurements in bars were taken at the point where a drop of water emerged from the cut end of the twig.

Analysis of variance was used to determine statistical differences between the treated plots and the controls. Statistical analysis between treatments was not considered due to confounding differences in application parameters.

RESULTS

INITIAL CONTROL OF BEAR CLOVER

Comparison of bear clover cover over the three evaluation periods was influenced by a second order interaction between herbicide, time of evaluation and dose (P=.044).

Table 1.3 Bear clover percent crown reduction (Cr. Red.) and percent cover values at 2, 5, and 13 months after treatment. Standard errors are in parenthesis. Treatment date was 4/15/92.

Treatment	%Cr Red. 6/15/92	% Cover 6/15/92	% Cover 9/02/92	% Cover 5/15/93
Glyphosate Low Dose	33.0 (2.5)	48.0 (2.5)	37.5 (2.5)	1.1 (0.95)
Glyphosate High Dose	67.0 (8.75)	22.5 (2.5)	7.0 (3.35)	0.1 (0.0)
Triclopyr Low Dose	97.5 (2.5)	1.0 (1.0)	7.5 (2.5)	27.5 (12.5)
Triclopyr High Dose	97.5 (1.5)	0.15 (.05)	2.5 (1.5)	12.5 (2.5)
2,4-DP Low Dose	92.5 (2.5)	2.0 (0.25)	5.0 (2.0)	23.0 (17.0)
2,4-DP High Dose	96.0 (0.0)	0.5 (0.45)	2.0 (1.0)	21.5 (18.5)
Fluroxypyr Low Dose	74.0 (6.25)	11.5 (3.5)	11.0 (1.0)	60.0 (5.0)
Fluroxypyr High Dose	60.0 (12.5)	11.5 (6.5)	3.0 (1.0)	26.5 (8.5)
Control	0.0 (0.0)	85.0 (0.0)	82.5 (2.5)	82.5 (2.5)

Excellent initial crown reduction of bear clover was achieved two months after treatment with both doses of triclopyr and dichlorprop (Table 1.3). Poorer initial control was achieved with fluroxypyr and glyphosate.

Percent cover increased from the two to the five month evaluation for triclopyr and dichlorprop, while it decreased for both doses of glyphosate and the high dose of fluroxypyr. The low dose fluroxypyr treatments remained relatively constant. The doses of fluroxypyr and glyphosate were directly related to effect.

By the 13-month evaluation, cover was increasing for all treatments except glyphosate. The low dose of triclopyr, the low and high doses of dichlorprop and the low dose of fluroxypyr all had significantly more bear clover at the 13 month evaluation than at the 2 month evaluation (P=.005, .020, .022, & .0001, respectively). Almost total control was achieved with either dose of glyphosate 13 months after treatment. Glyphosate produced better control than all other treatments except the high dose of triclopyr by the 13 month evaluation (all P=.0001).

All treatments except for the low dose of fluroxypyr had significantly less bear clover at 13 months than the control plots (all P=.0001).

ABOVE-GROUND SPROUTING

Analysis of variance determined the main effects of herbicide and distance to be significant (P=.0004 & .0001, respectively. Sprouting was significantly lower with

Table 1.4 Above ground sprouting versus distance from the edge. Average number of sprouts per 30 x 60 cm section. Standard errors in parenthesis.

Average Number of Sprouts				
Distance (Feet)	Triclopyr Low Dose	Triclopyr High Dose	Dichlorprop Low Dose	Dichlorprop High Dose
-4*	0.2	0.0	0.0	0.0
	(0.17)	(0.00)	(0.00)	(0.00)
-2	0.5	0.3	0.3	0.1
	(0.00)	(0.00)	(0.25)	(0.08)
2	8.6	5.6	3.3	4.4
	(2.67)	(2.92)	(1.92)	(3.42)
4	16.0	7.1	7.7	8.4
	(6.83)	(0.08)	(5.83)	(6.92)
6	22.1	13.7	8.3	13.6
	(8.75)	(2.00)	(6.08)	(10.42)
Distance (Feet)	Fluroxypyr Low Dose	Fluroxypyr High Dose	Glyphosate Low Dose	Glyphosate High Dose
-4	0.0	0.0	0.0	0.8
	(0.00)	(0.00)	(0.00)	(0.83)
-2	0.7	0.0	0.0	0.0
	(0.50)	(0.00)	(0.00)	(0.00)
2	3.8	0.3	0.0	0.0
	(1.75)	(0.33)	(0.00)	(0.00)
4	6.0	2.5	0.0	0.0
	(2.33)	(2.50)	(0.00)	(0.00)
6	11.5	5.0	0.0	0.0
	(8.67)	(5.00)	(0.00)	(0.00)

* Negative number are outside the treated zone.

with glyphosate than triclopyr or dichlorprop (P=.0001 & .0061, respectively). The heaviest degree of sprouting occurred with triclopyr, which was not only significantly greater than glyphosate but also fluroxypyr (P=.0078). Sprouting with fluroxypyr was greater than for glyphosate, however, the difference was only marginally significant (P=.068).

Table 1.5 Regression analysis of number of above ground sprouts vs. distance from treated edge of plots. No transformations were made.

Treatment	Slope	P-value	R-squared
Glyphosate Low Dose	0.0	.0001	1.000
Glyphosate High Dose	-6.30	.1628	0.033
Triclopyr Low Dose	2.26	.0001	0.540
Triclopyr High Dose	1.29	.0001	0.382
Dichlorprop Low Dose	0.91	.0001	0.340
Dichlorprop High Dose	1.34	.0001	0.279
Fluroxypyr Low Dose	1.06	.0001	0.301
Fluroxypyr High Dose	0.46	.0005	0.188

Treatment alone did not account for all the explained variation in sprouting. Sprouting increased with increasing distance from the treated edge of the plots. The majority of the sprouting was concentrated in the center of the plots.

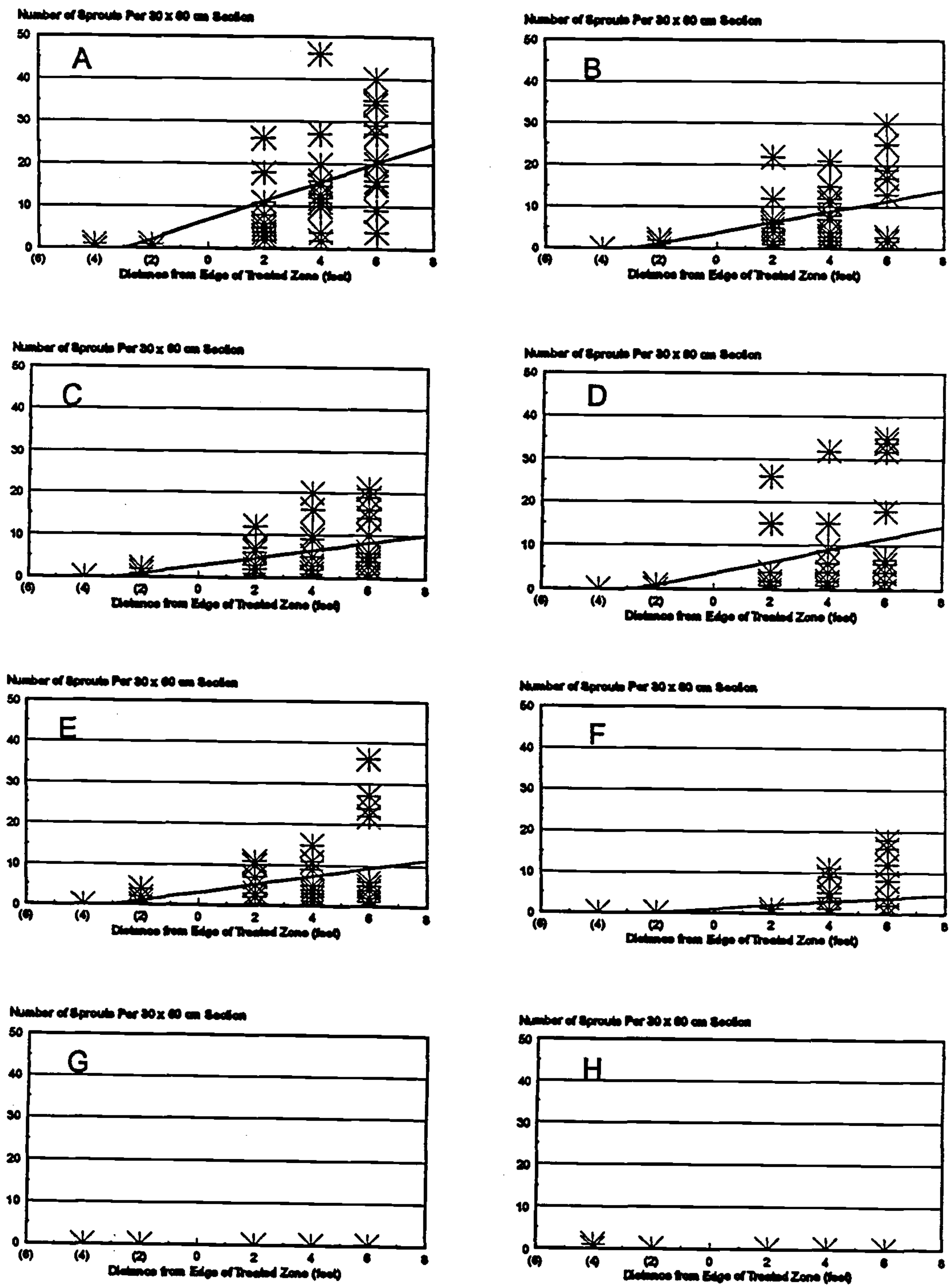

Figure 1.4 Regressions of above ground sprouting vs. distance from the plot edge. A) Triclopyr-low dose. B) Triclopyr-high dose. C) Dichlorprop-low dose. D) Dichlorprop- high dose. E) Fluroxypyr-low dose. F) Fluroxypyr-high dose. G) Glyphosate-low dose. H) Glyphosate-high dose. Negative numbers are outside the treated zone.

This trend was very consistent for treatments which exhibited sprouting (Table 1.4 & Figure 1.4).

Regression analysis revealed that sprouting increased most dramatically with the low dose of triclopyr, as was indicated by the high slope (Table 1.5 & Figure 1.4). The high dose of triclopyr, all dichlorprop treatments, and the low dose of fluroxypyr followed similar patterns and shared similar slopes. Fairly heavy sprouting occurred with all of the above treatments.

Sprouting also tended to be concentrated in the center of the plots with the high dose of fluroxypyr. However, sprouting occurred to a lower degree than other treatments and the slope was lower.

Glyphosate showed little slope because there was virtually no sprouting.

The main effect of distance showed that transect sections 2 feet outside the treated portion of the plot were significantly different from sections 4 and 6 feet within the treated zone (P=.0024 & .0001, respectively) as were sections 4 feet outside the treated zone (P=.0018 & .0001, respectively).

RHIZOME SPROUTING

Although trenches were sampled down to the 75 to 90 cm depth class, variation in the depth of trenches within and between treatments produced incomplete data sets below 45 cm.

Therefore, only the first three depth classes were compared. This was adequate for the purposes of this study, because the majority of the sprouting occurred in this zone.

Overall, the trenches provided an excellent picture of the herbicides' ability to control resprouting. Most

Table 1.6a Percent of rhizomes sprouting by depth class. Means are over all treatments excluding control plots.

Treatment I.D. # *	Depth Class	Percent of Rhizomes Sprouting	Standard Error
1	0-15 cm	25.86	2.355
2	15-30 cm	20.35	2.355
3	30-45 cm	7.92	1.516

* Treatment I.D. numbers are used to compare treatments that are significantly different.

Table 1.6b Treatments which are significantly different as denoted by their I.D. numbers.

I.D. Numbers	P-Value	I.D. Numbers	P-Value
1-2	.0313	2-3	.0001
1-3	.0001		

trenches were heavily occupied by fresh sprouts from deep roots. The majority of the sprouts were contained in the However, sprouting rhizomes were found at the 45 to 60 cm depth class.

Due to unavoidable double coding of indicator variables with the control trenches, the analysis was broken up into

Table 1.7a Percent of rhizomes sprouting by distance from treatment edge. Negative numbers are outside the treated zone. Means are over all treatments excluding the control plots.

Treatment I.D. # *	Distance from Treated Edge (Feet)	Percent of Rhizomes Sprouting	Standard Error
1	-4	7.53	1.672
2	-2	15.26	2.563
3	2	18.98	2.792
4	4	22.71	3.231
5	6	23.66	3.191

* Treatment I.D. numbers are used to compare treatments which are significantly different.

Table 1.7b Treatments which are significantly different as denoted by their I.D. numbers.

I.D. Numbers	P-Value	I.D. Numbers	P-Value
1-2	.0241	1-5	.0001
1-3	.0002	2-4	.0052
1-4	.0001	2-5	.0012

several parts. An ANOVA was run including all treatments, however, the control plots were excluded. To compare treated sections of trench within the plot and untreated sections of trench outside the treated zone to the controls sets of orthogonal contrasts were run (Table 1.9a & b). To avoid violating the laws of independence, contrasts were run on the high and low doses seperately.

The analysis of variance which excluded the control plots, determined there to be a significant first order

Table 1.8a Percent of rhizomes sprouting by treatment. Trench sections 2 and 4 feet outisde the treated zone are included due to their inclusion in the analysis of variance. Control plots are excluded.

Treatment I.D. # *	Treatment**	Percent of Rhizomes Sprouting	Standard Error
1	Glyphosate 1.5# a.i./ac.	0.43	0.247
2	Glyphosate 3.0# a.i./ac.	1.4	0.640
3	Triclopyr 0.9# a.i./ac.	32.74	4.640
4	Triclopyr 1.5# a.i./ac.	22.17	3.323
5	Dichlorprop 2.0# a.i./ac.	19.21	2.583
6	Dichlorprop 4.0# a.i./ac.	24.63	4.689
7	Fluroxypyr 0.5# a.i./ac.	36.20	3.839
8	Fluroxypyr 1.0# a.i./ac.	16.03	3.141

* Treatment ID numbers are used to compare treatments which are significantly different.
** a.i./ac. = Active ingredient per acre.

Table 1.8b Treatments which are significantly different as denoted by their ID numbers.

ID Numbers	P-value	ID Numbers	P-value	ID Numbers	P-value
1-3	.0001	2-3	.0001*	3-5	.0112
1-4	.0001*	2-4	.0001	3-8	.0012*
1-5	.0001	2-5	.0001*	4-7	.0009*
1-6	.0001*	2-6	.0001	5-7	.0001
1-7	.0001	2-7	.0001*	6-8	.0387
1-8	.0002*	2-8	.0005	7-8	.0001

* Bonferronis' adjusted probability technique was used to adjust the significance level where more than one factor varied between comparisons.

Table 1.9a Percent of rhizomes sprouting by treated and untreated portions of plots. Control values are listed twice because there was no treatment applied to deliniate between treated and untreated sections.

	Combined means for trench sections outside the treated zone.		Combined means for trench sections in the treated zone.	
Treatment *	Percent of Rhizomes Sprouting	Standard Error	Percent of Rhizomes Sprouting	Standard Error
Glyphosate 1.5# a.i./ac.	0.63	0.510	0.19	0.194
Glyphosate 3.0# a.i./ac.	2.50	1.313	0.67	0.560
Triclopyr 0.9# a.i./ac.	21.20	5.063	39.56	5.625
Triclopyr 1.5# a.i./ac.	12.58	3.513	28.56	4.470
Dichlorprop 2.0# a.i./ac.	8.35	1.966	26.11	2.997
Dichlorprop 4.0# a.i./ac.	12.13	4.112	32.97	6.752
Fluroxypyr 0.5# a.i./ac.	29.71	6.301	41.33	4.526
Fluroxypyr 1.0# a.i./ac.	9.58	4.073	20.33	4.309
Control	6.33	1.531	6.33	1.531

* # a.i./ac. = Pounds active ingredient per acre.

interaction between herbicide type and dose (P=.0001). No other interactions were significant. However, the main effects for depth and distance were significant (P=.0001 & .0001, respectively).

The majority of the sprouting was concentrated in the 0-15 cm depth class (Table 1.6a). In general, sprouting decreased with increasing depth.

Table 1.9b Orthogonal contrast data. P-values are the probability that the means being compared are equal.

Comparison	P-Values Low Dose Treatments Within*	 Outside*	 High Dose Treatments Within*	 Outside
Control vs. all others.	.0001	.0333	.0029	.3277
Glyph. vs. tric., dich., and flur. **	.0001	.0001	.0001	.0133
Dich. vs. tric. and flur. **	.0015	.0027	.0983	.7801
Triclopyr vs. fluroxypyr	.7251	.1097	.1665	.4868

* "Within" refers to trench sections within the herbicide treated zone of the plot. "Outside" refers to trench sections outside of the herbicide treated zone.
** Glyph.=Glyphosate Tric.=Triclopyr Dich.=Dichlorprop Flur.=Fluroxypyr

Sprouting from rhizomes tended to increase towards the center of the treated areas (Table 1.7a). However, the pattern was much less distinct than for above-ground sprouts. Results were also highly variable between treatments and doses. Regression analysis failed to come up with any patterns consistent enough to be considered useful.

The low-dose triclopyr and fluroxypyr treatments had the highest degree of sprouting of any treatment (Table 1.8a). All growth regulator products exhibited vigorous resprouting. The high rate of fluroxypyr controlled resprouting the best of all growth regulator products. However, control did not extend past the 5 month evaluation. Increasing dose decreased the amount of sprouting for triclopyr and fluroxypyr, but the opposite was true for dichlorprop.

Glyphosate controlled virtually all rhizome sprouting. Only minimal sprouting occurred in the 0 to 15 and 15 to 30 centimeter depth classes (Table 6a). Both doses of glyphosate controlled resprouting more than any other treatment (Table 1.7a).

The orthogonal contrasts revealed that the control plots had significantly less sprouting than all treatments when compared to trench sections within and outside of the treated zone with the exception of trench sections outside the treated zone for high dose treatments (Table 1.9b). Glyphosate treatments were shown to have less sprouting than all other herbicide treatments within and outside the treated portion of the trenches. Low doses of dichlorprop also had less sprouting than the low doses of triclopyr and fluroxypyr within and outside the treated portions of the plots.

SOIL MOISTURE

Analysis of variance of soil moisture data indicated a significant interaction between herbicide type, depth, and whether or not the soil samples came from treated or untreated areas (P=.0025). All herbicide treated areas had higher soil moisture contents in the 0 to 30 centimeter depth class than the control plots. Of these differences, glyphosate, triclopyr, and dichlorprop were significant (Table 1.10b).

Soil moistures were also generally higher for herbicide treated areas in the 30 to 60 cm depth class. This is with the exception of the glyphosate treatments which had lower soil moisture contents than the untreated ares. This may be due in part to confounding factors associated with the surrounding mature stand of ponderosa pine taking up available water through the roots. The higher soil moistures for triclopyr treated areas were slightly significant (Table 1.10b). Whereas, dichlorprop treatments had significantly higher soil moistures than untreated areas. Fluroxypyr treatments were not significantly different from control treatments.

Glyphosate treatments provided significantly higher soil moisture contents in the 0 to 30 cm depth class than either the dichlorprop or the fluroxypyr treatments (P=.008 and .0004, respectively) (Table 1.10c). Triclopyr also had fairly high moisture contents at this depth, but fluroxypyr was significantly less. No other differences occurred between treatments at this depth. The differences shown are all minor at this depth.

No significant differences existed between herbicide treatments at the 30 to 60 cm depth class.

Table 1.10a Soil moisture content means on data for treated vs. control areas by depth.

Treat.** I.D. #	Treatment	Depth Class*	% Moisture Content	Standard Error
1	Glyphosate	1	10.59	.369
2		2	8.43	.537
3	Control	1	8.58	.450
4		2	10.30	.681
5	Triclopyr	1	9.79	.261
6		2	10.01	.544
7	Control	1	8.20	.193
8		2	8.73	.378
9	Dichlorprop	1	8.88	.437
10		2	10.03	.423
11	Control	1	7.43	.362
12		2	7.89	.737
13	Fluroxypyr	1	8.29	.459
14		2	8.28	.504
15	Control	1	8.06	.610
16		2	8.24	.674

* Depth class 1 = 0 to 30 cm, 2 = 30 to 60 cm.
** Treatment ID numbers are used to compare treatments which are significantly different.

Table 1.10b Significant differences from Table 1.10a for comparison of treated vs. untreated areas by depth class.

ID Numbers	P-Value
1-3	.002
5-7	.014
9-11	.024
2-4	.004
6-8	.045
10-12	.001

Table 1.10c Significant differences from Table 1.10a between herbicide treatments by depth class.

ID Numbers	P-Value
1-9	.008
1-13	.0004
5-13	.020

Table 1.10d Significant differences from Table 1.10a between depth classes for treated and untreated areas.

ID Numbers	P-Value
1-2	.0009

* All control data were combined for comparison of depth classes and no significant differences were found.

Table 1.11a Soil moisture means for herbicide type by dose.

Treat. * I.D. #	Treatment	Dose**	% Soil Moisture	Std. Error
1	Glyphosate	1.5# a.i./ac.	9.72	.499
2		3.0# a.i./ac.	9.23	.354
3	Triclopyr	0.9# a.i./ac.	8.86	.302
4		1.5# a.i./ac.	9.50	.311
5	Dichlorprop	2.0# a.i./ac.	9.23	.321
6		4.0# a.i./ac.	7.88	.461
7	Fluroxypyr	0.5# a.i./ac.	7.49	.250
8		1.0# a.i./ac.	8.95	.406

* Treatment I.D. numbers are used to compare treatments which are significantly different.
** a.i./ac. = Active ingredient per acre.

Table 1.11b Significant differences for Table 1.11a for comparison of soil moistures by herbicide type and dose.

ID Numbers	P-Value
5 - 6	.003
7 - 8	.002

Table 1.12a Soil Moisture content means for treated areas by depth class and dose. *

Treatment I.D. # ***	Depth Class **	Dose	% Soil Moisture	Std. Err.
1	1	Low	9.50	.370
2	1	High	9.27	.310
3	2	Low	8.66	.417
4	2	High	9.71	.333

* Means for untreated areas were eliminated due to the fact that dose was not a factor.
** Depth class 1 = 0 to 30 cm, 2 = 30 to 60 cm.
*** Treatment ID numbers are used to compare treatments which are significantly different.

Table 1.12b Significant differences from Table 1.12a for treated areas by depth class and dose.

ID Numbers	P-Value
3 - 4	.024

Differences in soil moisture content between depth classes tended to follow the same trend for treated and untreated areas. Moisture contents tended to be higher in the 30 to 60 cm depth class than in the 0 to 30 cm depth class. This was true for all samples taken in untreated areas. However, analysis of the combined data for untreated areas did reveal the difference to be significant.

Results were more variable for treated areas. Triclopyr and dichlorprop treated areas had slightly higher moisture contents in the 30 to 60 centimeter depth class, although the differences were not significant. Moisture contents were similar between depth classes for the fluroxypyr-treated areas. Interestingly, the glyphosate-treated areas had significantly lower soil moisture in the 30 to 60 centimeter depth class (P=.0009) (Table 1.10d).

A significant interaction also existed between herbicide type and dose (P=.0001). Soil moistures for glyphosate and dichloprop treatments were higher with the low dose applications (Table 1.11a). However, only the high vs. low dose of dichlorprop were significantly different (Table 1.11b). The opposite was true for triclopyr and fluroxypyr treatments. The high dose treatments produced higher soil moistures compared to the low dose treatments. Only the low and high dose of fluroxypyr were significantly different.

A three way interaction was also significant between depth, dose, and whether or not the area was treated or untreated (P=.039). It did not appear as though the dose of treatment made a difference in soil moisture content in the 0 to 30 centimeter depth class (Table 1.12a). However, in the 30 to 60 centimeter depth class, high dose treatments had significantly higher moisture contents (Table 1.12b).

PRE-DAWN MOISTURE STRESS

Analysis of predawn moisture stress levels showed bear clover to have a highly erratic effect on water stress of ponderosa pine seedlings. Moisture stress levels averaged 2.08 MPa's for ponderosa pine seedlings growing in untreated bear clover and only 1.26 MPa's where bear clover had been removed via herbicide (Table 1.13) (P=.083). Although speculative, much of the variance may be directly related to

Table 1.13 Predawn moisture stress means and standard errors for ponderosa pine seedlings by herbicide type.

Herbicide	Moisture Stress (MPa) *	Standard Error	Number of plots
Control	2.08	0.17	3
Triclopyr	1.58	0.21	3
Glyphosate	1.43	0.38	2
Dichlorprop	1.27	0.32	2
Fluroxypyr	0.83	0.11	3

* Means are based on three sampled seedlings per plot.
(MPa) stands for MegaPascal.

the herbicide applications causing some stress on seedlings.

Uncertainty regarding direct pine damage from herbicide used to modify bear clover cover may reduce reliability of the above comparison. At least three samples were chosen from each herbicide type. Because dose, nozzle, and surfactant varied between plots, only a comparison of treated versus untreated bear clover could be made.

DISCUSSION

INITIAL CONTROL OF BEAR CLOVER

Triclopyr provided the most complete initial topkill of bear clover. A small amount of chemical was required for this compared to spring applications in other studies (Lanini, 1981). However, gains achieved from this type of control may have been negligible due to rapid resprouting. Dichlorprop and fluroxypyr functioned similarly, but fluroxypyr took longer for maximum dieback. All growth regulators had led to resprouting by the second season, hence must be regarded as temporary (but significant) relief.

Glyphosate acted more slowly than other herbicides tested. Little result was obtained by the two-month evaluation for low-dose applications, and only marginal results were recorded for the high-dose applications. The full results of glyphosate were seen at the thirteen month evaluation. Virtually total control was eventually achieved. Most importantly, sprouting was 100 percent inhibited and it appeared that the rhizomes had been killed. Thus, glyphosate uniquely provides long term control of bear clover as has been reported by others (Potter, 1984, McHenry, et al., 1980). These results differ somewhat from work by Jackson and Lemon, (1987) where little difference in control occurred between 3 and 12 months after April applications of Roundup® on bear clover.

One important observation that was observed was that in areas where bear clover had been removed the site was quickly occupied by grass. Therefore, there may be a need to included some type of residual product such as hexazinone along with glyphosate to insure adequate control of competing vegetation.

RESPROUTING OF BEAR CLOVER

Bear clovers resprouting characteristics were consistent over all treatments in which resprouting occurred. Bear clover has a remarkable ability to react to virtually any disturbance to the above ground vegetation. One interesting characteristic of bear clover is that very few new sprouts from rhizomes occur in the understory of healthy vegetation. In the course of this study, it was shown that sprouting which occurred in treated plots stopped abruptly at the edge of the treated zone.

A second characteristic which was rather unexpected was the trend for above-ground resprouting to increase as distance from the plot edge increased into the treated zone. This, concentrates the highest proportion of sprouts in the center of the disturbed area. This was consistent with all treatments where sprouting occurred. This may be due to moisture gradients across the plot, or possibly nutrient availablity. Carbohydrate reserves may also play a role in the short term (Hogg & Lieffers, 1990, Huang et al., 1987, and McIntyre & Hsiao, 1982). However, this trend was less distinct in the analysis of exposed rhizomes. Therefore, above ground sprouting will most likely become more uniform across the plot as time goes by.

Regression analysis of the amount of sprouting versus distance from the treated edge showed the slopes of the regression lines to vary somewhat with treatment. This would suggest that the amount of sprouting which occurs is more or less dependent on distance from the treatment edge depending what herbicide type and dose was used. This could have important implications to land managers when it comes to spot spray applications. For example, a herbicide that has a steeply sloped regression line may require a smaller spot spray to avoid heavy sprouting. Whereas, a herbicide with a gradually sloping line could be sprayed over a larger area and have a lower degree of resprouting. However, more research is needed to determine a spot size that is most beneficial to the seedling.

The pattern of above ground sprouting was consistent for all growth regulator products. Of the growth regulators, triclopyr ester produced the most rapid and heaviest sprouting especially with the lower dosage. Fluroxypyr also had more sprouting with low dose. This would indicate higher rates may be able to produce better control. However, in the case of fluroxypyr this would be very costly. Dichlorprop showed slightly more sprouting with high-dose treatments which may indicate increased damage to the transport system at higher doses which is not unusual for the phenoxy herbicides (Newton & Knight, 1981).

Fluroxypyr may provide better short term control than triclopyr or dichlorprop. This was indicated by the gradual slope of the regression line at the higher doses and by less sprouting above and below ground up to five months after treatment. However, long term control does not appear to be possible.

Glyphosate proved to be slow acting, but by far the most effective herbicide for long term control of bear clover. These results are in agreement with those found by McHenry et al., 1980, where glyphosate was found to inhibit resprouting. Benefits of glyphosate were seen up to five years after treatment. The superior results with glyphosate are most likely due to its highly phloem-mobile behavior which does little damage to the translocating tissue (Newton & Knight, 1981). The observation was reinforced by the fact that trench sections outside of the treated zone had less sprouting than the control plots which would indicate the herbicide had indeed translocated through the rhizomes. Therefore, it should be readily transported through the rhizome system.

Poor results in the past with glyphosate are likely due to spraying too soon after site preparation where not enough sprouting has occurred before treatment. Poor results have also been obtained when glyphosate was applied in combination with phenoxy chemicals which may have damaged the transport system before glyphosate could translocate to the rhizomes (Potter, 1984).

Patterns of below ground sprouting were also fairly consistent for growth regulator products. Sprouting was greater in the treated sections of the trenches. However, the highest concentration of sprouts was not neccessarily in the center of the plot. This would indicate that the pattern of above ground sprouting will most likely become more uniform over time. Thus, differences in sprouting based on choice among growth regulators should be considered only short term. Based on results with glyphosate, growth regulator products are not recommended for long-term control of bear clover.

One unique possibility for glyphosate may be to treat bear clover before timber harvesting occurs. This would substantially decrease the time between harvesting and planting. Due to the slow acting nature of glyphosate, this would allow enough time for rhizomes to be controlled, and allow for treatment while bear clover is undisturbed. It has also been shown that once totally removed from a site, it recolonizes very slowly (Tappeiner & Radosevich, 1981).

SOIL MOISTURE

Soil moistures were extremely low at the time of evaluation. Very little variation occurred between samples within plots. Differences in moisture contents between treatments and depths was very small. Similar results were obtained by Tappeiner & Radosevich, (1981) in September. Some anomolous results were also obtained within the study. For example, moisture contents in the 30 to 60 centimeter depth class tended to be higher on the average for all treatments than the 0 to 30 centimeter depth class. However, in the glyphosate treated plots soil moistures were over two percent lower in the 30 to 60 centimeter depth class. The reverse trend occurred within the untreated sample. The conflicting patterns suggest entry of a random unidentified factor that caused unforseeable variability.

Results could have been confounded by the presence of the surrounding stand of mature ponderosa pine, taking water up through the roots. This could account for more water being lost in the deeper depth classes, as three of the four glyphosate plots were adjacent to the surrounding pine stand. The lack of variance within samples may be attributable to the fact the soils may have been at wilting point. The overall range of soil moistures was very small. Therefore, differences deemed as significant in the analysis of variance may be suspect.

The small differences between treatments that were seen were most likely related to cumulative days without cover vs. days with. The continually decreasing cover of bear clover with glyphosate could account for the higher soil moistures. Whereas, the early removal of nearly all bear clover from triclopyr and dichlorprop plots most likely led to higher soil moistures than fluroxypyr.

PRE-DAWN MOISTURE STRESS

Although no comparisons between herbicide types could be made due to a wide array of application factors, strong differences were noted in predawn moisture levels between trees in treated and untreated areas. Ponderosa pine seedlings in untreated bear clover had moisture stress levels roughly twice as high as in treated areas. The differences were not significant due to variation between plots of treated bear clover. This variation may be partly explained by stress or injury induced by some of the herbicide applications.

This does show that water is a very important limiting factor for seedling growth when in competition with bear clover. It also shows that soil moisture depletion due to the presence of bear clover is more pronounced at depths greater than two feet. The reason for this is that there was very little difference in soil moisture between treated and untreated areas at depths of 0 to 30 and 30 to 60 centimeters in the previous section. However, differences in moisture stress levels were substantial. This would lead one to believe that more water is being lost at greater depths where bear clover is present or that less is depleted where it's absent. Similar results were shown by Radosevich, (1984), who found differences in soil moisture potential of 2.5 MPa at a soil depth of 5 feet between areas where manzanita was present and where it was not.

CONCLUSIONS

First, applications of triclopyr, fluroxypyr and dichlorprop provided unacceptable control of resprouting at all rates tested. While initial topkill was excellent for these treatments, failure to control resprouting will negate any possibilities for long term control. It is imperative to consider control of the rhizomes as well as control of the above ground plant portions to achieve any success in long term control of bear clover.

Second, glyphosate applications provided the most promise for long term control of bear clover. Virtually one hundred percent control of resprouting was achieved above and below ground. By negating the need for repeat chemical applications costs of labor and chemicals would be considerably reduced.

Third, glyphosate provides an excellent opportunity for both site preparation and release treatments on bear clover.

One unique opportunity which exists for glyphosate treatments is treating the vegetation before harvesting occurs through some manual broadcast application such as the waving wand technique. This would require allowing enough time for treatment effects to occur before actual harvesting took place. However, it would significantly reduce the time required before planting took place.

Fourth other important aspect of bear clover is the fact that if it could be totally erradicated from a site, reinvasion would be slow due to poor regeneration from seed and the slow spread of rhizomes. Therefore, more emphasis should be placed on achieving total control than on temporary reductions in cover.

Fifth, it should also be noted that the degree of sprouting varies with type of herbicide, dose and distance from treated vegetation. Therefore, herbicides which have a high increase in the rate of sprouting as distance from treated vegetation increases such as triclopyr, dichlorprop, and low dose fluroxypyr treatments should be avoided in spot spray applications. Higher doses of fluroxypyr may be used, however, the amount of sprouting will increase as spot spray radius increases. Therefore, distances of over 6 feet should probably not be used. Glyphosate treatments are independent of distance.

Sixth, an important factor to consider while treating bear clover is the possibility of invading grass after bear clover has been removed. Therefore, treatments to remove bear clover should also include a residual product to control potential grass problems.

Finally differences in soil moisture due to the presence of bear clover appear to be at greater depths than were sampled in this study. High predawn moisture stress levels in untreated bear clover compared to much lower measurements in treated bear clover indicate water to be a limiting factor in the presence of bear clover. The fact that differences in soil moisture from 0 to 60 centimeters were small between treated and untreated areas indicates the differences occur at greater depths.

Chapter 2

The Relationship of Volume, Dose, Drop Size and Surfactant to Herbicide Efficiency

INTRODUCTION

Herbicides are an extremely important management tool for the control of competing vegetation in the Pacific Northwest. Without some type of release or site preparation treatment, the establishment of a forest crop is often delayed for decades, and sometimes centuries (Newton & Knight, 1981). In most instances, herbicides are the most effective control method for competing vegetation, from both a biological and economic standpoint.

Various application parameters such as volume of liquid delivered per acre, dosage of active ingredient, drop-size, and the addition of some type of adjuvant, can have an effect on the efficacy and efficiency of herbicides applications (Brewster & Appleby, 1990, Burrill et al., 1990, Richardson, 1988, Buhler & Burnside, 1987). However, the relationship between these factors is relatively complex and unclear. Many experiments designed to look at one or more of these factors have been undertaken in laboratory conditions, and it is not known whether the results are applicable to field situations.

The benefits from an increased understanding of how these factors interact with each other in the field so as to relate to operational efficacy would be substantial. Gains in the efficiency of herbicide applications would lead to decreased costs by obtaining the maximum effect with less total chemical.

The objectives of this study are to, 1) evaluate the partial contributions of drop-size, surfactant, dosage, and volume on efficiency of several herbicides over a variety of sites for site preparation and release, and 2) to develop a management guide for foresters which incorporates the findings into a practical document to aid in improving herbicide efficiency. The scope includes many of the species found in the Sierra Nevada, the Oregon Coast Range, and the east side of the Oregon Cascades. Herbicides to be evaluated include growth regulators, systemic foliage-active products, and residual products.

LITERATURE REVIEW

RETENTION AND PENETRATION

Retention of herbicides on foliage has been determined to be one of the most critical factors determining efficacy (Spillman, 1984). Factors which affect the retention and penetration of herbicides include leaf orientation, density of plant canopy, leaf pubescence, degree and type of epicuticular wax, and surface tension of the spray solution (Hess & Falk, 1990 & Hess, 1985).

The most significant barrier for herbicide penetration into leaf tissue is the cuticle. Cuticle composition varies between plant species and age of leaf, and even within different locations on the same leaf (Hess, 1985). The amount of cuticle present is dependent on both the age of the plant part and on environmental conditions during cuticle deposition (Hess, 1985). Herbicide penetration can be affected by changes in environmental conditions which may cause changes in cuticle composition throughout the year. Hess, 1990, has also shown that herbicide droplets spread over large areas on leaf surfaces with minimal epicuticular wax, but they do not spread well over leaves with a thick layer of epicuticular wax.

Other work by Baker et al., (1983), has shown that aqueous solutions spread more readily over smooth surfaces with thin wax layers, but droplets dried quickly with no further lateral spread. In contrast, leaves with thick hydrophobic surfaces displayed poor adhesion and low spread factors. Oil formulations were found to spread readily through layers of crystalline wax, while wettable powders tended to have poor spread factors for all species of vegetation treated.

Hess, 1990, has also shown that trichomes on leaf surfaces can intercept the majority of spray droplets. Even when trichomes are at low densities, interception is still prevalent. Although some absorption does occur through trichomes (Hull, 1970), it is generally believed that interception by trichomes decreases the phytotoxic effect of chemical applications.

Leaf morphology tends to have a large effect on the retention of spray droplets. Surface roughness and protuberances can greatly increase the the capture efficiency of spray particles (Spillman, 1984). Specifically, spray droplets are more likely to bounce from a smooth surface than from one which has roughness. Therefore, old leaves are more retentive than new ones. Baker & Hunt, (1985) found that chlormequat was more readily retained by damaged leaves of wheat and barley than by undamaged plants, due to disruption of the crystalline wax layer. Leaves may have certain areas that are more retentive than others. The ribs and extreme leaf edges of banana leaves are highly retentive but other parts of the leaf are reflective (Spillman, 1984).

Young, (1987), has shown leaf orientation to be a critical factor in determining how much spray is retained. Generally, as the angle of orientation increases, retention decreases. Western & Woodley, (1987), have shown better spray deposits on cleavers (*Galium aparine*) which have horizontal leaves compared to ryegrass which has vertical leaves.

Dew and rain can also decrease the retention of spray droplets on leaf surfaces. This is due to the existence of an air film between the droplet and the wet leaf surface which causes the impinging drop to bounce (Spillman, 1984).

Physical properties of liquids also have a large influence on retention. One such property is surface tension (Reichard, 1987, Spillman, 1984). The higher the surface tension of a droplet, the more likely it is to bounce, especially when kinetic energy is also high. Therefore it would make sense that large droplets with high surface tension and high falling velocity have more of a tendency to bounce than small droplets. Anderson & Hall, (1986) found no correlation between retention and equilibrium surface tension, but dynamic surface tension was related to retension at 20 msec.

Sundaram, (1987) has shown that other properties such as relative viscosity, apparent viscosity-shear rate relationship, and volatility of the vehicle play significant roles on the droplet size and deposit patterns of herbicide sprays. This in turn effects the retention of the spray mixture.

Spray trajectory was also found to be a significant factor attributing to retention (Richardson, 1987). It was found that retention was increased over 100% when nozzles were oriented forward horizontally, and by 50% when nozzles were oriented backward horizontally compared to to straight down . However, this depends entirely on the speed of the sprayer.

DROP SIZE

Factors Influencing Drop Size

Drop size is influenced by many factors. Haq et al. (1983), tested the influence of viscosity, surface tension, liquid throughput, and viscoelasticity on drop size. Of these physical properties, viscoelasticity was found to have the greatest effect; increasing drop size as viscoelasticity increased. Increasing surface tension was found to increase drop size significantly (and vice versa). Increasing the nozzle orifice diameter and hence liquid throughput, also increased drop size. Viscosity was not found to have an effect on drop size. These results do not correlate well with those of Sundaram, (1987) who found that viscosity does play a significant role in drop size.

Barry, (1984), stated that drop size is related to flow rate, pressure, fluid behavior, and shear at the nozzle orifice. Among the most important factors is rate of breakup of liquid films, as on fans and hollow cones determined by angle of spread.

<u>**Drop Size Effects on Retention and Penetration**</u>

There are many conflicting opinions about the influence of drop size on retention and penetration. It is generally believed that small droplets are retained better than larger droplets because large droplets tend to bounce off leaf surfaces (Baker & Hunt, 1985, Spillman, 1983). However, Taylor & Shaw, (1983), have shown that large drops are retained better at high speeds compared to small drops especially on broadleaf species. The reverse was true for barley at slower speeds. This is somewhat speculative due to the tests being carried out under laboratory conditions. It has also been shown that drops less than 50 microns tend to go around leaves with air movement and not be caught (Bode, 1991, as reported by Hooper & Newton, 1991). Work by Reichard, (1980) has shown that higher velocities increase rebound, and that larger droplets have higher velocities, hence ricochet rates.

Brady, (1972), has shown that absorption of 2,4,5-T was four times greater with droplets 100 microns in diameter than with 300 and 400 micron droplets (27 and 64 times their volume). However, it has been reported that losses up to 90% of the material applied can occur from aerial sprays when the droplets are less than 50 microns; when droplets are greater than 150 microns, losses never exceeded 20% (Bode et al., 1968). The results obtained by Brady also conflict with those of Baker & Hunt, (1985), who found that while retention was increased by smaller droplets, uptake (% of retained dose) was higher with larger droplets compared to small droplets.

Similar work by Stevens & Bukovac with 2,4-D and daminozide showed that uptake was not affected by application parameters such as drop size and area wetted. This is in strong disagreement with much of the current literature.

Efficacy

The information from the literature regarding the relationship of drop size to efficacy is fairly inconsistent. B. Richardson, (1988), has shown that fluroxypyr controlled greenleaf manzanita (*Arctostaphylos patula*), and bracken fern (*Pteridium aquilinum*) better with droplets of 240 microns compared to 830 micron droplets. However, he also determined that area of foliage wetted contributed more to efficacy than did drop size with manzanita.

R.G. Richardson, (1983), has shown that boneseed (*Chrysanthemoides monilifera*) was better controlled by 2,4-D with droplets of 212 and 302 microns than by droplets with diameters of 172 and 461 microns. Control increased as droplet density increased from 4.2 to 15 droplets per square centimeter and then remained constant at higher densities. This is in agreement with early work by Behrens, (1957) who demonstrated that droplet size was less important than spacing for mesquite. He calculated at least 72 drops per square inch (11 per square Cm) were neccessary for maximum phytotoxic effect. R.G. Richardson also showed variegated thistle (*Silybum marianum*) did not respond to changes in drop size within the above range, nor did Patersons curse (*Echium plantagineum*). Although differences in efficacy were found for different drop sizes and spacings, these differences were small compared to changes in dose rates.

Brady, (1972), suggests that Behrens's number of 72 drops per square inch may be beyond the range of incremental response for some species. This is based on Brady's findings that the area wetted from drop sizes ranging from 100 to 400 microns had little to do with the amount of 2,4,5-T that was absorbed.

Italian ryegrass (*Lolium italicum*) and cleavers also showed no significant increase in control from changes in droplet size for fluroxypyr and diclofop-methyl (Western & Woodley, 1987).

Prasad, (1985), has shown efficacy to increase as droplet size decreased on white birch (*Betula papyrifera*). This was especially true for Velpar. Droplets between 155 and 335 microns produced better results than droplets of 465 and 665 microns. The author attributed this to increased coverage by the finer droplets, hence better translocation. Efficacy of glyphosate and triclopyr was slightly less correlated with droplet size and efficacy than was hexazinone, which is surprising considering the degree of soil activity only for hexazinone.

Drift

Drop size is a large factor influencing the bouyancy of drops, hence potential particle drift of herbicide sprays. Klingman, (1964), found that 100 micron drops released 15 feet above the ground in an 8 mph crosswind were blown completely off a 40 foot swath. As stated earlier, Bode, (1968) recorded losses of 90% of the liquid when 50 micron drops were applied as an aerial spray.*cant find article?

Large drops are popular with applicatiors and regulators because they are percieved to fall on target with no drift, and because they suffer less from evaporation in flight (Brady, 1972). Newton, (1984) has stated that the contribution of large drops to total efficacy is minor because of their small contact with the treatment area. This is explained by large drops being a small number of the total drops while containing a large portion of the total spray volume.

Barry, (1984) states that small drops can be managed with minimal drift when the surface is cool and winds are slight. Newton (personal communication) maintains the most effective and only certain way to manage drift is by wind. Fears et al., (1986), have demonstrated that the amount of off-site drift is increased with increasing flight height, increasing rate of application, and increasing wind speed. They also noted Raindrop nozzles were not suitable for forestry applications due to high drift potential.

SURFACTANT

Efficacy

The addition of various adjuvants to chemical sprays can improve efficacy on competing vegetation (Burrill et al., 1990, Whitson & Adams, 1990, Swietlik, 1989, and O'Sullivan et al., 1981). Swietlik, (1989), has shown the addition of Li 700, Frigate, and VPG improved control of guinea grass (*Panicum maximum*) and Li-700 and frigate improved control of purple nutsedge (*Cyperus rotundus*) and bermudagrass (*Cynodon dactylon*), respectively when added to glyphosate. He also noted that losses in efficacy due to decreases in dose could be made up through the addition of surfactant. Similar results were obtained by B. Richardson, (1988) with glyphosate on bracken and fluroxypyr on manzanita.

The addition of the surfactant PDP was shown to increase control of both gorse and broom (*Cytisus scoparius*) with

2,4,5-T, glyphosate, and metsulfuron-methyl (Balneaves, 1985). Further work by Balneaves, (1986) has shown that the addition of the surfactant Silwet M to glyphosate increases control regardless of season of application.

Results of the addition of surfactant on efficacy vary widely between herbicide types and type of vegetation (Burrill et al., 1990). Whitson and Adam, (1990) have shown that the addition of surfactant to fluroxypyr had no effect on control of leafy spruge (*Euphorbia esula*). O'Sullivan et al., (1981), have shown that the addition of several surfactants individually, actually decreased the phytotoxicity of glyphosate. They also noted that with increasing spray volumes, the phytotoxicity of glyphosate was reduced, even with the addition of surfactant.

Babiker & Duncan, (1974), noted that the surfactant Tween 20 increased retention and uptake of asulam on bracken fronds. However, increases in surfactant concentration over 0.1% (w/v) gave no further increase. This trend was also shown by Brewster & Appleby, (1990) who showed little additional effect from concentrations of surfactant greater than .25% (v/v) in imazamethabenz on wild oat. Therefore, there may be a practical upper limit to surfactant concentration.

It may not always be beneficial to increase the rate of absorption through addition of surfactant. Mcwhorter, (1985), has shown that instant absorption of some contact compounds such as the phenoxys can neutralize the transport system, thus decreasing overall efficacy. However, this may not be as much of a problem with more systemic herbicides such as glyphosate which don't directly damage the transport system.

Vanner & Richardson, (1986), noted increased control on bracken with the addition of Silwet M to glyphosate and asulam. They determined the herbicidal activity of these chemicals was related to the rate of Silwet M expressed on a per hectare basis. Their findings also suggested that the use of surfactant on a volume/volume percentage would not be effective with low application volumes. These results due not agree with those of Brewster & Appleby, (1990), who demonstrated a greater surfactant effect in low volumes compared to high volumes on a v/v basis with imazamethabenz at low rates. At higher rates, the relationship was unclear.

Results by Sundaram, (1990), found that the addition of the polymeric adjuvant Nalco-Trol II® to glyphosate did not make a difference in absorption or translocation in trembling aspen (*Populus tremuloides*). Other work by Sundaram, (1990), has shown that the polymeric adjuvants Sta-Put® and Silwet® L-7607 do increase uptake of glyphosate in Vision® formulation. However, no differences were found in translocation between mixes with and without these adjuvants. She also observed a relationship between drop spread and uptake of herbicide. L-7607 caused a greater degree of drop spread and also had a greater amount of uptake in white birch seedlings.

Further work by De ruiter et al., (1988), has shown that the surfactants Ethomeen T/25 (a cationic surfactant) and Renex 688 (a nonionic surfactant) both improved the phytotoxicity of glyphosate. However, absorption was decreased with the addition of Renex 688 to winter wheat compared to no-surfactant applications of glyphosate, but absorption was enhanced with Ethomeen T/25. This was attributed to Renex being retained in the cuticle, whereas Ethomeen T/25 penetrated the underlying tissue which may have led to increased permeability of the cell wall.

Effects of Surfactants on Spray Physics

The effects of surfactants can influence control and spray parameters in many ways. Anderson et al., (1987), looked at the influence of surfactant on spray retention. Surfactant was found to influence contact angle and leaf coverage more than retention. They also concluded that retention was related to dynamic rather than equilibrium surface tension. Wyrill & Burnside, (1977) noted that contact angle was not related to surfactant effectiveness at high or low concentrations of surfactant. Dynamic surface tension for solutions of water and the surfactant Triton N150 tended to decrease as surfactant concentration increased. The reduction of surface tension is the main reason for incresed coverage (Hess & Falk, 1990).

The trend of decreasing dynamic surface tension with increasing concentration was also reported by Berger et al., (1988). The dynamic surface tension properties of surfactant solutions are related to their ability to reduce droplet size from a hydraulic nozzle (Anderson, unpublished observation). Retention of sprays was increased with the addition of surfactant on some plant species, but not others. This was assessed as being due to plant surface roughness and plant habit. Young et al., (1987), has demostrated the ability of surfactants to alleviate some of the problems in retention associated with leaf angle.

Several studies have noted increased deposition on leaf surfaces by adding suractant to spray mixtures (De ruiter et al., 1988 and Bovey et al., 1987). There are several reason why this occurs. Reichard, (1988), demonstrated that if the concentration were high enough, the surfactant X-77 could significantly reduce the rebound of spray droplets on cabbage leaves. Surfactants have been shown to cause spray droplets to break up into smaller droplets when coming in contact with trichomes on the leaf surface, hence increasing the amount of chemical coming in contact with the epidermal surface (Hess

& Falk, 1990). Surfactants have also been found to increase permeability and retention on the leaf cuticle (Geyer & Schnerr, 1988).

Sundaram, (1990a), has shown that the addition of the adjuvants Sta-Put and Silwet L-7607 did not have any influence on viscosity or volatility of glyphosate in Vision formulation. L-7607 had the lowest surface tension and hence the most drop spread. A decrease in the droplet drying time was also noted. This was attributed to a thick waxy crust that formed over the droplets of Sta-Put, that may have decreased the rate of evaporation.

Sparks et al., (1988), has noted that the chemical nature of the adjuvants can have a marked effect on the droplet size spectra. This was supported by the evidence that mixtures with lower surface tensions than water had markedly larger VMD's. Therefore, when polymeric adjuvants are in the spray mixture the mechanism of atomization is more complex than can be explained by physical factors. It was also noted that the polymeric adjuvants Nalco-Trol and Nalco-Trol II significantly increased drop size of spray deposits, and hence, decreased coverage, but small drops were not eliminated.

The addition of surfactant has also been shown to increase rainfastness (Sundaram, 1990a, Sundaram, 1990b, & Stevens & Zabkiewicz, 1990). Sundaram, (1990a), has shown that both Sta-Put® and Silwet® Y-6652 have some effect on improving washoff of glyphosate. However, the best results have been obtained with Silwet® L-77 (Sundaram, 1990a, and Stevens & Zabkiewicz, 1990). L-77 allows for quick absorption into the stomata without damaging the translocating tissue.

DOSAGE AND VOLUME

Dosing Parameters

It has been shown that efficacy increases with increasing dose (Brewster & Appleby, 1990, and Richardson, 1988). A single concentrated droplet has been shown to be more effective on velvetleaf and barley than more dilute drops in greater number, but with the same quantity of herbicide (Ambach & Ashford, 1982, and Cranmer & Linscott, 1990). It was also determined that efficacy of the more dilute droplets could be restored with the addition of surfactant.

In contrast, work by Stevens & Bukovac, (1987), has shown that efficiency of uptake was not related to drop size or number, leaf coverage, concentration of active ingredient (g/l), or application volume. They determined uptake was inversely related to applied dose (g/ha).

R.G. Richardson, (1983), has noted that changes in dose rate were more important in determining efficacy than were changes in drop size or droplet spacing.

Volume

The effects of changing carrier volumes for herbicide applications has varying effects depending on type of vegetation and chemical used (Richardson, 1988, Stevens & Bukovac, 1987, and O'Sullivan et al., 1981). Several authors have shown that glyphosate applications may be enhanced by low application volumes (Buhler & Burnside, 1987, and O'Sullivan et al, 1981). However, work by Richardson, (1988), showed that efficacy was increased using high application volumes with fluroxypyr on manzanita, but no differences were seen between varying volumes for glyphosate on bracken. High volumes were also found to be most effective for control of wild oat with imazamethabenz (Brewster & Appleby, 1990).

It has also been speculated that increased control from higher volumes may be due to increased penetration of the canopy (Brewster & Appleby, 1990). Johnstone, (1973), has stated to the contrary that high volumes may decrease deposition due to coalescence and run-off. Richardson, (1988), has stated that the area of foliage wetted was the most important factor for control of manzanita. He further stated that this could be better achieved with high volume applications. However, Western & Woodley, (1987), showed increased deposition with low volume applications, although they attributed this to an unavoidable increase in surfactant concentration.

Parochetti, et al., (1979) studied the effects of 23 surfactants, nozzles and liquid carriers on spray volume. They concluded the addition of surfactant had no effect on spray volume, but the type of liquid carrier and nozzle type did. Liquid carriers used were water, a 30% aqueous nitrogen solution, and a 14-8-8 fertilizer solution. The nozzles were a cone jet, flat fan, and a flood jet nozzle.

CONIFER DAMAGE

Herbicide Effects on Conifers

Several authors have demonstrated the ability of herbicides to cause injury to conifer seedlings (Cole et al., 1987, and Kelpsas, 1987). Cole et al. noted severe damage of Douglas-fir after treatments with granular hexazinone plus metsulfuron methyl in mid-April. Triclopyr ester, and sulfometuron methyl also produced heavy damage with mid-April treatments. Heavy damage to ponderosa pine seedlings was also noted with treatments of 2,4-D, and less severe damage with triclopyr ester, picloram, colpyralid, metsulfuron methyl, and sulfometuron methyl with May 1st applications.

Kelpsas, (1987), noted that the amount of damage to Douglas-fir seedlings depended on the timing of application. Higher injury to Douglas-fir occurred in the dormant season (March) with fluroxypyr treatments compared to minimal damage in September. The amount of damage was also shown to be dependent on the dose of the treatment. Seasonal damage varies with species and product (Cole & Newton-glyphosate, Gratkowski-phenoxys,).

Paley & Radosevich, (1984), determined that the least injury to ponderosa pine occurred from applications of glyphosate, triclopyr, and 2,4-D in September, when compared to April and June applications. They determined the highest herbicide selectivity occurs when pine has ceased growing, and the xylem water potential of the pine is fairly low (high water stress). Other work by King & Radosevich, (1985), has shown that the seasonal trend in degree of injury and the relationship of herbicide tolerance to various physiological factors were unique for each species. However, most species of conifer tested showed a high correlation of injury to leader or needle growth rate and xylem pressure potential.

Surfactants

One aspect of surfactant application that has received little attention is that of the effect of surfactant on conifer damage. Unpublished data by Kelpsas (Northwest Chemical Corporation), has indicated that the surfactants Li-700, Activator 90, and R-11 all contributed to increases in damage to Douglas-fir seedlings treated with Accord® and Arsenal®. Of the surfactants tested, Li-700 produced the least damage of the three. Other data has indicated similar results with ponderosa pine seedlings.

The experiments in this study should provide more information regarding the influence of surfactant to conifer damage over a wide range of herbicide types and surfactants.

Surfactants vary in molecular structure. The above are all non-ionic, but may differ in effect somewhat (Kelpsas). Beyond that L-77 is a silicon-based product. There are oil/surfactant/emulsifier adjuvants, anionic and cationic materials. From brand names, we cannot deduce what they are. However, their differences help formulate hypothesis about how to study the, and thats where we are now.

METHODS

The need to develop efficient application systems in a broad range of environments entailed several series of experiments to generate the neccessary field data on drop size, surfactant, and volume of spray for several herbicides on key target and crop vegetation. The following procedures were used to obtain these data and our findings.

SITE SELECTION

Sierran Brush Site I

Six sites were chosen for this study. The first site was chosen to assess the effects of various herbicide application parameters on several Sierran brush species. It is located approximately twenty miles southeast of Placerville, California in the Sierra Nevada Mountains on land managed by the U.S. Forest Service. Elevation is approximately 4200 feet. Slope ranges from 10 to 15 percent with a southeast aspect. Average annual precipitation is estimated at 50 inches. The soil type is a granitic-derived clay loam underlain by decomposed bedrock and boulders. This is an excellent pine site.

The area was clearcut in 1987 and planted to ponderosa pine (Pinus ponderosa). Seedlings were 1 - 0 stock and were in their third growing season at the time of site selection. After logging, the slash was piled and burned and the site was ripped. After site preparation, bear clover (*Chaemebatia foliolosa*) and whiteleaf manzanita (*Arctostaphylos viscida*) germinated and became the predominant vegetation. Annual grasses, thistle, and fireweed were also present. Estimated average cover was approximately 15 percent bear clover and 5 to 10 percent whiteleaf manzanita with the gaps mostly occupied by herbs.

Sierran Brush Site II

The second site was established the following year in April to reevaluate herbicide trials done at the first site due to anomolous results obtained with glyphosate on bear clover and dosing problems with the original triclopyr applications. The site is located approximately 25 miles southeast of Placerville, California in the Sierra Nevada Mountains on land managed by the U.S. Forest Service. Elevation of the site is approximately 4500 feet. Slope ranges from 5 to 10 percent with a south aspect. Soil type is a shallower phase of the soil on the previous site.

The area was clearcut in approximately 1988 and planted to ponderosa pine. Seedlings were 1 - 0 stock and were currently starting their third growing season at the time of treatment. After logging, the slash was piled and burned and the site was ripped. After site preparation, bear clover resprouted to become the predominant vegetation. Annual grasses, thistle, and gooseberry were also present.

Estimated average cover is approximately 10 percent bear clover, overall, with much denser patches.

West Side Salmonberry

The third site was established to assess the effects of various application paramaters on coastal salmonberry. The site is located in the Oregon Coast Range approximately fifteen miles northwest of Nashville, Oregon on land managed by the State of Oregon Department of Forestry. Elevation of the site is approximately 700 feet. Slope is 10 to 35 percent with a north to northeast aspect. Average annual precipitation is estimated at 100 inches. The soil type is Slickrock clay loam, a highly productive site.

The area was clearcut in early 1990 and planted to Douglas-fir (*Pseudotsuga menziesii*) with no other site preparation. Seedlings were 1 - 1 stock and are currently entering their fourth growing season. After logging, salmonberry (Rubus spectabilis) resprouted and became the predominant vegetation. Bracken fern, velvet grass, woodland groundsel and trailing blackberry also colonized the site. Estimated average salmonberry cover is approximately 10 percent.

West Side Grass

The fourth site was established to evaluate the effects of various application paramaters on low elevation grassy sites in the Douglas-fir Region. The site is located in the central Coast Range approximately five miles southwest of Blodgett, Oregon on land owned and managed by Starker Forests Inc.. Elevation of the site is approximately 400 feet on flat clay loam alluvium. Average annual precipitation is estimated at 70 inches. The soil type is a deep alluvial clay loam with organic content about 6 percent.

The area was converted from abandoned pasture land and planted to Douglas-fir. Seedlings were 1 - 1 stock and are currently starting their second growing season. Small patches were hand scalped for seedlings during planting. The site is colonized by mixed annual and perennial grasses including substantial velvet grass (*Holcus lanatus*). Estimated average cover is approximately 90 percent grass.

East Side Grass

The fifth site was established to evaluate the effects of various application paramaters for residual herbicides on ponderosa pine plantings on grassy sites. The site is located on the east side of the Cascade Mountains approximately fifteen miles west of Sisters, Oregon on land owned by Willamette Industries. Elevation of the site is approximately 4000 feet. Slope ranges from 0 to 10 percent with a south aspect. Average annual precipitation is approximately 24 inches. Soils are pumice overlying cobbly volcanic ash.

The area was clearcut approximately 10 years ago and planted to ponderosa pine. Seedlings were 2 - 0 stock and were currently starting their sixth growing season when the experiment was installed. After logging, the slash was piled and burned with no further site preparation. After logging, annual and perennial grasses invaded to become the predominant vegetation. Snowbrush Ceanothus (*Ceanothus velutinus*), thistle, and some volunteer grand fir (*Abies grandis*) were also present. Estimated average cover in herbaceous species is approximately 25 percent, mostly bunch grasses.

East Side Brush

The final site was established to determine the influence of various application parameters on snowbrush Ceanothus and greenleaf manzanita (*Arctostaphyllos patula*). The site is located approximately 12 miles west of Bend, Oregon on land owned and managed by Crown Pacific Corporation. Elevation of the site is approximately 4500 feet. Slope is between 5 and 30 percent with a south aspect. Estimated annual average rainfall is approximately 20 inches. Soils are a medium depth cobbly volcanic ash over andesitic bedrock, an estimated site IV for ponderosa pine.

The site was burned by a wildfire approximately ten years ago and was replanted to ponderosa pine. Seedlings were 2-0 stock and are currently in their seventh to ninth growing season. After the fire, snowbrush ceanothus and greenleaf manzanita germinated and became the predominant vegetation. Average cover values are approximately 35% ceanothus and 40% manzanita. Sparse grass and other herbaceous species also exist at low densities. A few residual ponderosa pine also remain from the original stand, which was comprised of grand fir, Douglas-fir, lodgepole pine (*Pinus contorta*), and ponderosa pine.

EXPERIMENTAL DESIGN

The experimental design for all sites was very similar. Each was a completely randomized design with two or three replicates per treatment. Treatment tables can be found for each site in Tables 2.1 through 2.5. Plot size was 12 x 36 feet (.01 acre) for all sites. Treatments were applied with a nitrogen-powered twelve-foot backpack boom sprayer. Prior to applications, the sprayer was calibrated for delivery rate, and each plot was sprayed with a single timed pass.

The rates of application used for this study were selected to provide a moderate degree of control (40-70%) so that treatment effects would be in the range of potential response, and could be readily discerned.

Sierran Brush Site I

For the first set of California brush trials, the herbicides used were glyphosate with no surfactant (Accord, Monsanto) and triclopyr emulsifiable ester (Garlon 4, Dow). Treatments are found in Table 2.1. Volume per acre for all treatments was 5 and 10 gallons per acre, and the carrier was water. Three nozzle types (80015, 9503, RD-6) representing small medium and large drops were used for the high volume glyphosate and triclopyr treatments. The low volume applications consisted of only the 80015 and 9503 nozzles;

Table 2.1 Treatments for Placerville bear clover & manzanita plots.

Treatment	Rate * a.i./acre	Surfactant	Volume g.p.a.**	Month
Glyphosate	1.2 lbs	none	5	June
Glyphosate	1.2 lbs	L-77 (.15%)	5	June
Glyphosate	1.2 lbs	Act 90 (.5%)	5	June
Glyphosate	1.2 lbs	none	10	June
Glyphosate	1.2 lbs	L-77 (.15%)	10	June
Glyphosate	1.2 lbs	Act 90 (.5%)	10	June
Glyphosate	2.0 lbs	none	5	June
Glyphosate	2.0 lbs	L-77 (.15%)	5	June
Glyphosate	2.0 lbs	Act 90 (.5%)	5	June
Glyphosate	2.0 lbs	none	10	June
Glyphosate	2.0 lbs	L-77 (.15%)	10	June
Glyphosate	2.0 lbs	Act 90 (.5%)	10	June
Triclopyr	.9 lbs	none	5	June
Triclopyr	.9 lbs	L-77 (.15%)	5	June
Triclopyr	.9 lbs	none	10	June
Triclopyr	.9 lbs	L-77 (.15%)	10	June
Triclopyr	1.5 lbs	none	5	June
Triclopyr	1.5 lbs	L-77 (.15%)	5	June
Triclopyr	1.5 lbs	none	10	June
Triclopyr	1.5 lbs	L-77 (.15%)	10	June

* a.i./acre = Active ingredient per acre.
** g.p.a. = Gallons per acre.

RD-6 nozzles could not be calibrated for the low volume. All glyphosate treatments were sprayed with and without Silwet® a silicone based agent (Union Carbide) and Activator 90® a non-ionic surfactant (Loveland Industries). Only Silwet® was used with the triclopyr treatments; however, Garlon 4 contains an emulsifier and surfactant of unknown identity. Both herbicides consisted of high and low dose applications.

Sites for which selectivity and efficacy were largely unknown had the most complete and complex experiments (Sierran sites). Where efficacy had been well developed, relatively simple experiments were all that was needed to evaluate the basic application parameters.

Sierran Brush Site II

The second set of California herbicide trials dealt with control of bear clover exclusively. The site entailed spring applications with dosages adjusted for obtaining results in the response range. The herbicides used were glyphosate (Accord®, Monsanto), triclopyr ester (Garlon 4, Dow), dichlorprop emulsifiable ester (Weedone, Union carbide), fluroxypyr (Starane, Dow) and 2,4-D emulsifiable ester (Loveland Ind.). Treatments are listed in Table 2.2.

Volume per acre for all treatments was 10 gallons per acre, with water carrier. Three nozzle types (80015, 11003, RD-6) were used for the triclopyr applications. Only 80015 and RD-6 nozzles were used for the glyphosate applications.

Table 2.2 Treatments for Sierran brush site II. Bear clover only. All treatments were sprayed at 10 gallons per acre. Treatments were applied in mid April.

Treatment*	Rate (a.i./ac.) **	Surfactant
Triclopyr	0.4 lbs	None
Triclopyr	0.4 lbs	Mor-act (5%)
Triclopyr	0.6 lbs	None
Triclopyr	0.6 lbs	Mor-act (5%)
Triclopyr	0.9 lbs	None
Triclopyr	0.9 lbs	Mor-act (5%)
Glyphosate	1.2 lbs	None
Glyphosate	1.2 lbs	L-77 (.15%)
Glyphosate	2.0 lbs	None
Glyphosate	2.0 lbs	L-77 (.15%)
Glyphosate	3.0 lbs	None
Glyphosate	3.0 lbs	L-77 (.15%)
Fluroxypyr	0.5 lbs	None
Fluroxypyr	0.5 lbs	L-77 (.15%)
Fluroxypyr	0.5 lbs	Mor-act (5%)
Fluroxypyr	0.75 lbs	None
Fluroxypyr	0.75 lbs	L-77 (.15%)
Fluroxypyr	0.75 lbs	Mor-act (5%)
Fluroxypyr	1.0 lbs	None
Fluroxypyr	1.0 lbs	L-77 (.15%)
Fluroxypyr	1.0 lbs	Mor-act (5%)
Fluroxypyr	1.5 lbs	Mor-act (5%)
Dichlorprop	1.2 lbs	None
Dichlorprop	1.2 lbs	L-77 (.15%)
Dichlorprop	1.2 lbs	Mor-act (5%)
Dichlorprop	2.0 lbs	None
Dichlorprop	2.0 lbs	L-77 (.15%)
Dichlorprop	2.0 lbs	Mor-act (5%)
Dichlorprop	4.0 lbs	None
Dichlorprop	4.0 lbs	L-77 (.15%)
Dichlorprop	4.0 lbs	Mor-act (5%)
2,4-D	2.0 lbs	Mor-act (5%)
2,4-D	4.0 lbs	Mor-act (5%)
Control	*******	Mor-act (5%)
Control	*******	None

* All triclopyr treatments were applied with 80015, 11003, and RD-6 nozzles. All glyphosate treatments were applied with 80015 and RD-6 nozzles. All other treatments were applied with 80015 nozzles only.
** a.i./ac. = active ingredient per acre.

Fluroxypyr, dichlorprop, and 2,4-D applications used the 80015 nozzles only. All fluroxypyr and dichlorprop applications were sprayed with and without surfactants L-77 and Mor-act® oil-emulsifier-surfactant adjuvant (Wilbur-Ellis). Glyphosate treatments were sprayed with and without Silwet®, and triclopyr treatments were sprayed with and without Mor-act. All 2,4-D treatments were sprayed with Mor-act. Three doses were used with triclopyr, glyphosate, and dichlorprop treatments. Fluroxypyr treatments entailed four doses, and 2,4-D applications had two.

West Side Salmonberry

Field trials on west side salmonberry consisted of treatments with glyphosate only. Treatments are found in Table 2.3. Volume per acre for all treatments except those using RD-6 nozzles was 5 and 10 gallons per acre, and carrier was water. Volume for all treatments using RD-6 nozzles was 10 gallons per acre. Three nozzle types (80015, 11003, RD-6) were used for the high volume glyphosate treatments. Only the 80015 and 11003 nozzles could be used with the low volume applications. All treatments were sprayed with and without surfactants Silwet® and Activator 90®. Two doses of glyphosate were evaluated for each volume.

Table 2.3 Treatments for Salmonberry Plots. Treatments were applied in September, 1991.

Treatment*	Rate** a.i./acre	Surfactant	Volume g.p.a.***
Glyphosate	0.36 lbs	none	10
Glyphosate	0.36 lbs	L-77 (.15%)	10
Glyphosate	0.36 lbs	Act 90 (.5%)	10
Glyphosate	0.6 lbs	none	10
Glyphosate	0.6 lbs	L-77 (.15%)	10
Glyphosate	0.6 lbs	Act 90 (.5%)	10
Glyphosate	0.36 lbs	none	5
Glyphosate	0.36 lbs	L-77 (.15%)	5
Glyphosate	0.36 lbs	Act 90 (.5%)	5
Glyphosate	0.6 lbs	none	5
Glyphosate	0.6 lbs	L-77 (.15%)	5
Glyphosate	0.6 lbs	Act 90 (.5%)	5

* High volume treatments were sprayed with 80015, 11003, and RD-6 nozzles. The low volume treatments excluded RD-6 applications.
** a.i./acre = Active ingredient per acre.
*** g.p.a. = Gallons per acre.

West Side Grass

Herbicides utilized in the west side grass trials were atrazine (United Ag. Prod. Inc.), hexazinone (Velpar L, Dupont), and granular hexazinone (Velpar ULW, Dupont). Treatment lists are found in Table 2.4.

All liquid treatments were applied in 10 gallons per acre, and carrier was water. Two nozzle types (80015, RD-6) were used for all atrazine and hexazinone treatments. Both herbicides were sprayed with and without the adjuvant Mor-act®. Both herbicides were applied at two dosages.

Granular hexazinone treatments were applied using a hand

Table 2.4 Treatments for Coast Range and East Side Cascade grass plots. All treatments were applied at 10 g.p.a. Treatments were applied in mid March, 1992.

Treatment*	Rate a.i./acre	Surfactant
Atrazine	2.0 lbs	None
Atrazine	2.0 lbs	Moract (5%)
Atrazine	3.0 lbs	None
Atrazine	3.0 lbs	Moract (5%)
Hexazinone	0.6 lbs	None
Hexazinone	0.6 lbs	Moract (5%)
Hexazinone	1.0 lbs	None
Hexazinone	1.0 lbs	Moract (5%)
Gran. Hex.	0.6 lbs	----
Gran. Hex.	1.0 lbs	----
Control	*******	None

* All treatments except granular were applied with 80015 and RD-6 nozzles.

held Whirly bird® fertilizer spreader. Prior to applications, the spreader was calibrated for delivery rate, and applications were made in two passes. Granular hexazinone was brought up to volume with 400ml Superphosphate (0-45-0) fertilizer as an inert after thorough mixing. The fertilizer added about 40 lbs/ac. phosphate, an amount not expected to elicit a response on this site.

East Side Grass

Treatments for the east side grass trials were identical in every aspect to those of the west side trials (Table 2.4).

East Side Brush

For the east side ceanothus and manzanita trials the chemicals used were triclopyr ester, dichlorprop, Fluroxypyr ester, Imazapyr (Arsenal, American Cyanamid), and 2,4-D ester. Treatments are found in Table 2.5. All application were sprayed at 10 gallons per acre in the same manner as previous sites.

Table 2.5 Treatments for east side Cascade plots. Ceanothus and manzanita. All treatments were sprayed at 10 g.p.a.. Treatments were applied in mid April, 1992.

Treatment*	Rate (a.i./ac.)	Surfactant
Triclopyr	0.4 lbs	None
Triclopyr	0.4 lbs	Mor-act (5%)
Triclopyr	0.6 lbs	None
Triclopyr	0.6 lbs	Mor-act (5%)
Imazypyr	0.4 lbs	None
Imazypyr	0.4 lbs	L-77 (.15%)
Imazypyr	0.6 lbs	None
Imazypyr	0.6 lbs	L-77 (.15%)
Fluroxypyr	0.5 lbs	None
Fluroxypyr	0.5 lbs	L-77 (.15%)
Fluroxypyr	0.75 lbs	None
Fluroxypyr	0.75 lbs	L-77 (.15%)
Dichlorprop	1.2 lbs	None
Dichlorprop	1.2 lbs	Mor-act (5%)
Dichlorprop	2.0 lbs	None
Dichlorprop	2.0 lbs	Mor-act (5%)
2,4-D	1.2 lbs	Mor-act (5%)
2,4-D	2.0 lbs	Mor-act (5%)
Control	*******	None
Control	*******	Mor-act (5%)
Control	*******	L-77 (.15%)

* All triclopyr treatments were applied with 80015, 11003, and RD-6 nozzles. All imazypyr treatments were applied with 80015 and RD-6 nozzles. All other treatments were applied with 80015 nozzles only.

Triclopyr was applied with and without Mor-act® at 5%. Fluroxypyr and dichlorprop applications were made with and without Mor-act® at 5% and Silwet® at .15%. Imazapyr treatments were made with and without Silwet® at .15%. 2,4-D treatments were made with Mor-act® only at 5%.

Triclopyr treatments were sprayed using 80015, 11003, and RD-6 nozzles. Imazapyr treatments were sprayed with 80015 and RD-6 nozzles. All other herbicides were sprayed with 80015 nozzles only.

DROPSIZE DETERMINATION

The above choices of nozzles was calculated to provide large-medium-and small-drop arrays of spray drop sizes. To validate assumptions about drop size distributions of the various nozzle types, it was neccessary to determine the relative drop size spectra for each nozzle type for each class of product. Glyphosate solutions, triclopyr and fluroxypyr emulsions, and water were tested with and without surfactant. The surfactants Silwet® (0.15%) and Activator 90® (0.5%) were used with all treatments.

For the 80015, 9503 and 11003 nozzles, true droplet diameter was determined using the magnesium oxide (MgO) method (May, 1950). Microscope slides coated with MgO were sprayed to evaluate deposits in the same manner as all field experiments, using the backpack boom sprayer. Two replications per treatment were used, consisting of three slides per plot, with one being in the center of the swath and two being placed three feet to each side of the center line. These coated slides registered the in flight droplet diameter by creating small craters in the MgO layer. This method is very accurate for droplets below 600 microns in diameter regardless of liquid.

Although the largest drops in the drop size spectra may have exceeded the optimum size range for the MgO procedure, the number of droplets > 600 microns was minimal for these nozzles. To alleviate some of the problems with the larger droplets, the MgO layer was made fairly thick. No fracturing of the MgO layer occurred during spraying, hence, estimates of in flight diameters of the larger drops should be fairly close to true size.

For the larger drops produced by the RD-6 nozzles, it was neccessary to spray the mixture over Kromekote cards and send them to the Texas Forest Service for analysis with an image analyzer.

Volume median diameters (VMD's) were calculated in the following manner. One square centimeter of each slide was sampled. Drops were counted and measured under a microscope with a stage micrometer in the eyepiece reticule. Drops were placed into 100-micron size classes. Volume of the drop size was calculated using the formula $4/3\Pi r^3$. Droplet volume was multiplied by the number of droplets in the size class to determine total droplet volume per size class. Drop size was displayed graphically on a percent volume basis. The VMD was the drop size at which 50% of the volume was contained in droplets above or below the determined point.

EVALUATION AND STATISTICAL ANALYSIS

Evaluation of herbicide efficacy was made by ocular inspection. For bear clover, a point frame was used to calibrate actual cover and surface area. The point frame could not be adapted to taller vegetation, hence those estimates are relative values.

Measurements made varied between vegetational type. For bear clover and manzanita in California, percent crown reduction and percent residual cover were estimated three and five months after treatment for the first and second sites respectively. Evaluation of salmonberry consisted of estimating percent crown reduction and percent stem reduction 10 months after treatment. Grass plots were evaluated four months after treatment on the basis of percent residual grass and forb cover was also measured. The east side brush site also measured percent crown and stem reduction for ceanothus and manzanita. All treatments were compared to control plots in all experiments, many of which showed partial defoliation from freezing.

On the two California sites and the east side Cascade brush site, pine damage was also rated. To assess pine damage, a six point rating scale was used where 0=no damage, vigorous; 1=slight discoloration; 2=off color, some needle damage; 3=terminal dieback, <50% defoliation; 4=severe bud/terminal damage, >50% defoliation; and 5=dead.

Analysis of variance was used to evaluate the data. Where complete factorial treatment structures existed, sums of squares III (SAS) were used to determine main effects and interactions. With the California data, and the east side Cascade brush series, the over-all design was an incomplete factorial from which the data sets were broken down to form smaller complete factorials treatment structures. All analyses relied on SAS statistical software for microcomputers. Orthogonal contrasts were performed to compare treatment effects with controls.

RESULTS

NOZZLE-DROPSIZE TESTS

The results of the nozzle tests on magnesium oxide slides provided some interesting and disappointing results. Unfortunately, these tests were not carried out until the plots were installed. The 9503 nozzles were switched to 11003 nozzles after the first set of California experiments were installed due to problems in obtaining a full set. The 11003 nozzles were assumed to provide a mid-range of drop sizes between the 80015 and RD-6 nozzles. Unfortunately, this was not the case. The 11003 nozzles provided a drop size range that was comparable to the 80015 nozzles for glyphosate (see Figure 1-graphs a &b). The VMD for triclopyr treatments was even smaller with the 11003 than 80015 nozzles.

The 9503 nozzles provided larger VMD's than the 80015 nozzles for glyphosate, triclopyr or water (Figure 2.1., graphs a & b, & Figure 2.2). 11003 nozzles were not tested with water but are assumed to provide patterns similar to those of the 80015 nozzles. Glyphosate behaved very similarly to water in no-surfactant treatments when comparing VMD's and drop densities from the 80015 nozzles. Water with no surfactant had a much larger VMD with the 9503 nozzles than glyphosate, and not surprisingly, a lower concentration of drops per square centimeter.

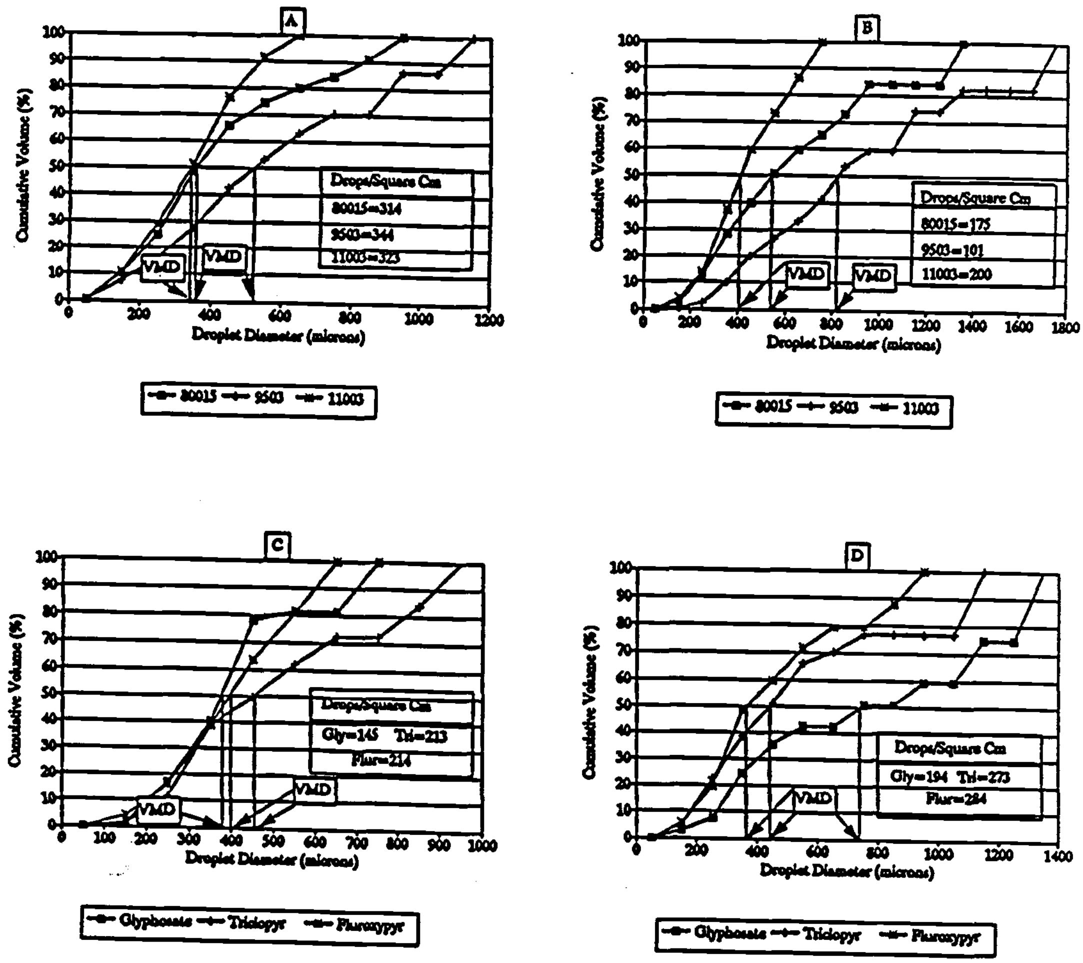

Figure 2.1 Drop size spectra and cumulative volume graphs, including VMD and drops per square centimeter for three nozzle types and eight spray mixtures. All VMD's are in microns. A) Glyphosate-no surfactant, VMD's for 80015, 9503 and 11003 nozzles are 360, 525, & 345 respectively. B) Triclopyr-no surfactant, VMD's for 80015, 9503 and 11003 nozzles are 540, 815, & 405 respectively. C) 11003 nozzles w/ Activator 90® (.5%), VMD's for gly, tri and flur are 380, 450 & 395 respectively. D) 11003 nozzles w/ Herbimax® (5%), VMD's for gly, tri and flur are 740, 440 & 365 respectively. See page 95 for definition of VMD.

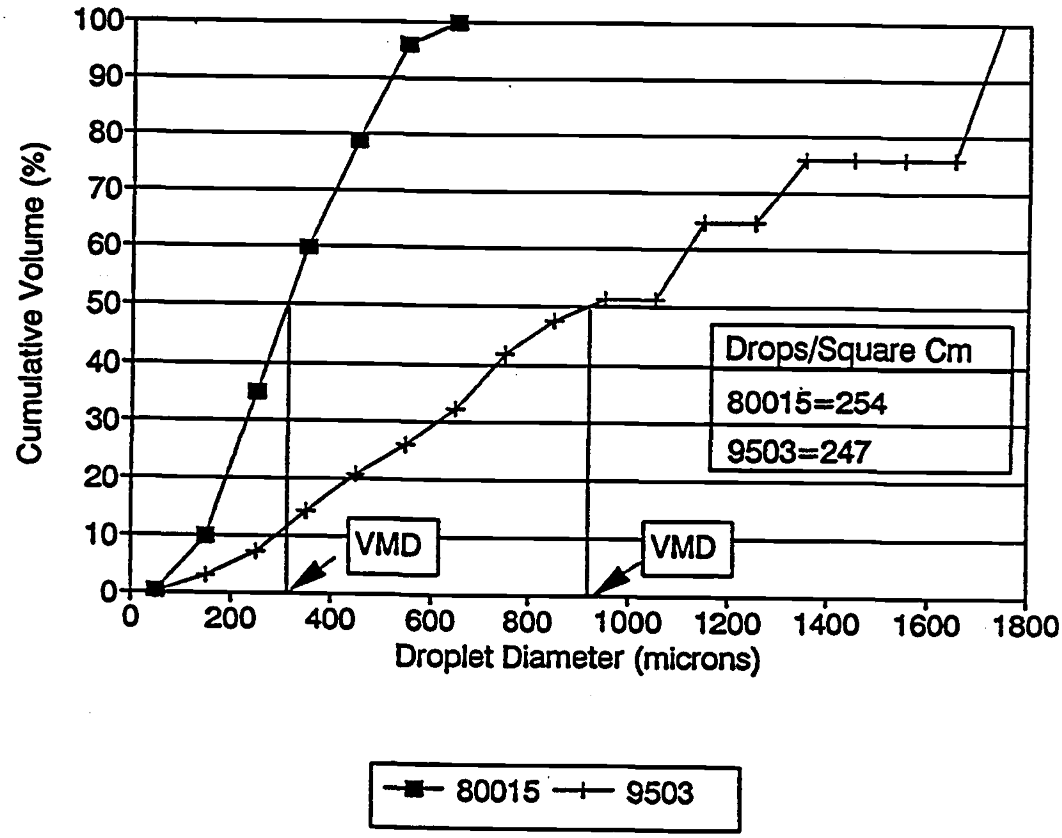

Figure 2.2 Drop size spectra and cumulative volume graph, including VMD and drops per square centimeter for two nozzle types with water and no surfactant. VMD's for 80015 and 9503 nozzles are 310 and 920 respectively. See page 95 for definition of VMD.

One unusual finding was that triclopyr with no added surfactant (i.e. containing only the formulated ingredients), provided larger VMD's for all nozzles than glyphosate treatments with no surfactant. Only the VMD for water with 80015 nozzles was smaller than the analogous triclopyr application, water with the 9503 nozzles was actually larger than triclopyr with the same nozzle. Triclopyr also had a much lower density of droplets per square centimeter than did glyphosate or water for all nozzle types. All nozzle types had well over the 15-20 drops per square centimeter coverage usually identified as minimum for effective coverage.

Fluroxypyr without added surfactant behaved much like triclopyr, having much lower droplet numbers for the 11003 nozzles than glyphosate, and even less than triclopyr. Fluroxypyr with no surfactant added had the highest VMD for 11003 nozzles with no surfactant.

The addition of Silwet® to triclopyr slightly decreased the VMD's for the 80015 and 9503 nozzles, but the drop density did not change (Figure 2.1 graphs c & d). However, the VMD slightly increased with the 11003 nozzles when the non-ionic surfactant Activator 90® was added to triclopyr, but again the droplet density did not change. The same can be said for Herbimax® with triclopyr, although droplet density increased slightly.

Glyphosate behaved very differently from ester products when surfactant was added to the mixture. Activator 90® did not change the VMD, but the density of droplets decreased markedly, indicating a decrease in small drops. Whereas the adjuvant Herbimax® increased the VMD and decreased drop density for glyphosate with 11003 nozzles compared to no surfactant, indicating a general increase in dropsize. The addition of Silwet® to glyphosate increased drop spread so dramatically that individual drops could not be distinguished on Kromkote cards. Unfortunately, the MgO slides were not measured because at the original intent of the tests was to calculate spread factors to enter into a computer program to calculate VMD.

Fluroxypyr behaved more logically in 11003 comparisons. When either Activator 90 or Herbimax was added, the VMD's decreased. This was followed by a corresponding increase in droplet density compared to no-surfactant tests.

Data received from the Texas Forest Service concerning the RD-6 and 80015 nozzles that was run on the image anylizer did not correspond well with manufacturer data or data from wind tunnel drop size tests compiled by Skyler and Barry, (1990) for RD-7 nozzles. Therefore, VMD's for RD-6 nozzles were estimated from drop size tests with similar nozzles and herbicide mixtures (Skyler and Barry, 1990).

In brief, surfactants of three types had different effects on drop formation. In some instances, average drop size did not change, but the range of drop sizes varied. In others, drop size changed but numbers did not, and in some instances, certain products were affected and others were not. We have demonstrated that these recipes influenced spray patterns, but the detail in the data are not adequate to say which is "best" for each situation.

SIERRAN BRUSH SITE I

The data sets for the first set of California trials were analyzed in subsets that formed complete factorial treatment structures. Where possible, data were combined from glyphosate and triclopyr sets to compare between herbicide types. Although analysis of the entire data set was possible, it proved to be very time consuming and extremely difficult to interpret, because of the large number of higher order interactions.

Glyphosate

Glyphosate data were broken down into two subsets to look at differences among surfactants, drop sizes and volumes by dosage. The first subset looked at high volume applications only. The second looked at both volumes but excluded the RD-6 nozzle type because it could not deliver the low volume.

Both data sets yielded the same results for control of bear clover (Treatment means are found in Tables 2.6a & 2.6b for bear clover, manzanita, and pine damage). Control of bear clover was positively related to dose, and addition of a surfactant had a significant effect. The high volume data set showed dose and surfactant to be significant (P=.0003 &

Table 2.6a Bear clover (BCCR) and manzanita (MANCR) crown reduction means, in percent, for June glyphosate treatments. Sierran brush site I. Dose is pounds active ingredient per acre. Volume is in gallons per acre. Plots were evaluated 3 months after treatment.

Volume	Dose	Surf. Type *	Nozzle Type	BCCR	Std. Error	ManCr	Std. Error
10	1.2	None	80015	27.5	17.5	5.4	2.63
			9503	12.9	0.9	6.6	0.95
			RD-6	22.1	19.6	33.8	31.25
		L-77	80015	32.5	2.5	23.8	11.2
			9503	49.5	24.5	19.5	2.5
			RD-6	50.5	9.5	14.5	4.5
		Act 90	80015	36.3	3.75	15.5	0.5
			9503	32.5	4.5	46.7	34.65
			RD-6	54.0	9.0	39.0	14.0
	2.0	None	80015	61.8	14.25	25.4	19.6
			9503	36.5	3.5	22.0	2.0
			RD-6	43.3	10.75	22.0	8.0
		L-77	80015	43.0	8.0	32.0	8.0
			9503	44.0	4.0	30.5	10.5
			RD-6	78.2	6.85	42.6	26.25
		Act 90	80015	59.4	9.4	43.3	0.74
			9503	65.5	9.5	68.5	20.5
			RD-6	55.0	5.0	95.3	4.70
5	1.2	None	80015	11.9	0.6	11.9	4.40
			9503	22.2	5.85	7.45	0.07
		L-77	80015	30.8	1.75	33.9	4.90
			9503	49.0	21.0	17.0	5.0
		Act 90	80015	26.0	7.0	22.0	5.0
			9503	45.6	1.1	55.9	7.9
	2.0	None	80015	45.0	15.0	17.8	0.22
			9503	33.0	13.0	25.0	16.0
		L-77	80015	55.0	8.0	50.0	6.0
			9503	62.5	7.5	43.8	6.25
		Act 90	80015	50.0	15.0	56.9	20.6
			9503	49.3	13.25	64.7	1.66

* Surf. Type = Surfactant type.

.021, respectively), and the second data set without the RD-6 nozzles also showed these factors to be significant at (P=.002 & .030, respectively).

Table 2.6b Pine damage means for June glyphosate treatments. Sierran brush site I. Dose is in pounds active ingredient per acre. Volume is gallons per acre. Plots were evaluated 3 months after treatment.

Volume	Dose	Surf. Type *	Nozzle Type	Pine Damage**	Standard Error
10	1.2	None	80015	1.0	1.0
			9503	0.2	0.22
			RD-6	2.5	2.5
		L-77	80015	4.0	1.0
			9503	4.1	0.67
			RD-6	3.0	0.0
		Act 90	80015	4.0	0.22
			9503	3.9	0.95
			RD-6	4.2	0.59
	2.0	None	80015	2.5	0.95
			9503	2.0	0.0
			RD-6	3.1	1.25
		L-77	80015	4.1	0.07
			9503	4.2	0.74
			RD-6	4.3	0.71
		Act 90	80015	4.7	0.39
			9503	5.0	0.0
			RD-6	5.0	0.0
5	1.2	None	80015	2.8	1.5
			9503	1.5	0.1
		L-77	80015	3.4	0.59
			9503	3.6	0.39
		Act 90	80015	4.5	0.55
			9503	4.3	0.22
	2.0	None	80015	3.9	0.39
			9503	2.4	0.67
		L-77	80015	3.9	0.1
			9503	4.9	0.1
		Act 90	80015	4.9	0.22
			9503	5.0	0.0

* Surf. Type = Surfactant type.
** Pine damage codes: 0=No damage 5=Dead

In both data sets, control was increased with the addition of surfactant. There were no differences in control between surfactant types. At the low dose evaluated, only moderate control was achieved with glyphosate, as had been planned to keep results within the response range.

Control of manzanita with glyphosate was also influenced by several application parameters. Dose was found to be a significant factor in both the high volume data set and the data set consisting of both volumes (P=.015 & .001, respectively). Increasing the dose approximately doubled the degree of control. However, control of manzanita was very poor at doses selected to provide the appropriate range of effects on bear clover, a more susceptible species.

The high and low volume data set found the interaction between surfactant and nozzle to be significant (P=.029). The interaction showed there to be no difference in control with no surfactant applications between nozzle types. However, the 80015 nozzles performed better with the surfactant Silwet® than did the 9503 nozzles. The opposite was true for applications using Activator 90®. In this case the 9503 nozzles performed better. It is difficult to interpret the validity of the results, because the differences between nozzle types are small. The 9503 nozzles produce only slightly larger droplets than the 80015 nozzles. There is no known explanation for this interaction, and no further attempt will be made to interpret it.

In the high-volume-only data set, the surfactant by nozzle interaction was not significant, but the main effect of surfactant was distinct (P=.005). Crown reduction of manzanita was slightly increased with the addition of Silwet®; Activator 90® more than doubled crown reduction.

Volume of spray did not materially affect degree of control for either species.

Pine damage was significantly increased by increasing dose and/or adding either surfactant in both analyses. The high volume data set showed dose and surfactant to be significant (P=.045 & .0002, respectively). Whereas the data set without the RD-6 nozzles showed dose and surfactant to be significant at P=.002 & .0001, respectively. Volume per acre of spray did not materially affect the degree of injury.

Pine damage was only slightly increased by increasing the dose. The effect of surfactant was more pronounced at the high dose. Damage to pine seedlings was almost doubled by the addition of either surfactant. No differences existed between surfactant type in regards to pine damage.

Triclopyr

Triclopyr treatments in this series of experiments suffered from a prior overestimate of the rates of application needed for "medium" control. Almost total brownout of bear clover was achieved on all plots without major injury to manzanita, so it was nearly impossible to determine specific effects of application technology. The second set of California trials was applied to rectify this, and will be discussed later (Treatment means for bear clover, manzanita and pine damage are found in Tables 2.7a & 2.7b).

The data set which consisted of high volume treatments

Table 2.7a Bear clover (BCCR) and manzanita (MANCR) crown reduction means for June triclopyr treatments. Sierran brush site I. Dose is pounds active ingredient per acre. Volume is gallons per acre. Plots were evaluated 3 months after treatment.

Volume	Dose	Surf. Type *	Nozzle Type	BCCR	Std. Error	ManCr	Std. Error
10	0.9	None	80015	99.3	0.22	12.5	2.5
			9503	97.0	0.0	6.0	3.0
			RD-6	75.0	0.0	1.8	1.75
		L-77	80015	93.5	3.5	13.8	1.25
			9503	99.7	0.39	11.3	3.75
			RD-6	89.0	9.0	7.0	2.0
	1.5	None	80015	98.7	1.36	47.5	2.5
			9503	99.8	0.22	11.9	1.9
			RD-6	93.0	5.5	4.0	3.5
		L-77	80015	100.0	0.0	48.8	3.75
			9503	89.3	6.75	7.0	3.0
			RD-6	96.5	0.0	6.5	0.0
5	0.9	None	80015	95.0	4.95	14.5	5.5
			9503	99.8	0.22	8.8	1.25
		L-77	80015	97.8	0.74	11.3	1.25
			9503	98.8	1.25	15.0	5.0
	1.5	None	80015	98.3	1.75	15.8	9.25
			9503	99.8	0.22	35.0	2.5
		L-77	80015	99.8	0.22	17.5	2.5
			9503	99.5	0.5	28.8	11.25

* Surf. Type = Surfactant type.

only included all three nozzle types and treatments with and without the surfactant Silwet®. All of the treatments produced between 75 and 100 percent crown reduction in bear clover. The main effects were slightly observable and there was a first order interaction between dose and nozzle (P=.028) suggested this was a valid observation. There was virtually no difference in control of bear clover between nozzle types with the high dose of triclopyr (i.e. everything was severely damaged). However, with the lower dose applications where some comparative contrasts could be

Table 2.7b Pine damage means for June triclopyr treatments. Sierran brush site I. Dose is pounds active ingredient per acre. Volume is gallons per acre. Plots were evaluated 3 months after treatment.

Volume	Dose	Surf. Type *	Nozzle Type	Pine Damage**	Standard Error
10	0.9	None	80015	3.0	0.0
			9503	3.2	0.39
			RD-6	1.3	0.22
		L-77	80015	2.9	0.1
			9503	3.1	0.22
			RD-6	2.7	0.22
	1.5	None	80015	4.2	0.39
			9503	3.0	0.5
			RD-6	2.7	0.39
		L-77	80015	4.7	0.39
			9503	2.9	0.39
			RD-6	2.5	0.0
5	0.9	None	80015	2.8	0.0
			9503	3.2	0.67
		L-77	80015	2.8	0.22
			9503	3.2	0.39
	1.5	None	80015	3.3	0.74
			9503	4.0	0.5
		L-77	80015	2.9	0.1
			9503	4.5	0.5

* Surf. Type = Surfactant type.
** Pine damage codes: 0=No damage 5=Dead

observed, the RD-6 nozzles produced poorer results than did either the 80015 or 9503 nozzles. Therefore, it appears that with a non-lethal dose, smaller drop sizes contribute more to efficacy on bear clover.

Data for manzanita crown reduction was much more reflective of the treatment effects. Generally, control of manzanita with triclopyr was so poor that these to illustrated little contrast. Analysis of the high volume data set produced a significant first order interaction between dose and nozzle type (P=.0001). There were very small differences between nozzle types with the low dose of triclopyr. However, control tended to increase with decreasing drop size. In the high dose applications, manzanita crown reduction was increased significantly with the use of the 80015 nozzles which produce fine spray droplets. Virtually no difference was seen between the 9503 and RD-6 nozzles.

Analysis of the data set that contained both high and low volume applications, produced a significant second order interaction between volume, dose, and nozzle type (P=.0001). The interaction indicates that as volume per acre is increased, the contribution of drop size to efficacy increases more with the higher dose applications than at the low doses.

No differences existed in the low volume, low dose applications of triclopyr between nozzle types. With the low volume, high dose applications, the 9503 nozzles actually produced slightly better results than the 80015 nozzles. However, as volume per acre was increased from five to ten gallons, 80015 nozzles consistantly produced better results than the 9503 nozzles. The difference was most apparent at high doses and volumes.

Pine damage with triclopyr applications was extremely high (Treatment means are found in Table 2.7b). Analysis of the high-volume-only data set, indicated a significant interaction between dose and nozzle type (P=.009). The data indicated that as dose was increased, the RD-6 nozzles which produce very large droplets caused less increase in damage than other nozzle types. Damage associated with the 80015 nozzles also increased when moving from low to high doses of triclopyr. Damage did not appear to increase significantly with the 9503 or RD-6 nozzles as dose was increased.

Analysis of the data set containing both high- and low-volume applications indicated a significant second order interaction between volume, dose, and nozzle type (P=.008). Nozzle type did not have an effect with low dose applications of triclopyr at either dose.

Combined Data

Analysis of the combined data for glyphosate and triclopyr applications on bear clover for high volume treatments, excluding the surfactant Activator 90, indicated that herbicide type was a significant factor (P=.0001), as well as dose (P=.006). There was also a significant interaction between surfactant and nozzle type (P=.041).

Triclopyr initially reduced crown area of bear clover at these dosages considerably more than glyphosate applications. Higher doses of both products also tended to control bear clover more completely. The interaction between surfactant and nozzle type indicated that without surfactant, efficacy on bear clover decreased with increasing drop size. However, when the surfactant L-77 was added to the mixtures, the trend reversed and efficacy increased as drop size increased.

Manzanita control was significantly influenced by both dose (P=.009), and an interaction between herbicide type and nozzle (P=.015). The higher doses tended to increase control of manzanita. However, manzanita control was poor with either herbicide at these dosages.

The interaction between herbicide type and nozzle indicated that glyphosate treatments, in general were more slightly more effective with the larger drop sizes produced by the RD-6 nozzles; triclopyr showed better control with the smaller drop sizes.

Pine damage was influenced by an interaction between herbicide type and surfactant (P=.006). Glyphosate damage to pine was strongly increased when surfactant was added to the mixture. Damage to pine by triclopyr was only very slightly increased with the addition of surfactant; damage by all triclopyr treatments was close to maximum, hence nearly unresponsive. However, triclopyr without surfactant caused more damage to pine than glyphosate with no surfactant.

The second combined subset included both high and low volume applications of triclopyr and glyphosate, but excluded RD-6 nozzles and the surfactant Activator 90. Control of bear clover was found to be influenced by two first order interactions between herbicide type and dose (P=.006), and herbicide type and surfactant (P=.014). This is expected due to glyphosate doses were low enough to respond where triclopyr was not. Therefore, the interactions show up due to being artifacts of overkill with one product but not the other. Thus they are biased and not definitive.

SIERRAN BRUSH SITE II

The second set of California trials provided a set of triclopyr data at a low enough dosage to compare technologies and also provided an assessment of treatments at another season and also broadened the alternatives evaluated for selective release. However, before the data sets had to be broken down into smaller subsets for analysis due to weakness of the SAS software in handling incomplete factorial designs. Therefore, each herbicide was evaluated separately. Herbicide types were combined where a complete factorial treatment structure could be obtained for two or more products with analogous treatment regimes.

Orthogonal contrasts of all treatments versus control plots by dose revealed bear clover crown reduction to be significant for all doses (All P=.0001). Pine damage was also significantly different from control plots. For low, medium, and high doses p-values were .0093, .0013, & .0001 respectiviely.

Triclopyr

Analysis of spring triclopyr treatments at lower dosage rates showed there to be several significant application parameters (Treatment means are found in Tables 2.8a & 2.8b). Dose was highly significant (P=.007). The high- and medium-dose applications of triclopyr provided good control of bear clover, but low dose applications provided significantly less control than either (P=.004 & .008, respectively).

There was also a significant interaction between surfactant and nozzle type (P=.016). Applications with no added surfactant tended to provide greater control of bear clover with the 80015 nozzles, lesser efficacy with increasing drop size. With Mor-act®, efficacy increased approximately 30% for applications made with the 11003 and RD-6 nozzles. Good control was achieved overall with the

Table 2.8a Bear clover crown reduction (BCCR) means for April triclopyr treatments. Sierran brush site II. Dose is pounds active ingredient per acre. Plots were evaluated 5 months after treatment.

Dose	Surfactant Type	Nozzle Type	BCCR	Standard Error
0.4	None	80015	67.5	17.5
		11003	45.0	10.0
		RD-6	35.0	5.0
0.4	Mor-act	80015	35.0	10.0
		11003	82.5	2.5
		RD-6	70.0	5.0
0.6	None	80015	82.5	7.5
		11003	77.5	2.5
		RD-6	62.5	2.5
0.6	Mor-act	80015	77.5	7.5
		11003	65.0	5.0
		RD-6	75.0	10.0
0.9	None	80015	77.5	2.5
		11003	52.5	22.5
		RD-6	75.0	15.0
0.9	Mor-act	80015	75.0	5.0
		11003	90.0	5.0
		RD-6	80.0	15.0

larger drop sizes combined with the addition of surfactant.

There also existed a weak third order interaction between dose, surfactant, and nozzle (P=.058). However, the interaction was difficult to interpret, especially in view of the nozzle anomaly. It appeared as though the lower dose applications had a distinct decrease in efficacy with increasing drop size in no surfactant applications. As dose increased, differences were less apparent between applications with and without surfactant as efficacy approached the upper asymptote.

Table 2.8b Pine damage means for April triclopyr treatments. Sierran brush site II. Dose is pounds active ingredient per acre. Plots were evaluated 5 months after treatment.

Dose	Surfactant Type	Nozzle Type	Pine Damage*	Standard Error
0.4	None	80015	1.0	0.0
		11003	1.5	0.5
		RD-6	1.0	0.0
0.4	Mor-act	80015	2.75	0.75
		11003	1.75	1.75
		RD-6	2.90	0.1
0.6	None	80015	0.5	0.5
		11003	1.25	0.25
		RD-6	2.25	1.25
0.6	Mor-act	80015	3.5	0.0
		11003	3.75	0.25
		RD-6	3.5	0.5
0.9	None	80015	3.0	0.0
		11003	3.4	0.6
		RD-6	2.25	0.75
0.9	Mor-act	80015	3.25	0.75
		11003	4.65	0.35
		RD-6	4.5	0.5

* Pine damage codes: 0=No Damage 5=Dead

Pine damage with triclopyr was relatively high, although much less than previously observed in summer treatments (Treatment means are found in Table 2.8b). Only dose and surfactant were significant factors affecting the level of damage (P=.0009 & .0001, respectively). Damage increased with increasing rates of application, and the addition of Mor-act® increased damage twofold within dosages. The medium rate (.6 lb/ac.), with no surfactant and small drop size, did a commendable selective removal of bear clover from pine.

<u>Glyphosate</u>

Bear clover responses to glyphosate treatments were not influenced by application parameters other than rate of application (P=.006) (Treatment means are found in Tables 2.9a & 2.9b). The low and medium doses provided little control of bear clover, and moderate results were obtained with the high dosages. However, excellent control was achieved with the high rate of glyphosate with no surfactant and the 80015 nozzles.

Pine damage with spring glyphosate applications was minimal. There a significant first order interaction

Table 2.9a Bear clover crown reduction (BCCR) means for April glyphosate treatments. Sierran brush site II. Dose is pounds active ingredient per acre. Plots were evaluated 5 months after treatment.

Dose	Surfactant Type	Nozzle Type	BCCR	Standard Error
1.2	None	80015	27.5	17.5
		RD-6	17.5	7.5
1.2	L-77	80015	37.5	2.5
		RD-6	27.5	12.5
2.0	None	80015	25.0	15.0
		RD-6	37.5	12.5
2.0	L-77	80015	20.0	10.0
		RD-6	30.0	5.0
3.0	None	80015	80.0	10.0
		RD-6	40.0	0.0
3.0	L-77	80015	45.0	15.0
		RD-6	50.0	0.0

between surfactant and nozzle type. The larger drop sizes tended to increase damage slightly in either surfactant or no surfactant applications. With the addition of Silwet®, damage increased threefold with the RD-6 nozzles with

Table 2.9b Pine damage means for April glyphosate treatments. Sierran brush site II. Dose is pounds active ingredient per acre. Plots were evaluated 5 months after treatment.

Dose	Surfactant Type	Nozzle Type	Pine Damage*	Standard Error
1.2	None	80015	0.0	0.0
		RD-6	0.0	0.0
1.2	L-77	80015	0.0	0.0
		RD-6	1.25	0.75
2.0	None	80015	0.5	0.5
		RD-6	0.5	0.5
2.0	L-77	80015	0.25	0.25
		RD-6	1.5	0.5
3.0	None	80015	0.25	0.25
		RD-6	1.0	1.0
3.0	L-77	80015	0.0	0.0
		RD-6	1.75	0.25

* Pine damage codes: 0=No Damage 5=Dead

remarkable consistancy. However, a slight decrease in damage was shown with the 80015 nozzles in combination with surfactant.

Fluroxypyr

Fluroxypyr treatments were also not influenced by application factors other than dose (P=.012) (Treatment means are found in Tables 2.10a & 2.10b). However, only the 80015 nozzle types were used in the fluroxypyr treatments on the assumption that nozzle x surfactant responses would resemble those observed with the closely related triclopyr. Control increased with increasing dose, and good control of bear clover was achieved with doses ≥ 1.0 lb/ac.. Surfactant did not influence the degree of control.

Table 2.10a Bear clover crown reduction (BCCR) means for April fluroxypyr treatments. Sierran brush site II. Dose is pounds active ingredient per acre. Plots were evaluated 5 months after treatment.

Dose	Surfactant Type	Nozzle Type	BCCR	Standard Error
0.5	None	80015	40.0	10.0
	L-77	80015	35.0	15.0
	Mor-act	80015	40.0	25.0
0.75	None	80015	75.0	10.0
	L-77	80015	65.0	10.0
	Mor-act	80015	55.0	20.0
1.0	None	80015	80.0	5.0
	L-77	80015	82.5	5.0
	Mor-act	80015	80.0	7.5
1.5	Mor-act	80015	75.0	10.0

Table 2.10b Pine damage means for April fluroxypyr treatments. Sierran brush site II. Dose is pounds active ingredient per acre. Plots were evaluated 5 months after treatment.

Dose	Surfactant Type	Nozzle Type	Pine Damage*	Standard Error
0.5	None	80015	0.5	0.0
	L-77	80015	1.5	0.5
	Mor-act	80015	2.0	1.0
0.75	None	80015	2.25	1.41
	L-77	80015	1.0	1.0
	Mor-act	80015	3.75	0.25
1.0	None	80015	1.75	0.75
	L-77	80015	3.0	0.0
	Mor-act	80015	4.40	0.4
1.5	Mor-act	80015	4.00	0.5

* Pine damage codes: 0=No damage 5=Dead.

Both surfactant and rate of application influenced the amount of pine damage (P=.023 & .047, respectively). Pine damage increased significantly with each increase in dose. The addition of Silwet® did not obviously influence damage, but responses were erratic. However, adding Mor-act® to the fluroxypyr treatments more the doubled pine damage. Silwet® should be regarded with caution concerning the amount of pine damage. High dose treatments did show substantial pine damage when Silwet® was added, but other doses did not.

<u>Dichlorprop</u>

Bear clover control with dichlorprop was strongly influenced by rate of application (P=.0001) (Treatment means are found in Tables 2.11a & 2.11b). No other factors were found to be significant.

Good control of bear clover was achieved with the high rates of application. Only marginal to poor control was achieved with the lower rates. Although there was only a very weak interaction of surfactant with dose (P=.082), the evidence suggests the addition of Mor-act® in the four-pound applications does substantially increase efficacy. These observations also had extremely low variances. This trend was not consistent in the lower doses.

A significant interaction between surfactant and dose also existed for pine damage (P=.035). The trend showed that as the rate of application was increased, the addition of surfactant caused more pine damage. This was especially true for the addition of Mor-act®. Overall, pine damage was low for dichlorprop applications especially in the 1.2 and 2.0 pound applications. Only high dose treatments with Mor-act® showed major damage.

Table 2.11a Bear clover crown reduction (BCCR) means for April dichlorprop treatments. Sierran brush site II. Dose is pounds active ingredient per acre. Plots were evaluated 5 months after treatment.

Dose	Surfactant Type	Nozzle Type	BCCR	Standard Error
1.2	None	80015	25.0	5.0
	L-77	80015	12.5	2.5
	Mor-act	80015	10.0	5.0
2.0	None	80015	65.0	10.0
	L-77	80015	50.0	10.0
	Mor-act	80015	57.5	7.5
4.0	None	80015	67.5	7.5
	L-77	80015	67.5	2.5
	Mor-act	80015	94.0	4.0

Table 2.11b Pine damage means for April dichlorprop treatments. Sierran brush site II. Dose is pounds active ingredient per acre. Plots were evaluated 5 months after treatment.

Dose	Surfactant Type	Nozzle Type	Pine Damage*	Standard Error
1.2	None	80015	0.0	0.0
	L-77	80015	0.0	0.0
	Mor-act	80015	0.0	0.0
2.0	None	80015	0.0	0.0
	L-77	80015	0.0	0.0
	Mor-act	80015	1.0	0.0
4.0	None	80015	1.25	0.25
	L-77	80015	1.5	0.5
	Mor-act	80015	2.75	0.25

* Pine damage codes: 0=No damage 5=Dead.

2,4-D

Spring treatments with 2,4-D provided moderately good control of bear clover at both the high and low rates (2.0 and 4.0 lb/ac) (Treatment means are found in Tables 2.12a & 2.12b). 2,4-D was assumed to respond similarly to dichlorprop regarding changes in application parameters. Therefore, applications were only made with the surfactant Mor-act and 80015 nozzles.

Table 2.12a Bear clover crown reduction (BCCR) means for April 2,4-D treatments and controls. Sierran brush site II. Dose is pounds active ingredient per acre. Plots were evaluated 5 months after treatment.

Dose	Surfactant Type	Nozzle Type	BCCR	Standard Error
2.0	Mor-act	80015	75.0	5.0
4.0	Mor-act	80015	82.5	7.5
Con.	Mor-act	*****	0.0	0.0
Con.	None	*****	0.0	0.0

Table 2.12b Pine damage means for April 2,4-D treatments. Sierran brush site II. Dose is pounds active ingredient per acre. Plots were evaluated 5 months after treatment.

Dose	Surfactant Type	Nozzle Type	Pine Damage*	Standard Error
2.0	Mor-act	80015	4.00	0.0
4.0	Mor-act	80015	4.65	0.16
Con.	Mor-act	80015	0.0	0.0
Con.	None	*****	0.0	0.0

* Pine Damage Codes: 0=No Damage 5=Dead

Pine damage was severe for either rate of application. Slightly more damage was incurred with the high dose applications, but neither could be used for broadcast conifer release.

Combined Data

It was possible to combine data from glyphosate, fluroxypyr, and dichlorprop treatments which consisted of the 80015 nozzles, no surfactant and Silwet® mixes, and three doses. From this analysis, a two way interaction was found to be significant between herbicide type and dose (P=.030). Thus, increments of efficacy occurred at different rates with increasing doses for these products. Specifically, fluroxypyr provided more early cover reduction overall, than either glyphosate or dichlorprop, especially on an active-ingredient basis. Generally, increased control was associated with increasing the rate of application for fluroxypyr and dichlorprop. However, not until the rate of application reached the high dose, was any increase in control seen with glyphosate treatments.

Analysis of pine damage between these three herbicides revealed that herbicide type and dose were significant factors (P=.0001 & .009, respectively). No differences between glyphosate and dichlorprop were observed regarding pine damage, but both had significantly less damage than treatments with fluroxypyr. The amount of damage was found to increase with increasing rates of application for all three herbicides.

COAST RANGE SALMONBERRY

Data for the Coast Range salmonberry sites were also split into subsets of high and low volume applications. A third set for analysis consisted of both high and low volume applications, excluding the RD-6 nozzle types (Treatment means are found in Table 2.13).

Analysis of the five-gallon-per-acre treatments indicated a significant second order interaction between dose, surfactant, and nozzle type (P=.044) for salmonberry crown reduction. The same third order interaction for stem reduction was marginally significant (P=.059). However, the data displayed an unusual degree of variation between plots treated similarly. No main effects or first order interactions were found to be significant. The second order interaction has no obvious explanation and is probably attributable to random chance. The results did not hold strong distinguishable patterns. No treatment effects stood out for crown or stem reduction for this data set.

Analysis of the ten-gallon per acre treatments indicated that dose was the only significant factor contributing to variation in crown and stem reduction (P=.0001 & .0001, respectively). The amount of crown and stem reduction was significantly increased with increasing dosage.

The combined data for the five and ten gallon treatments without RD-6 nozzles showed there to be a significant

Table 2.13 Salmonberry crown (C.R.) and stem reduction (S.R.) means for September glyphosate treatments. Big Rock Creek. Dose is pounds active ingredient per acre. Volume is gallons per acre. Plots were evaluated 10 months after treatment.

Volume	Dose	Surf. Type*	Nozzle Type	C.R.	Std. Error	S.R.	Std. Error
10	0.36	None	80015	40.0	3.5	29.0	8.5
			11003	11.8	5.25	9.5	4.5
			RD-6	21.5	6.5	19.3	8.75
		L-77	80015	5.8	13.75	9.8	2.75
			11003	-43.8	8.75	7.5	3.0
			RD-6	34.5	5.0	22.0	1.0
		Act. 90	80015	-5.3	39.75	17.0	8.5
			11003	16.3	2.25	17.5	3.0
			RD-6	36.0	4.5	19.8	3.75
10	0.60	None	80015	76.5	5.0	48.3	14.25
			11003	62.0	24.0	43.8	18.75
			RD-6	63.8	1.25	46.0	3.5
		L-77	80015	76.0	14.5	54.5	18.0
			11003	69.0	2.5	41.5	2.0
			RD-6	72.3	2.25	44.5	1.0
		Act. 90	80015	69.5	18.5	44.3	10.75
			11003	65.5	2.5	33.8	4.75
			RD-6	66.3	17.75	61.5	5.0
5	0.36	None	80015	89.8	7.75	78.3	15.75
			11003	34.8	15.25	18.5	7.0
		L-77	80015	30.3	22.25	24.3	4.25
			11003	40.3	7.75	17.3	3.25
		Act. 90	80015	46.5	25.5	31.3	16.25
			11003	44.5	34.5	36.5	28.5
5	0.60	None	80015	20.3	1.75	14.0	2.0
			11003	74.8	7.75	49.3	1.25
		L-77	80015	70.5	6.0	45.0	11.5
			11003	50.8	31.25	36.8	27.75
		Act. 90	80015	72.4	8.85	47.8	7.25
			11003	74.3	3.75	53.5	12.5

* Surf. Type = Surfactant type.

interaction between volume and dose (P=.0008), and between dose and surfactant (P=.045) for crown reduction of salmonberry. The interaction between volume and dose revealed that fairly good control of salmonberry was achieved with the high dose treatments in either the high or low volume treatments. However, the low dose treatments provided virtually no control with the high volume treatments. When the volume was decreased to five gallons per acre, control significantly increased with low dosages.

The dose by surfactant interaction indicated that the addition of surfactant may have actually decreased the crown reduction achieved with the low dose applications. However, with the high dose applications, control was slightly increased with the addition of either surfactant. There were no differences in the control achieved between the two surfactants.

The analysis of stem reduction for the combined volume data indicated a significant first order interaction between volume and dose (P=.036) and a significant second order interaction between dose, surfactant, and nozzle (P=.033). The interaction between dose and volume indicated the same pattern as was achieved with crown reduction. Little difference existed between volumes for the stem reduction response to the high dose treatments. Poor stem reduction was achieved with the low dose treatments. However, control improved slightly when volume increased to ten gallons per acre. The amount of stem reduction achieved with any treatment overall was poor at this range of doses.

The second order interaction between dose, surfactant, and nozzle type had several interesting characteristics. With the low dose applications, stem reduction was reduced with the 80015 nozzles when surfactant was added to the solution. Control was slightly increased when the surfactant Activator 90 was included with the 11003 nozzles. However, the difference was slight and overall control was poor. In view of similarity between drop sizes of 80015 and 11003 nozzles, validity of this interaction is unclear.

WEST SIDE GRASS

Tests on the west side grass plots revealed that none of the application parameters affected the outcome of herbicide treatments (Treatment means are found in Tables 2.14a, 2.14b & 2.14c). Herbicide type was the only factor determined to be significant in the analysis of percent grass cover (P=.0001).

Of the herbicides tested, Velpar L® was the only product that produced adequate reductions in grass cover in the range of doses used. Velpar L® provided significantly more reduction in grass cover than the Atrazine, Velpar ULW, and the control treatments.

Grass reduction by atrazine was not significantly different from the untreated plots, but all Velpar L treatments were. Velpar L reduced grass cover more than Atrazine did. Granular Velpar ULW® controlled significantly less grass than Velpar L®, but control was slightly better than with atrazine.

Table 2.14a Grass and forb percent cover means for March hexazinone treatments. Coast Range grass site. Dose is pounds active ingredient per acre. Plots were evaluated 4 months after treatment.

Dose	Surf. Type*	Nozzle Type	% Grass Cover	Std. Error	% Forb Cover	Std. Error
0.6	None	80015	4.4	2.57	8.2	3.17
		RD-6	5.5	3.78	6.8	2.49
0.6	Mor-act	80015	1.2	0.71	10.5	3.69
		RD-6	3.0	1.49	8.2	1.37
1.0	None	80015	0.1	0.0	10.8	2.92
		RD-6	0.4	0.32	8.0	3.46
1.0	Mor-act	80015	0.7	0.32	17.5	0.87
		RD-6	0.7	0.32	11.3	3.18

* Surf. Type = Surfactant type.

Table 2.14b Grass and forb percent cover means for March Atrazine treatments. Coast Range grass site. Dose is pounds active ingredient per acre. Plots were evaluated 4 months after treatment.

Dose	Surf. Type*	Nozzle Type	% Grass Cover	Std. Error	% Forb Cover	Std. Error
2.0	None	80015	71.7	4.64	9.8	3.18
		RD-6	75.0	2.50	10.5	3.13
2.0	Mor-act	80015	65.0	6.29	12.8	6.22
		RD-6	65.8	9.28	21.7	8.7
3.0	None	80015	73.3	3.63	6.0	1.27
		RD-6	69.0	8.25	18.0	8.54
3.0	Mor-act	80015	50.0	9.01	14.2	4.21
		RD-6	75.8	0.84	4.8	0.61

* Surf Type = Surfactant Type.

Table 2.14c Grass and forb percent cover means for March Velpar ULW treatments and control plots. Coast Range Grass Site. Dose is pounds active ingredient per acre. Plots were evaluated 4 months after treatment.

Dose	Surf. Type*	Nozzle Type	% Grass Cover	Std. Error	% Forb Cover	Std. Error
0.6	***	***	45.8	4.41	15.3	5.96
1.0	***	***	40.0	9.02	8.5	2.60
Control	***	***	73.3	1.66	8.7	3.28

* Surf. Type = Surfactant type.

No factors were determined to be significant in the analysis of forb cover, although there was a trend for RD-6 nozzles to be associated with reduced forb cover when using hexazinone.

Orthogonal contrast of all treatments versus control plots by dose revealed that grass cover was significantly different between control and treated plots for both doses (All P=.0001). Forb cover in treated plots was not significantly different from control plots with the high dose treatments (P=.1265), however, low dose treatments were (P=.0463).

EAST SIDE GRASS

The results of the east side grass study were more variable than those of the Coast Range Site (Treatment means are found in Tables 2.15a, 2.15b & 2.15c). A significant second order interaction between herbicide type, dose, and nozzle existed for reductions in grass cover for Velpar L and

Atrazine treatments (P=.0004). Surfactant was determined to not be a significant factor in contributing to reductions in grass cover.

Generally, control varied little between treatments. Best control of grass was achieved with the high dose of Velpar L®. No significant differences in control were found between nozzle types for this treatment. However, slightly poorer control was achieved with RD-6 nozzles in all treatments except the 1.0 lb/ac. treatment with Mor-act®.

The only significant difference between nozzle types was found for the low dose Atrazine applications (Table 15b). For this treatment, the RD-6 nozzles produced better control of grass than did the 80015 nozzles. This pattern was very inconsistent for other atrazine treatments, and reliability is unclear.

Forb cover patterns were slightly more consistent than were the results of grass cover reductions. A significant three way interaction existed between herbicide type, surfactant, and nozzle type (P=.014). Overall, treatments with Velpar L tended to control forbs slightly better than the analogous atrazine treatments.

Addition of surfactant did not generally influence the control of forbs. Only when Atrazine was applied with Mor-act® and RD-6 nozzles did the control of forbs significantly increase compared to the analogous treatment without surfactant.

Table 2.15a Grass and forb percent cover means for March hexazinone treatments. East side grass site. Dose is pounds active ingredient per acre. Plots were evaluated 4 months after treatment.

Dose	Surf. Type*	Nozzle Type	% Grass Cover	Std. Error	% Forb Cover	Std. Error
0.6	None	80015	2.7	0.32	0.7	0.32
		RD-6	7.0	2.30	2.0	0.58
0.6	Mor-act	80015	4.3	1.45	0.4	0.32
		RD-6	6.7	0.32	2.2	0.45
1.0	None	80015	1.4	0.63	0.1	0.0
		RD-6	2.0	0.58	1.4	0.86
1.0	Mor-act	80015	3.5	1.05	0.1	0.0
		RD-6	0.1	0.0	1.0	0.55

* Surf. Type = Surfactant type.

Table 2.15b Grass and forb percent cover means for March Atrazine treatments. East side grass site. Dose is pounds active ingredient per acre. Plots were evaluated 4 months after treatment.

Dose	Surf. Type*	Nozzle Type	% Grass Cover	Std. Error	% Forb Cover	Std. Error
2.0	None	80015	13.3	3.53	3.3	1.2
		RD-6	5.3	2.4	9.2	4.42
2.0	Mor-act	80015	9.0	2.08	4.0	1.73
		RD-6	3.5	1.76	0.9	0.8
3.0	None	80015	2.3	0.88	0.7	0.32
		RD-6	6.0	1.53	7.3	2.73
3.0	Mor-act	80015	5.3	2.4	0.7	0.32
		RD-6	5.0	1.0	1.0	0.55

* Surf. Type = Surfactant type.

Nozzle type did tend to make a difference in the abundance of forbs, although the difference was slight. This was especially true with the Velpar L® treatments. Treatments which included RD-6 nozzles tended to have slightly higher forb cover than did the 80015 treatments.

Table 2.15c Grass and forb percent cover means for March Velpar ULW treatments and control plots. East side grass site. Dose is pounds active ingredient per acre. Plots were evaluated 4 months after treatment.

Dose	Surf. Type*	Nozzle Type	% Grass Cover	Std. Error	% Forb Cover	Std. Error
0.6	***	***	6.0	2.08	4.0	1.73
1.0	***	***	24.0	6.66	3.0	1.16
Control	***	***	40.0	7.64	5.7	3.28

* Surf. Type = Surfactant type.

This was true for all treatments except the atrazine treatments with Mor-act®, which had slightly more forb cover with the 80015 than with RD-6 nozzles.

All treatments with Atrazine and Velpar L produced significantly better control of grass than high dose granular formulation of Velpar, with the exception of low dose atrazine treatments with 80015 nozzles. Low doses of granular Velpar ULW were not significantly different from any Atrazine or Velpar L treatments.

Orthogonal contrasts of all treatments versus control plots by dose revealed that grass cover in treated plots was significantly lower than control plots for both doses (All P=.0001). Forb cover was significantly lower in the treated plots for the high dose treatments (P=.0175), but not in the low dose applications (P=.2093). However, in the absence of residual herbicide, removal of grass would undoubtedly have led to an increase in forbs.

EAST SIDE BRUSH

The very large incomplete factorial treatment structure necessitated the breakdown of data into smaller complete factorials for analysis. Where possible, data from more than one herbicide treatment were combined to form a complete factorial. Treatments from each individual herbicide formed a complete factorial and were analyzed as such.

Orthogonal contrasts of all treatments versus control plots by dose revealed manzanita crown and stem reduction to be significantly greater in treated plots compared to controls for both doses (All P=.0001). Ceanothus Crown and stem reduction was also significantly greater than control plots with the low (P=.0010 & .0033, respectively) and the high doses (P=.0002 & .0001, respectively). Pine damage was also significatnly greater in the treated plots compared to control plots for the low and the high doses (P=.0051 & .0001, respectively).

Triclopyr

Triclopyr provided some interesting results. All treatments were effective on Ceanothus (Treatment means are found in Tables 2.16a, 2.16b, & 2.16c). Greater than 90 percent crown reduction was achieved with virtually all applications. Stem reduction also averaged over 90 percent for all treatments except the low dose, no surfactant, 11003 and RD-6 nozzle treatments.

Analysis of variance on crown reduction of Ceanothus showed dose to be the only significant factor (P=.026). The high-dose of triclopyr provided slightly better results than the low dosea, although low-dose applications still generally provided greater than 90 percent control. Nozzle type and surfactant had no effect on crown or stem reduction of Ceanothus. Dose was only slightly significant with stem reduction (P=.060). No other factor was found to be significant for stem reduction.

Most triclopyr treatments were unsuccessful on manzanita, yet, some distinct patterns were present. The most striking pattern of the triclopyr applications was the effect of drop size on crown and stem reduction. In all cases, the RD-6 nozzles provided significantly more crown and stem reduction than analogous treatments with the 80015 and 11003. Moderate control was achieved with the RD-6 nozzles in the low dose applications. However, 90 percent crown reduction and nearly 90 percent stem reduction was achieved with the RD-6 nozzles in the high dose applications.

A three way interaction was significant between dose, surfactant, and nozzle type for manzanita crown reduction (P=.008) and stem reduction (P=.0001). Surfactant tended to increase crown and stem reduction with the 80015 and 11003 nozzles in the low dose applications although control was still poor. Surfactant did increase crown and stem reduction in the high dose applications with 11003 nozzles compared to no surfactant applications. However, surfactant did not increase control with the other nozzle types. In virtually all cases, the higher dose treatments provided more control than the comparable low dose treatment.

Table 2.16a East side crown (C.R.) and stem (S.R.) reduction means for April triclopyr treatments on ceanothus. Dose is pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surf. Type*	Nozzle Type	C.R.	Std. Error	S.R.	Std. Error
0.4	None	80015	94.0	4.0	90.0	10.0
	None	11003	90.0	0.0	65.0	5.0
	None	RD-6	89.0	9.0	65.0	35.0
0.4	Mor-act	80015	90.0	0.0	90.0	0.0
	Mor-act	11003	96.5	1.5	97.5	2.5
	Mor-act	RD-6	94.0	4.0	90.0	0.0
0.6	None	80015	95.5	0.5	92.5	2.5
	None	11003	98.0	0.0	91.0	1.0
	None	RD-6	98.0	0.0	99.0	1.0
0.6	Mor-act	80015	96.5	1.5	97.5	2.5
	Mor-act	11003	98.0	0.0	95.0	5.0
	Mor-act	RD-6	95.0	0.0	100.0	0.0

* Surf. Type = Surfactant type.

Pine damage was significantly influenced by dose (P=.0003), surfactant (P=.0004), and nozzle type (P=.0013). However, no significant interactions existed between application factors (Treatment means are found in Table 2.16c). The low dose caused less damage than the high dose. Pine damage was increased almost twofold with the addition of the oil surfactant. Increasing drop size also increased the intensity of damage. The RD-6 nozzles caused more damage than either the 80015 or the 11003 nozles.

Table 2.16b East side crown (C.R.) and stem (S.R.) reduction means for April triclopyr treatments on manzanita. Dose is pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surf. Type*	Nozzle Type	C.R.	Std. Error	S.R.	Std. Error
0.4	None	80015	15.0	5.0	2.5	2.5
	None	11003	12.5	2.5	2.5	2.5
	None	RD-6	70.0	0.0	70.0	0.0
0.4	Mor-act	80015	37.5	7.5	12.5	2.5
	Mor-act	11003	37.5	2.5	15.0	5.0
	Mor-act	RD-6	65.0	5.0	65.0	5.0
0.6	None	80015	56.0	16.0	50.0	10.0
	None	11003	40.0	15.0	15.0	5.0
	None	RD-6	90.0	5.0	87.5	2.5
0.6	Mor-act	80015	10.0	5.0	2.0	2.5
	Mor-act	11003	65.0	5.0	65.0	5.0
	Mor-act	RD-6	90.0	2.0	85.0	5.0

* Surf. Type = Surfactant type.

Table 2.16c East side pine damage means for April triclopyr treatments. Doses are pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surfactant Type	Nozzle Type	Pine Damage*	Standard Error
0.4	None	80015	0.2	0.16
	None	11003	0.5	0.5
	None	RD-6	1.8	0.74
0.4	Mor-act	80015	1.6	0.1
	Mor-act	11003	2.0	0.32
	Mor-act	RD-6	2.8	0.45
0.6	None	80015	1.3	0.22
	None	11003	2.0	0.0
	None	RD-6	3.2	0.5
0.6	Mor-act	80015	2.5	0.5
	Mor-act	11003	3.6	0.89
	Mor-act	RD-6	4.2	0.16

* Pine damage codes: 0=No damage 5=Dead

Imazapyr

No main factors or interactions were found to be significant for Ceanothus crown reduction by imazapyr (Treatment means are found in Tables 2.17a, 2.17b, & 2.17c). There did appear to be a weak interaction between surfactant and nozzle for Ceanothus crown reduction (P-value=.087). When no surfactant was added to the herbicide mix, the 80015 nozzles produced better results than the RD-6 nozzles. Control greater than 90 percent was achieved with the 80015 nozzles, but only moderate control was achieved with the RD-6 nozzles. However, when Silwet® was added to the solution, the RD-6 nozzles reduced crown area by 80 percent or more. Crown reducton of Ceanothus did not appear to be influenced by dose for any imazapyr treatments, indicating that optimum dosage may be less than 0.2 lb/ac.

A significant interaction existed between dose and surfactant for Ceanothus stem reduction (P=.006). Low dose applications appeared to provide better control with no surfactant applications, whereas high dose applications tended to have higher stem reduction values when the surfactant L-77 was added to the herbicide mix.

Control of manzanita with imazapyr was extremely poor. Both dose and surfactant were found to be significant factors (P=.048 & .048, respectively). High dose treatments and treatments with Silwet® tended to produce slightly better results. However, control of manzanita was so poor that gains achieved by these two factors are inconsequential. No application parameters or interactions were found to be significant for manzanita stem reduction. Stem reduction was negligable.

Table 2.17a East side crown (C.R.) and stem (S.R.) reduction means for April imazapyr treatments on ceanothus. Dose is pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surf. Type*	Nozzle Type	C.R.	Std. Error	S.R.	Std. Error
0.2	None	80015	94.0	4.0	75.0	5.0
	None	RD-6	65.0	25.0	72.0	22.0
0.2	L-77	80015	72.5	22.5	35.0	15.0
	L-77	RD-6	90.0	5.0	50.0	0.0
0.4	None	80015	90.0	0.0	60.0	10.0
	None	RD-6	60.0	20.0	40.0	0.0
0.4	L-77	80015	72.5	7.5	85.0	5.0
	L-77	RD-6	80.0	15.0	65.0	5.0

* Surf. Type = Surfactant type.

Table 2.17b East side crown (C.R.) and stem (S.R.) reduction means for April imazapyr treatments on manzanita. Doses are pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surf. Type*	Nozzle Type	C.R.	Std. Error	S.R.	Std. Error
0.2	None	80015	2.5	2.5	0.0	0.0
	None	RD-6	2.5	2.5	0.0	0.0
0.2	L-77	80015	5.0	5.0	5.0	5.0
	L-77	RD-6	15.0	5.0	2.5	2.5
0.4	None	80015	15.0	0.0	5.0	5.0
	None	RD-6	5.0	5.0	0.0	0.0
0.4	L-77	80015	20.0	10.0	5.0	5.0
	L-77	RD-6	17.5	2.5	5.0	5.0

* Surf. Type = Surfactant type.

Pine damage by imazapyr appeared to be very slight. Only slight foliage discoloration along with slight inhibition of needle elongation was observed. Damage did not vary with changes in application parameters, and no factors or interactions were found to be significant. Long-term

Table 2.17c East side pine damage means for April imazapyr treatments. Doses are pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surfactant Type	Nozzle Type	Pine Damage*	Standard Error
0.2	None	80015	0.9	0.5
	None	RD-6	1.4	0.39
0.2	L-77	80015	1.0	0.0
	L-77	RD-6	1.0	0.0
0.4	None	80015	0.9	0.5
	None	RD-6	1.0	0.0
0.4	L-77	80015	1.0	0.0
	L-77	RD-6	1.0	0.0

* Pine damage codes: 0=No damage 5=Dead.

inhibition has been observed elsewhere by Newton on ponderosa pine (Personnal communication, 1993, OSU College of Forestry), hence caution is encouraged in the interpretation of these data until further years observations are reported.

Dichlorprop

Dichlorprop treatments provided the best overall control of both Ceanothus and manzanita without damaging ponderosa pine seedlings, (treatment means are found in Tables 2.18a, 2.18b, & 2.18c). Application parameters had little effect on control of either Ceanothus or manzanita. Dose was a significant factor in manzanita crown reduction (P=.014). This was the only significant factor found for either of the brush species or pine damage.

Better control was achieved overall with the high dose applications. This was true for both brush species and for both crown and stem reduction. Excellent control was

Table 2.18a East side crown (C.R.) and stem (S.R.) reduction means for April dichlorprop treatments on Ceanothus. Dose is pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surf. Type*	Nozzle Type	C.R.	Std. Error	S.R.	Std. Error
1.2	None	80015	65.0	25.0	60.0	20.0
	L-77	80015	57.5	7.5	60.0	30.0
	Mor-act	80015	90.0	0.0	70.0	0.0
2.0	None	80015	82.5	7.5	80.0	10.0
	L-77	80015	70.0	20.0	60.0	10.0
	Mor-act	80015	80.0	5.0	70.0	5.0

* Surf. Type = Surfactant type.

Table 2.18b East side crown (C.R.) and stem (S.R.) reduction means for April dichlorprop treatments on manzanita. Dose is pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surf. Type*	Nozzle Type	C.R.	Std. Error	S.R.	Std. Error
1.2	None	80015	77.5	7.5	65.0	15.0
	L-77	80015	70.0	15.0	65.0	25.0
	Mor-act	80015	67.5	2.5	60.0	10.0
2.0	None	80015	91.0	1.0	91.0	1.0
	L-77	80015	86.5	1.5	75.0	5.0
	Mor-act	80015	96.0	1.0	92.5	2.5

* Surf. Type = Surfactant type.

Table 2.18c East side pine damage means for April dichlorprop treatments. Dose is pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surfactant Type	Nozzle Type	Pine Damage*	Standard Error
1.2	None	80015	0.5	0.0
	L-77	80015	0.6	0.1
	Mor-act	80015	1.0	0.0
2.0	None	80015	1.3	0.45
	L-77	80015	1.2	0.5
	Mor-act	80015	1.0	0.32

* Pine damage codes: 0=No damage 5=Dead

achieved with the high-dose on manzanita, while only slightly less control was achieved on Ceanothus.

Surfactant did not have a measurable effect on the control of manzanita or on the efficacy of the high dose applications on Ceanothus. However, excellent control of Ceanothus was achieved with the low dose applications with the addition of Mor-act®, compared to only moderate control with no surfactant or Silwet®

Pine damage was also not influenced by varying application parameters. Less damage was achieved with the low dose applications, however, the difference was very small. No more than slight discoloration occured to treated pine seedlings. Thus, optimum selectivity was achieved at 2.0 lbs/ac. for favoring pine.

Fluroxypyr

Fluroxypyr provided moderate control of Ceanothus (Treatment means are found in Tables 2.19a, 2.19b, & 2.19c), but no significant factors or interactions were found among treatments. There is some indication that surfactant may inhibit the ability of fluroxypyr to control Ceanothus, but no logical explanation is available. No-surfactant applications tended to reduce crowns more than applications with surfactant. This was demonstrated with both the high and low-doses although the differences were not significant.

Fluroxypyr reduced Ceanothus stems poorly, compared to crown reduction achieved. Therefore, the potential for recovery is expected to be high. Neither surfactant nor dose seemed to have effect on the amount of stem reduction.

Excellent control of manzanita was achieved with the high dose of fluroxypyr. Dose was found to be the only

Table 2.19a East side crown (C.R.) and stem (S.R.) reduction means for April fluroxypyr treatments on Ceanothus. Dose is pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surf. Type*	Nozzle Type	C.R.	Std. Error	S.R.	Std. Error
0.5	None	80015	75.0	5.0	30.0	0.0
	L-77	80015	65.0	5.0	25.0	5.0
	Mor-act	80015	69.0	9.0	54.0	24.0
0.75	None	80015	80.0	0.0	20.0	0.0
	L-77	80015	67.5	1.5	55.0	25.0
	Mor-act	80015	50.0	4.0	30.0	10.0

* Surf. Type = Surfactant type.

Table 2.19b East side crown (C.R.) and stem (S.R.) reduction means for April fluroxypyr treatments on manzanita. Dose is in pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surf. Type*	Nozzle Type	C.R.	Std. Error	S.R.	Std. Error
0.5	None	80015	86.0	16.0	85.0	5.0
	L-77	80015	71.0	15.0	65.0	15.0
	Mor-act	80015	83.5	5.0	52.5	27.5
0.75	None	80015	96.5	5.0	92.5	2.5
	L-77	80015	95.0	5.0	92.5	2.5
	Mor-act	80015	96.5	2.0	96.5	1.5

* Surf. Type = Surfactant type.

Table 2.19c East side pine damage means for April fluroxypyr treatments. Dose is in pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surfactant Type	Nozzle Type	Pine Damage*	Standard Error
0.5	None	80015	1.4	0.1
	L-77	80015	1.2	0.5
	Mor-act	80015	1.2	0.5
0.75	None	80015	1.0	0.5
	L-77	80015	1.0	0.0
	Mor-act	80015	1.5	0.22

* Pine damage codes: 0=No damage 5=Dead

significant factor influencing manzanita crown reduction (P=.008), and stem reduction (P=.048). Slightly less control was achieved with the low dose, but crown reduction was still in excess of 80 percent. Stem reduction was excellent with the high dose applications. Only moderate increments to stem reduction were achieved when either Silwet® or Mor-act® were added to the low dose herbicide treatments. The no-surfactant applications provided excellent stem reduction. No other differences due to surfactant were found.

Fluroxypyr caused little pine damage. Damage did not vary with different application parameters. No more than slight discoloration or moderate needle loss occurred. No significant factors or interactions were found that influenced the degree of pine damage.

2,4-D

Excellent stem and crown reduction was achieved on both Ceanothus and manzanita with both doses of 2,4-D (Treatment means are found in Tables 2.20a, 2.20b, & 2.20c). The high-dose produced only slightly better results than the low, because both were near the maximum possible response. No significant differences between doses were found for either brush type. Pine damage was extreme for both doses of 2,4-D. Complete mortality or near mortality was the result of all treatments with 2,4-D. Effective selectivity was not demonstrated for this compound.

Combined Data

Analysis of the combined data for fluroxypyr, imazapyr, and dichlorprop excluded RD-6 nozzles and the surfactant Moract. Herbicide type and dose were found to be significant factors for manzanita crown reduction (P=.0001 & .0006, respectively). Generally, higher doses were more effective

Table 2.20a East side crown (C.R.) and stem (S.R.) reduction means for April 2,4-D treatments and controls on Ceanothus. Dose is pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surf. Type*	Nozzle Type	C.R.	Std Error	S.R.	Std. Error
1.2	Mor-act	80015	91.5	6.5	90.0	0.0
2.0	Mor-act	80015	99.0	1.0	100.0	0.0
Con.	Mor-act	*****	27.5	12.5	25.0	25.0
Con.	L-77	*****	65.0	15.0	35.0	15.0
Con.	None	*****	70.0	10.0	40.0	0.0

* Surf. Type = Surfactant type.

Table 2.20b East side crown (C.R.) and stem (S.R.) reduction means for April 2,4-D treatments and controls on manzanita. Dose is in pounds active ingrdient per acre. Plots were evaluated 13 months after treatment.

Dose	Surf. Type*	Nozzle Type	C.R.	Std. Error	S.R.	Std. Error
1.2	Mor-act	80015	99.0	1.0	99.0	1.0
2.0	Mor-act	80015	100.0	0.0	100.0	0.0
Con.	Mor-act	*****	2.5	2.5	0.0	0.0
Con.	L-77	*****	0.0	0.0	0.0	0.0
Con.	None	*****	2.5	2.5	0.0	0.0

* Surf. Type = Surfactant type.

on manzanita. Overall there was little difference between analogous doses of dichlorprop and fluroxypyr for control of manzanita, but both controlled it better than imazapyr. The same patterns were true for manzanita crown and stem reduction.

The herbicides behaved similarly for ceanothus crown reduction in terms of application systems. However, stem

Table 2.20c East side pine damage means for April 2,4-D treatments and controls. Dose is pounds active ingredient per acre. Plots were evaluated 13 months after treatment.

Dose	Surfactant Type	Nozzle Type	Pine Rating*	Standard Error
1.2	Mor-act	80015	4.45	0.45
2.0	Mor-act	80015	4.85	0.16
Con.	Mor-act	*****	0.85	0.16
Con.	L-77	*****	0.85	0.16
Con.	None	*****	0.85	0.2

* Pine damage codes: 0=No damage 5=Dead

reduction was influenced by herbicide type (P=.004). Poor stem reduction was achieved with fluroxypyr. Only moderate control was achieved with dichlorprop or imazapyr, however, stem reduction was significantly higher than by fluroxypyr.

Analysis of combined data for pine damage revealed a significant interaction between herbicide type and dose (P=.028). However, there was really very little variation between herbicides or doses. The significance of the interaction was most likely attributable to differences in efficacy scales and also the lack of variation between seedlings within treatments, leading to very low variances. In the event of unforseen confounding of treatment with initial condition of seedlings this could have triggered a "significant" response, despite the rejection of trees from the sample if they had obvious pre-treatment injuries.

The second combined data set included all dichlorprop and fluroxypyr treatments. No significant factors were found to influence Ceanothus crown reduction response. However, dichlorprop caused significantly more stem damage in these arrays of dosage (P=.005).

Control of manzanita was influenced only by dose for both crown and stem reduction (P=.0003 & .006, respectively).

Ceanothus showed considerable leaf-area and stem reduction attributable to freezing. This shows up in Table 20a, where spraying with clean water, a Silwet® solution, or Mor-act® emulsion before any herbicides were applied was followed by crown loss. Cole & Newton, (1989) have observed similar losses in the same area previously.

DISCUSSION

NOZZLE-DROPSIZE TESTS

The most surprising finding in the results of the drop size tests was that the growth regulator herbicides triclopyr and fluroxypyr with no added surfactant had larger volume median diameters and lower droplet densities than glyphosate with the same nozzles. This may be the result of the physical properties (emulsions) associated with the growth regulator herbicides, despite presence of surfactants in both products. Haq, et al, (1983), has shown that high viscoelasticities and increased surface tension can increase droplet size. The droplet size spectrum for triclopyr was shifted upward relative to water when using 9503 nozzles, yet the span of drop sizes remained the same. Sundaram, et al, (1987), has attributed atomization of water in larger drops than expected to its high surface tension. It follows that triclopyr ester emulsions must have higher surface tension than water alone since the VMD for ester emulsion through the 80015 nozzles was higher than for water, yet volume delivery was the same. The same reasoning may be applied to fluroxypyr.

The resulting shift in the droplet spectra will inevitably decrease coverage, as shown by the decrease in droplet density. Richardson, (1988), has reported that the area of foliage wetted was the most important factor for control of manzanita with fluroxypyr. Therefore, the existence of a larger droplet spectrum must be taken into account where vegetation has been shown to be more sensitive to smaller drop sizes and increased coverage when using fluroxypyr or triclopyr. Whereas some problems may be alleviated with higher volumes or nozzles which produce small drop sizes, the plot data just presented did not identify a clear single-factor pattern.

The addition of Herbimax® and Activator 90® to triclopyr with 11003 nozzles made little difference in either the VMD or droplet density compared to no-surfactant applications. This was also the case for triclopyr applications with the surfactant Silwet L-77® (not shown). This may be attributable to the existence of a formulation surfactant in Garlon 4® additions to which may be superfluous. There may also be little benefit from adding an oil based adjuvant to an ester formulation, as in the case of Herbimax®, because the spray mixture is already an emulsion in water.

Fluroxypyr on the other hand, showed a marked decrease in VMD, and a resulting increase in droplet density from the addition of either Herbimax® or Activator 90® with 11003 nozzles. Therefore, the surfactants may have decreased the surface tension enough to cause droplet breakup and increase coverage (Sundaram, 1987). In view of the proprietary nature of formulation surfactants, one can only hypothesize that the fluroxypyr surfactant was different or at a lower concentration so as to permit an additive effect.

Glyphosate showed some unusual patterns depending on the adjuvant used. Activator 90® caused relatively little change in the VMD, but the droplet density decreased markedly because of the narrower spectrum of drop sizes (fewer large drops). The oil- based Herbimax® had a dramatic effect on the VMD, increasing it almost twofold as with triclopyr emulsions vs. water. The droplet density was also significantly reduced, but not by the expected factor of eight. This indicates that the middle of the drop spectrum increased in size, but very small drops were not reduced proportionally in number.

SYSTEMIC HERBICIDES

The systemic herbicides in this study include glyphosate and imazapyr. Although imazapyr does have some soil activity, it was applied in a season when soil activity was not the primary mode of uptake. Therefore, it will be considered in the same category as glyphosate.

Application Variables & Efficacy

Application variables were less influential on efficacy than originally thought with this class of herbicide. However, selectivity on ponderosa pine was substantially affected by varying application parameters.

Efficacy of June treatments on bear clover and manzanita in the Sierra Nevadas were the only treatments throughout this study that were influenced by application variables other than dose for the systemic herbicides. Volume was not found to be a significant factor contributing to efficacy in any part of this study. This is in disagreement with Lund-Hoie (1977) who found low volume treatments to be more effective on deciduous species with glyphosate, and by others who have reported that high volumes and increased coverage led to optimal control.

Surfactant also influenced efficacy on both bear clover and manzanita. Increases in efficacy attributable to the addition of surfactant are of considerable importance. When control is achieved with lower doses through the addition of surfactant, efficiency of herbicide use is enhanced. This observation is similar to those found by Burrill (1990), who found addition of the surfactant Silwet L-77® significantly increased the efficacy of glyphosate, triclopyr amine, and imazapyr on gorse (*Ulex europaeus*). This principle appears to hold for such uses as do not entail emulsions.

Drop size was also a contributor to efficacy in the form of a two way interaction between nozzle type and surfactant for manzanita. The interaction showed that different surfactants may influence efficacy differently depending on drop size. Although not significant, there was also a similar trend for bear clover, where surfactant tended to increase efficacy with the larger drop sizes, as reported by B. Richardson, (1988). Activator 90® performed best with large drops on both manzanita and bear clover. However, effects of Silwet L-77® varied between species indicating that type of vegetation has considerable influence on the effects of application parameters.

Increased influence from surfactant on large drops may be attributable to increased drying rates of smaller drops as was shown by Zabkiewicz (1988). The larger droplets may also spread more because of the combination of larger volume and reduced contact angle.

These trends were not consistent within the April treatments on bear clover or Coast Range salmonberry trials. No factors besides dose were found to contribute to increased efficacy. Both these data sets were in situations where dew or light rain would have re-wet the surfaces. it is possible that wetting would redistribute the deposits if soon after application, rendering drop size inconsequential.

Although the data for the Coast Range salmonberry trials showed there to be a significant (p=.044) and slightly significant interaction (p=.059) in the 5 gallon per acre data set between dose, surfactant, and nozzle for crown and stem reduction the interaction did not occur in the higher volume sets, and is discounted.

The combined data set for the five and ten gallon per acre treatment indicated an interaction between dose and surfactant that showed the benefits of surfactant to increase as dosage increased. The tendency for glyphosate treatments with surfactant to be less effective than those without surfactant at low dosage has no obvious explanation. Thus, the above interaction may be due to chance or be the result of some unknown artifact.

Imazapyr applications on the east side of the Cascade Range in Oregon also showed no contribution from application parameters other than dose for Ceanothus control. There was a slight trend that small drop sizes produced the best results in no-surfactant applications. Although consistent with some other data, this trend is difficult to interpret due to large variance. Treatment effects may also have been masked due to a high incidence of frost damage on Ceanothus. Therefore, recommendations for imazapyr at this time would be premature, despite signs of good general activity and moderate selectivity.

The effects of application parameters with April applications of imazapyr differed from glyphosate in that imazapyr did show an effect from the addition of surfactant on greenleaf manzanita. However, control of manzanita was very poor. Cole & Newton, (1990), showed imazapyr treatments to be ineffective on manzanita at rates as high as 1.1 kg/ha. Therefore, control of manzanita may not be achievable with any combination of application parameters unless at extremely high doses, at which soil residue would cause injury to pine (Cole & Newton, 1990).

Selectivity

Pine damage was strongly influenced by changes in application variables for April or June glyphosate treatments. Selectivity was substantially increased with April treatments and choice of products. Heavy damage occurred with June treatments with glyphosate or triclopyr, but the more selective dichlorprop and fluroxypyr were not evaluated then.

The effects of application variables on pine damage varied slightly between April and June glyphosate treatments. With June treatments, damage was shown to be increased by increasing dose and the addition of surfactant. Broadcast release treatments for bear clover or manzanita would not be feasible due to the high rates needed to adequately control either species, and thus concurrent damage to pine.

April treatments included some options with relatively little damage to pine. Selectivity was shown to be increased also by using small drop sizes (300-400μm) and no surfactants. The involvement of surfactants with pine damage was a general phenomenon. Imazapyr produced relatively little pine damage and was not influenced by any application parameters. However, imazapyr did cause inhibition of needle elongation and because of the possibility of long term inhibition, it should be used with caution. Treatments to release ponderosa pine from Ceanothus should be possible with only slight damage to planted seedlings, but treatments would not provide appreciable release from manzanita. Thus, imazapyr may have to be combined with another product, such as a low rate of fluroxypyr or dichlorprop for broad spectrum release.

Chemical Effectiveness

In general, the initial evaluations of glyphosate treatments on bear clover did not differ very much between April and June treatments. Initial results were only moderate to poor with the rates used in this study. However, second year evaluations showed that despite poor initial results, dieback continued to increase with time, and new sprouts were not replacing the above-ground parts. Similar results were obtained by Newton & Fredrickson, (unpublished data), with April treatments of glyphosate on bear clover, in which resprouting was totally inhibited one year after treatment. Similar results were obtained by McHenry et al. (1980). Therefore, the ability of glyphosate to inhibit sprouting may provide the best means for long term control. However, there was also a tendency for treated bear clover to be replaced gradually by grasses and thistles so as to negate some of the release effect. Thus, there may be a need to use a residual product, such as hexazinone, in combination with glyphosate treatments.

The results for the June treatments of bear clover do not correspond well with Lanini, (1981), who obtained excellent results with 2.5 kg/ha applied in June. Higher rates may be required to control bear clover in June. Coombes & McHenry, (1983) obtained excellent control with 4.5 kg/ha of glyphosate. April treatments of glyphosate on bear clover also correlate reasonably well with work by Jackson & Lemon, (1986), who found that April treatments were slightly inferior to June treatments when bear clover was in full flower, evaluated one year after application. Lanini, (1981), also found control of bear clover to be positively correlated with photosynthesis. In the long run, it is not clear whether the later die-back will continue to reduce the competitive power of bear clover.

Control of manzanita was poor with the rates used in the June treatments. Lanini, (1981), reported good control with 9 kg/ha in June treatments, and 4.5 kg/ha in May. Considering the alternatives observed in our experiments, this is not an efficient use of herbicide, nor is it selective. The data presented for Oregon in this study gives a more suitable choice of chemicals for manzanita control.

Glyphosate is an effective chemical for control of salmonberry. In view of rate being the only important variable tested, the rates of 0.83 - 1.1 kg/ha currently practiced will not change because of these findings.

Imazapyr should provide good control of Ceanothus with rates as low as 0.2 lb/ac. using 80015 nozzles; surfactant was unnecessary. Observations for this treatment had relatively little variance, but the erratic occurrence of frost damage severely weakened sensitivity of the experiment because of heterogeneity from treatment to treatment.

GROWTH REGULATOR HERBICIDES

The growth regulator herbicides included in this study are triclopyr, dichlorprop, fluroxypyr and 2,4-D. Although triclopyr was the only growth regulator that was tested using different nozzle types, there is no physical or chemical reason for any of the other herbicides to behave differently. Therefore, triclopyr dropsize data will be interpreted as being applicable to the other growth regulator herbicides.

Application Variables & Efficacy

There were distinct similarities as well as some differences attributable to changes in application parameters between type of vegetation treated, geographic location, and timing of treatment. As demonstrated by triclopyr, drop sizes in the range of 500 to 600 μm consistently produced better results than larger drops on manzanita in June and bear clover in April in the Sierras. However, with April bear clover treatments the nozzle effect became less pronounced as surfactant was added to the solution. The reasoning was that differences in foliage wetted were removed when Silwet L-77® increased drop spread. Similar results were found by B. Richardson, (1988). The same may be said for the addition of Mor-act®(and presumably Herbi-Max®). June treatments on manzanita in California showed small drops to perform better than large drops. This became more apparent as dose and volume were increased. This varies from April treatments on the east side of the Cascades in that the drop size effect tended to become less apparent with increasing dose in April. The June results are in disagreement with work by R.G. Richardson, (1983), who has deemphasized the importance of leaf coverage and relates increases in efficacy to other factors such as dose.

East side Cascade treatments on Ceanothus and manzanita revealed strong differences attributable to application parameters between Oregon and California. No application factors besides dose played a role in increasing efficacy on Ceanothus. Furthermore, drop size effects on control of manzanita were the opposite of California trials (i.e. drops greater than or equal to 1100 μm produced better results). These results are in strong disagreement with results found by B. Richardson, (1988), who found sprays with a VMD of 240 μm increased control of manzanita compared to sprays with a VMD of 830 μm using fluroxypyr applied in September.

Therefore there may be a relationship between drop size and timing of application, perhaps related to humidity and/or dew. The reasoning for the greater efficacy with increasing drop size is unclear and contrary to most published work, but the pattern was highly significant here. However, Baker & Hunt, (1985), did find that while retention was increased with smaller drops, uptake (% of retained dose) was higher with larger drops.

The addition of surfactant did not increase efficacy with the growth regulator products in either the June California trials on bear clover, or the April east side Cascade treatments on Ceanothus or manzanita. Similar results were obtained by Whitson & Adam, (1990), with fluroxypyr on leafy spurge. Obtaining no effect or negative effects from the addition of surfactant may be due to increased abosorption of the chemical which could in turn neutralize the transport system as was shown by Mcwhorter, (1985), with phenoxy compounds. Added benefit from the addition of surfactant was seen with April treatments on bear clover in California. However, selectivity was strongly decreased by adding surfactant in all seasons and sites, which will be discussed further in the Selectivity section.

Selectivity

Seasonal selectivity of the growth regulator herbicides was increased with April treatments compared to triclopyr treatments in June. However, the selectivity of triclopyr was the poorest of any growth regulator other than 2,4-D, even in April. Therefore, triclopyr treatments for release of ponderosa pine should be avoided if possible if there are other suitable chemicals which are known to produce less damage without sacrificing efficacy. Triclopyr does have excellent potential for site preparation treatments.

The influence of drop size on selectivity varied with geographic region. June treatments with the growth regulator herbicides in California showed increases in pine damage using drop sizes in the range of 500 to 600 μm compared to larger drops with the ten-gallon-per-acre treatments, but this was a season of maximum damage anyway. The reverse pattern of the low volume treatments may be due to higher concentrations of active ingredient within each droplet coupled with the larger droplets achieving better penetration of the canopy. It would make sense that nozzles which produce smaller droplets and hence increase the density of droplets per unit area would cause more damage than larger droplets due to an increase in coverage. The exception would be on species affected so slowly by triclopyr that the highly concentrated large droplets would diffuse more completely into the foliage, hence they may move before phloem necrosis occurs. A similar pattern was seen in the April treatments on the east side of the Cascade range with triclopyr where large droplets also produced more damage. The April treatments in California showed no differences attributable to drop size with respect to pine damage. The reason for this is unclear when such distinct differences occurred in other areas of this study.

Pine damage was increased more than damage to target species by the addition of surfactant. This was true for triclopyr regardless of geographic location or timing, provided dosage was sublethal. The addition of surfactant increased the damage to seedlings with fluroxypyr and dichlorprop in the April treatments in California, but not with the April treatments on the east side of the Cascades in Oregon. However, the eastern Cascade treatments also did not benefit in any way from surfactant in terms of efficacy. Therefore, surfactant is ill-advised for all east side Cascade applications on Ceanothus or manzanita.

In almost all cases, increasing the rate of application increases damage to seedlings. The only exception to this was the April treatments on the East side of the cascades with fluroxypyr and dichlorprop which proved to be very selective at this time.

Chemical Effectiveness

All growth regulator herbicides will provide acceptable topkill of bear clover in the seasons tested, although rates may have to be adjusted from those used in this study. Good topkill by triclopyr was achieved with 0.9 lbs/ac. in June.

This is a much lower rate than has been used in previous studies such as Lanini, (1981). Lanini has also shown good control of bear clover by a very high rate of dichlorprop (4.5 kg/ha) in June. 2,4-D has been shown to provide good topkill in June with as little as 1.0 lbs/ac., McHenry et al., (1980). Good topkill has been shown in the previous chapter by April treatments of triclopyr, dichlorprop, and fluroxypyr at 0.9, 2.0 and 1.0 lbs/ac., respectively. Good topkill was achieved with April treatments of 2,4-D in this study with 2.0 lbs/ac..

The growth regulator herbicides are not recommended for long term control of bear clover. Rhizome excavations and evaluation of above ground post-treatment resprouting of bear clover has shown these chemicals to be ineffective in their ability to control resprouting of bear clover, even after complete topkill (See chapter 1).

Although manzanita was not treated with any chemical other than triclopyr in California, much of the oregon data should be applicable to determine suitable chemicals for control. As of yet, triclopyr has not been shown to be able to adequately control manzanita in California.

For control of manzanita and Ceanothus when they occur together, the best control of both species was achieved with dichlorprop. This treatment also resulted in minimal pine damage.

RESIDUAL HERBICIDES

The residual herbicides in this study include atrazine, and hexazinone in both liquid and granular form.

Application Variables & Efficacy

Oregon Coast Range grass sites and grass sites on the east side of the Cascade Range differed in their responses to changes in various application parameters. No effects were seen from changes in any application parameter on the Coast Range grass sites. Conversely, grass responses on the east side of the Cascade Range were influenced by such factors as product, dose, and nozzle.

The Coast Range data fails to show consistency with work done by Prasad, (1985), who found the addition of surfactant and smaller drop sizes increased the efficacy of Velpar® on white birch seedlings, but deciduous woody species with foliar uptake were not evaluated here. In the absence of a nozzle effect, it would be logical to use nozzles which deliver nearly all of a product to the target. Since surfactant was not found to be a significant factor, it is appropriate to apply residual herbicides without surfactant, through large orifice nozzles.

East side trials were more responsive to application parameters. However, the differences were slight and probably not distinguishable enough to provide bases for recommendations. The fact that 80015 nozzles produced better results than the RD-6 nozzles in the low dose liquid hexazinone treatments may be linked to reliance on foliar uptake in view of the lack of spring rain as was shown by Prasad, (1985). The fact that this trend was not apparent in the high dose applications may result from the effect of drop size being offset by increasing dose, and near-asymptotic effects with any drop size.

East side atrazine treatments showed the opposite trend, with large drops more effective in the lower doses. As dose increased, the smaller drop sizes actually produced better results. The pre-emergence nature of these treatments suggests this is an artifact probably due to random chance. Despite large drops producing better results in low dose applications, control was poor and doses as low as this would not be used in a practical setting. Therefore, drop size is likely not an important factor in prescribing atrazine or other pre-emergence treatments, except with regard for minimizing losses while spraying.

Addition of surfactant did not influence efficacy of Velpar L treatments with either nozzle type. Surfactant appeared to increase control of forbs with the RD-6 nozzles in the atrazine treatments. However, high variance associated with the no-surfactant RD-6 applications makes this a moot point. No added control of forbs was achieved from the addition of surfactant to atrazine treatments with the 80015 nozzles. The slight trend that 80015 nozzles performed slightly better on forb cover can probably be ignored. Forb cover reduction in any case was minimal.

The results of this series of experiments were not strong enough to modify or extend label recommendations. Therefore, optimum applications of Velpar L and atrazine largely as pre- or early post-emergence treatments, would likely entail drops large enough to deliver a maximum targeting of the spray, and without surfactants.

Chemical Effectiveness

Atrazine and granular hexazinone were not effective treatments in the Oregon Coast Range, Nor was granular hexazinone effective on the east side Cascade site. This may have been partially due to the lack of spring rain, hence lack of root contact, and also the high incidence of grasses of known tolerances to Atrazine. Atrazine efficacy on bent grass and most annuals is well known, and these findings do not apply where atrazine-resistant species are not prevalent. Many such experiments have been reported.

Higher residual grass density from 0.6 lb/ac. applications of Velpar L may lead to late season development of very vigorous clumps of weeds not removed by the submarginal treatment. Therefore, rates of at least 1.0 lb/ac. would be recommended for operational use in this plant community. Velpar L also produced better results with the east side plots than west side, and is the recommended chemical for operational use, at rates equal to or slightly higher than 1.0 lb/ac.

CONCLUSIONS

Several main points can be obtained from the data obtained in this study.

The first point is that June treatments may be recommended for site preparation, but not for release with both the systemic and the growth regulator herbicides. April treatments with glyphosate in California for bear clover, dichlorprop or fluroxypyr on manzanita and Ceanothus and imazapyr on Ceanothus are much more selective treatments when used over ponderosa pine.

Second, the use of surfactants should be avoided for release treatments with both systemic and growth regulator herbicides. Minimal gains in efficacy may be drastically offset by increased damage to conifers. Use of surfactants for site preparation has merit in few circumstances, and gains are minor. Selectivity on ponderosa pine may be further increased with no-surfactant applications in combination with drop sizes in the range of 300 to 400 μm for glyphosate in April release treatments in California, and in the range of 500 to 600 μm with April release treatments for growth regulator herbicides on the east side of Cascades.

Third, the addition of surfactant does not always increase herbicide efficacy. The only cases in this study where it did improve efficacy was with glyphosate in June treatments on bear clover and manzanita in California, and with the growth regulator herbicides in April treatments on bear clover. In any case, the addition of surfactant should only be used in site preparation treatments.

Fourth, dose played the most prominent role in this study for increasing efficacy, compared to other application parameters. This is in agreement with other findings by Brewster & Appleby, (1990), and R.G. Richardson, (1983). However, it should be noted that increasing dose also decreased selectivity for both systemic and growth regulator herbicides. Higher doses also increase efficiency if they are needed to achieve treatment objectives. In several of the treatments of these experiments, the higher or highest rate of application is needed to achieve longer term control.

Fifth, The relationship of drop size to efficacy is still fairly unclear and highly variable. However, drop sizes greater than or equal to 1100 μm appear to increase control of manzanita with the growth regulator herbicides for April treatments on the east side of the Cascades. Although drop sizes in the range of 500 to 600 μm produced better results with the growth regulator herbicides on manzanita in June and on bear clover in April in California, their use is not recommended due to poor control of manzanita and a high potential for resprouting of bear clover. The effect of drop size seems to vary with timing of application, chemicals used, surfactant used, and type of vegetation treated.

Sixth, it should also be noted that all chemicals do not physically behave in the same manner. This was demonstrated by the growth regulator herbicides with ester emulsions producing a larger drop size spectrum than the non-oily amine solutions through the same nozzle.

Seventh, the manager should be aware of the high potential for resprouting of bear clover with the growth regulator herbicides. Herbicides which directly inhibit the rhizome system such as glyphosate, should be used for long term control. Based on other research, imazapyr may hold similar promise.

Eighth, the invasion of other herbaceous vegetation should also be taken into account and possibly prevented or altered by follow up residual herbicide treatments. Thus, early observations are inappropriate bases for long-term estimates of reduction in competition. In many instances effective doses will also have to be mixed with residual products to prevent substitute weed cover from compensating for removal of target shrubs.

Chapter 3

Management Guide for Efficient Herbicide Use

INTRODUCTION

The purpose of this management guide is to assist forest managers in improving the efficiency and efficacy of forest herbicide applications for site preparation and release. The recommendations contained herein are generalizations in the form of "decision trees" for herbicide prescriptions. They are derived from experiments in several vegetation types for foliar and soil active products. Each experiment was designed to show the influence of application parameters to certain target species at a few selected times. A complete guide would be encyclopaedic. The user can adapt locally from the behavior of certain classes of product, even where the data originate elsewhere.

The management guide is designed to integrate some complex interactions, hence ease the decision making process. Application rates for individual herbicides are identified for only one level of control. Detailed treatment descriptions for individual products are contained in the previous chapter, and provide a guide for users with varying degrees of control and selectivity in their goals.

The dosage range in the experimental data was not always adequate. Some of the information for chemicals for which our data was lacking were taken from relevant literature pertaining to the vegetation treated and timing of application.

These recommendataions were made with the assumed goal of obtaining the maximum efficacy using the lowest amount of chemical, i.e. maximum efficiency. Various application parameters were added or deleted to herbicide treatments depending on their contribution to increased efficacy or selectivity. Both site preparation and release treatments were taken into account.

Surfactants, drop size, and volume per acre had only minor effects on efficiency. Surfactants generally increased conifer injury, as did large drops, with certain exceptions. Volume was not found to be a significant factor contributing to efficacy in these experiments. Therefore, recommendations on volume have been deleted from the management guide. The user should recognize that low volumes are innately less costly, but they were not evaluated here under any but low-stature vegetation conditions and moderate leaf areas. Further experimentation may be required to determine precise adaptation of drop size distributions from aerial applications. All patterns observed here were from ground-based experiments, but the range of drop sizes tested included the entire range of aerial spray drop sizes with conventional nozzles. Thus, it is unlikely that the choice of ground vs. aerial equipment will influence results appreciably.

Selectivity data are found in Table 1. Table 2 contains dosing suggestions to provide greater than 80% crown reduction of target species. It should be noted that the dosage table does not provide specific doses for all treatments, and it is likely that other effective treatments exist. A few of the herbicides do not provide adequate control of certain species, and much of the literature did not reflect high enough use rates to obtain greater than 80% control for species examined here.

Safety from herbicide drift has been a major concern. Whereas this is not a common problem in forestry applications because forests and susceptible crops are seldom in close proximity, the principle of minimizing losses is sound for many reasons. Moreover, drop size and density appear less critical to efficacy than expected. Thus, users are encouraged to use nozzle systems providing VMD's of over 400 microns in all routine applications unless fine drops are clearly indicated, as in certain release treatments. During periods of low humidity, or high-level aerial spraying, large drops are indicated. Thus, for aerial spraying, D-8-46 or D-10-46 angled back are suggested for most low flying under average or humid conditions. RD-4 or D-8 jet nozzles are appropriate for high flying or low-humidity conditions. Even RD-6's likely have a place for such work.

No nozzles eliminated all fine drops. Users are to assume that off-site movement will occur with all sprays. Drift free application can only be assured when air movement is away from or tangential to sensitive crops or residences. A smoke column at the property line is the only tangible proof of where the air is taking the fine particles. This is recommended practice near sensitive boundaries.

HOW TO USE FOLIAGE ACTIVE PRODUCTS

WEST SIDE SIERRAS

Herbicide treatments on the west side of the Sierra Nevada Mountains in California dealt with bear clover and manzanita with spring and summer applications. Included were both growth regulator and systemic herbicides. Figure 3.1. provides a decision tree illustrating the treatment selection choices for the west side of the Sierras.

Broadcast Release

Generally, release treatments applied broadcast to shrub-dominated ponderosa pine plantations should be applied in early spring. Midsummer treatments are extremely risky to pine. Glyphosate and triclopyr caused severe injury to pine in summer with minimal doses. Although good topkill of bear clover was achieved with triclopyr ester, directed sprays are not recommended due to high risk of injury from accidental overspray.

Release treatments in April are much more selective on ponderosa pine, in both California and Oregon, but dosages need to be somewhat lower in Oregon in most instances for comparable selectivity. The chemicals available are dichlorprop, triclopyr, and glyphosate. Although fluroxypyr provides moderate results on bear clover and on manzanita (from analogous Oregon data), it is currently not registered for use in forests except experimentally. Doses were selected to provide maximum control with the least injury to planted seedlings. Table 3.1 gives upper limit for conifers, Table 3.2 gives lower dosage to provide 80% crown reduction.

The chemicals suggested for spring manzanita control in California were taken from an analogous experiment on the eastern side of the Cascade Range in oregon. The glyphosate data were taken from Lanini, (1981). The high dosage of glyphosate should still be in the low-moderate damage range for conifers as long as no surfactant is added.

The optimal drop size was between 300 and 400 μm for glyphosate and 500 to 600 μm for triclopyr for control of bear clover. Triclopyr with no surfactant generally gave best control of bear clover with medium droplets. The other growth regulator herbicides were assumed to behave similarly to triclopyr with respect to dropsize. Pine damage from glyphosate was significantly reduced when using small droplets. Triclopyr showed no influence of drop size on pine damage.

Manzanita showed no clear response to drop size in early spring. Therefore, small droplets were again suggested for minimal pine damage in release operations, in general, in manzanita. Analogous evidence from Oregon determined that sprays with a VMD of approximately 1100 μm controlled greenleaf manzanita more effectively than smaller drop sizes. Since drop size was not a factor concerning pine damage with triclopyr, larger drops were suggested. This is not a strong recommendation.

One important factor to consider is that the growth regulator herbicides have a tendency to produce larger drop spectra for a given nozzle than glyphosate.

Selectivity data were presented for chemicals in California, and Oregon, with the observation that Sierra vegetation tolerates somewhat more herbicide in most instances. The rates for control may have to be adjusted downward between 25 and 50 percent between California and more northern applications. Increasing rates of triclopyr ester over 0.6 # a.i./ac. for release would not be possible due to severe pine damage.

The most important factor for release applications is avoidance of surfactants. This is not because surfactant gives no added control, but that it disproportionately increases the amount of damage to conifer seedlings. This trend is consistent for all herbicides tested and all surfactants. Surfactants are sometimes helpful in site preparation.

Site Preparation

Both June and April treatments are effective for site preparation. For June applications, glyphosate, triclopyr, and probably 2,4-D, dichlorprop and fluroxypyr are suitable products for bear clover and manzanita control in summer as well as spring. Dichlorprop was reported to be an effective product on bear clover by Lanini, (1981). Substantial resprouting can be expected after use of the growth regulators, but an undetermined percentage of those sprouts may eventually fail, based on experience with triclopyr.

Doses will be higher for site preparation than for release to provide for the longest possible term of competition reduction. Greater rates than were tested in the application technology study are neccessary for chemicals such as glyphosate and triclopyr on manzanita, and for glyphosate on bear clover in June. Efficacy of 2,4-D, dichlorprop and fluroxypyr suggest the use of mixtures for removal of several species. Hexazinone or its equivalent (e.g. sulfometuron) would prevent replacement of shrubs by grasses.

The addition of Silwet® L-77 at .15% v/v or Activator 90® at .5% v/v did improve control of bear clover with glyphosate, and Activator 90® significantly improved control of manzanita in June. Addition of a growth regulator product to the glyphosate mixture would be more efficient for controlling manzanita in a site prep situation.

Surfactant did not increase efficacy of glyphosate on bear clover in April. No spring data were available for the effects of surfactant on control of manzanita with glyphosate; presumably, surfactant effects are consistent from season to season. The oil based adjuvants at 5% v/v did increase control of bear clover for the growth regulator herbicides in April. However, no added benefit was seen from the addition of Mor-act® on greenleaf manzanita (analogous Oregon data) for the growth regulators.

Drop size was not a factor in control of bear clover by glyphosate in June. Therefore it is suggested that sprays be delivered with equipment that delivers a large-drop spray (VMD > 800 μm) for maximum targeting efficiency. Triclopyr and dichlorprop efficacy may be optimized on bear clover by using medium drop sizes at low doses (0.9#/ac. for triclopyr). Sprays with a VMD between 500 and 600 μm may produce maximum effect per unit of dosage when low doses are used. As dose increased to 1.5#/ac., the drop size effect became less pronounced. Therefore, it may be better to use larger drop sizes if higher rates are needed for other species.

Drop size does not obviously influence efficacy with glyphosate or growth regulator herbicides on bear clover in early spring treatments. Therefore, nozzles that deliver large drops to the target (=> 1100 μm) are recommended for bear clover alone.

Results of greenleaf manzanita work in Oregon suggest that growth regulator herbicides provide optimum control with larger drops. Therefore, the same application system is appropriate for improved control. These drop patterns should be applicable to California work as well.

Manzanita control with glyphosate appears somewhat influenced by drop-size when applied with the surfactant Activator 90. A drop spectrum with a VMD greater than 500 μm should produce more favorable results than smaller drop sizes. Again small-medium drop spectra (i.e. 500 - 600 μm) with growth regulators will produce better results for manzanita.

April site preparation treatments are backed by data for a wider array of chemicals. Rates which will produce greater than 80% control are listed in Table 3.2. The herbicides listed for control of both manzanita species are extrapolated from Oregon data on greenleaf manzanita. The rates may have to be elevated 50% for California. The glyphosate data were adapted from Lanini, (1981), and are applicable to California.

Long-Term Projections

One of the most important factors to consider for treating bear clover is the response of vegetation after treatment. All herbicides used to treat bear clover except glyphosate resulted in resprouting within months after application. Glyphosate has been shown to effectively control sprouting above ground by suppressing the rhizome system below with April treatments (Chapter 1). It therefore has the best potential for long term control of bear clover despite poor early ratings.

The full effects of glyphosate applications on bear clover may take more than a year to materialize. Rates between 3 and 4 pounds per acre should adequately control bear clover in April, but for greatest efficiency, site preparation is more appropriately done in a later season.

Grass invades after treating bear clover and manzanita. It was observed that on fertile sites where the bear clover and manzanita had been removed, grass colonized the treated areas soon after, and may preempt resources released for conifers. Tank mixes or follow-up treatments with residual herbicides such as hexazinone, sulfometuron or atrazine may be required to postpone the grass invasion, especially if the conifers are too small to be effective competitors.

It should also be noted that generally poor control of whiteleaf manzanita was achieved with June triclopyr or glyphosate treatments at the rates used in this study. Further trials may be required to determine adequate rates for control with triclopyr and glyphosate. Meanwhile, Oregon data for dichlorprop, 2,4-D, and fluroxypyr on greenleaf manzanita suggest these products for confirmation trials in whiteleaf manzanita/bear clover vegetation types.

EAST SIDE CASCADES

This section deals with greenleaf manzanita and ceanothus, two predominant brush species on the east side of the Cascade Range in Oregon. The herbicides of interest consisted of growth regulator herbicides and imazypyr. Due to findings in the California trials, volume was determined not to be a factor contributing to efficacy or efficiency of applications. Therefore, recommendations on volumes are not contained in this document. See Figure 3.2 for the east side Cascades decision tree.

Broadcast Release

April treatments were the only time period looked at for release and site preparation treatments. The data showed good control of ceanothus by triclopyr, dichlorprop, imazapyr, and fluroxypyr. All four herbicides are suitable for broadcast release of ponderosa pine under competition from ceanothus. Imazapyr may also be suitable in California, but was not evaluated.

Rates were determined to provide the maximum amount of control with the least amount of pine damage. Rates for chemical release treatments can be found in Table 3.1. Of the four chemicals suggested, fluroxypyr gave the least amount of control. Stem reduction will be poor for fluroxypyr treatments, and therefore, the possibly of resprouting is high.

The addition of surfactant added no additional control to any herbicide listed. Therefore no surfactant applications are recommended for treating east side brush. The addition of surfactant to triclopyr also significantly incresed the amount of pine damage even at low rates.

Drop size was not found to be a factor influencing efficacy on ceanothus. However, drop size was found to significantly influence pine damage. Large drops ($\approx$1100+μm) produced more damage than smaller drops (500-600 μm). Therefore, it is recommended that droplets in the medium or smaller range be used for early spring release of ponderosa pine from east side brush.

Dichlorprop and fluroxypyr were found to be the only suitable chemicals for release from manzanita. Triclopyr was not included due to the fact that the only suitable control was achieved with large droplets. Unfortunately, these large droplets also produced severe pine damage, even at low doses. Imazapyr provided no control of manzanita at all. Rates for manzanita control are shown in Table 3.2.

The surfactants tested for this study had no influence on control of greenleaf manzanita. Therefore, their addition to east side applications is superfluous.

The appropriate drop size range should have a VMD between 500 and 600 μm. Excellent control of manzanita was achieved with this drop size. If fluroxypyr and dichlorprop are assumed to behave as triclopyr, the amount of pine damage will also be less than if using large droplets.

Site Preparation

Control of east side ceanothus for site preparation treatments can be achieved with the same four chemicals as the release treatments, and also 2,4-D (this product is less effective on *Ceanothus velutinus* var. laevigatus on the west side). All herbicides except for imazapyr provided excellent control of manzanita. April was the only season looked at, but previous work by Cole & Newton, (1989) suggest near maximum effect at this time. Higher rates can be used if neccessary if there is no pine. Rates for site preparation can be found in Table 3.2.

Surfactants used in this study as noted in the release section provided no further control of brush species, and serve largely to injure pine if they happen to be present.

Since drop size also had no effect on control of ceanothus, large drops are appropriate to deliver the highest possible proportion of spray to the target. Because the largest drop sizes also gave superior control of manzanita the same drop size range is recommended for ceanothus and manzanita except when releasing pine.

<u>Long-Term Projections</u>

If one is using triclopyr to release from Ceanothus, adherance to the the recommendations in this guide should not be compromised. If it is not possible to use drop sizes within the range suggested, an alternative herbicide should be used.

It may be possible to obtain improved results on manzanita with growth regulator herbicides in general by use of large drops, based on triclopyr data. If large drop sizes improve control by dichlorprop, fluroxypyr and 2,4-D as they did with triclopyr, it may be possible to use lower rates. However, further testing should be conducted to verify this, and also to determine whether selectivity remains.

OREGON COAST RANGE

Figure 3.3 provides the decision tree for the Oregon Coast Range, based on data from glyphosate experiments on young Salmonberry. While Douglas-fir was present on the site, no damage was evident. There was also found to be no influence of volume on efficacy or efficiency, so it was not included in the recommendations.

Overall, there is little difference in application parameters between expected use for broadcast release and site preparation. Rates may be slightly higher for site preparation, and higher doses of imazapyr may be added to increase spectrum of control if needed. For adequate control to be achieved, higher rates than were used in this study are required. 0.75-1.0# a.i./ac. should provide excellent control of salmonberry with little risk to Douglas fir seedlings. Recommended rates are listed in Table 3.2.

The addition of surfactants Silwet® L-77, and Activator 90® provided little if any added benefit for control of salmonberry. Surfactant may be needed for other species if conifers are not present, but it is generally recommended that applications be made without surfactant. This would produce considerable savings in the costs of application.

The decision tree suggests use of large drops in all situations. Drop-size had no effect on the efficacy or efficiency of glyphosate on salmonberry. Because large drops deliver a high proportion of the spray to the target, they are recommended for all applications of this class of products to deciduous Coast Range brush types.

HOW TO USE RESIDUAL PRODUCTS

The residual herbicide decision tree is outlined in Figure 3.4. The timing for grass control on the east-side of the Cascades and the Coast range should take place in mid-March, eastside applications are also effective in the fall. Adequate rain is essential for enhanced control of grass through soil uptake. More precipitation is required for chemicals with low solubility, hence materials such as atrazine are often applied in fall where spring rains are less than 2-4 inches.

OREGON COAST RANGE

Liquid hexazinone was the only herbicide tested that provided adequate control of grass For April treatments in the Coast Range. Atrazine and the granular form of hexazinone, were found to be ineffective in the data sets developed in 1992, but these products have proven highly effective elsewhere. Application parameters do not differ between release and site preparation treatments.

Herbicide efficacy is very different on certain annual vs. perennial species. Atrazine is highly effective on annuals, but is registered for selective weeding in perennial grass seed crops. Hexazinone and sulfmeturon methyl are highly effective on perennials. 2,4-D may be added to broaden the spectrum of atrazine or sulfmeturon on forbs, but ponderosa pine is very sensitive, hence such mixtures must be applied before planting. On dry areas, atrazine will have to be applied in fall where pine is present. Other broadleaf products discussed earlier can substitute for 2,4-D in tank mixes provided pine is not growing actively.

Rates for adequate control of grass are presented in Table 3.2. The rates do not differ between site prep and release treatments. Velpar L is extremely selective on Douglas-fir and risk of injury to planted seedlings is minimal.

Neither an oil adjuvant or drop size had any effect on efficacy of Velpar treatments. Therefore, applications may be applied for maximum net benefit without surfactant. To deliver the highest proportion of product to the target, nozzles which produce a large drop-size range should be used.

Long-Term Considerations

Although no tests were run in California with the residual herbicides, their use should be considered for follow-up treatments or in combination with treatments designed to control manzanita or bear clover. Atrazine would be a good candidate for evaluation in this use.

EAST SIDE CASCADES

Both liquid hexazinone and atrazine were shown to provide adequate control of grass on the east side of the Cascades. Liquid hexazinone treatments produced slightly better results than atrazine. Granular treatments of hexazinone were found to be ineffective for control of grass, but may require fall application for maximum effect. Again there were no differences among application parameters between release and site preparation treatments. Therefore, they will be discussed together.

Doses are found in Table 3.2 that provide good control of grass. Both atrazine and liquid hexazinone are extremely selective on Douglas-fir. Therefore, obtaining adequate control from release treatments would not be constrained by the risk of fir injury within registered use rates.

An oil adjuvant had no effect on efficacy on grass. Therefore, no-surfactant applications are recommended for control of grass.

It did appear as though there was some interaction between drop size and efficacy, but the trends were hard to distinguish. They may have been more apparent if adequete amounts of rain had occurred. Therefore, no recommendations on drop size can be given other than applying herbicides with nozzles that provide a coarse spray to deliver a maximum percentage of the spray to the target.

EXPANDING THIS GUIDE

The recommendations in this guide concerning the various application parameters and types of herbicides may be expanded to encompass outside efficacy data from other herbicides of the same product class. In other words, other growth regulator, systemic, or residual products should behave similarly to those studied here. Therefore, the same efficiency guidelines are most likely applicable.

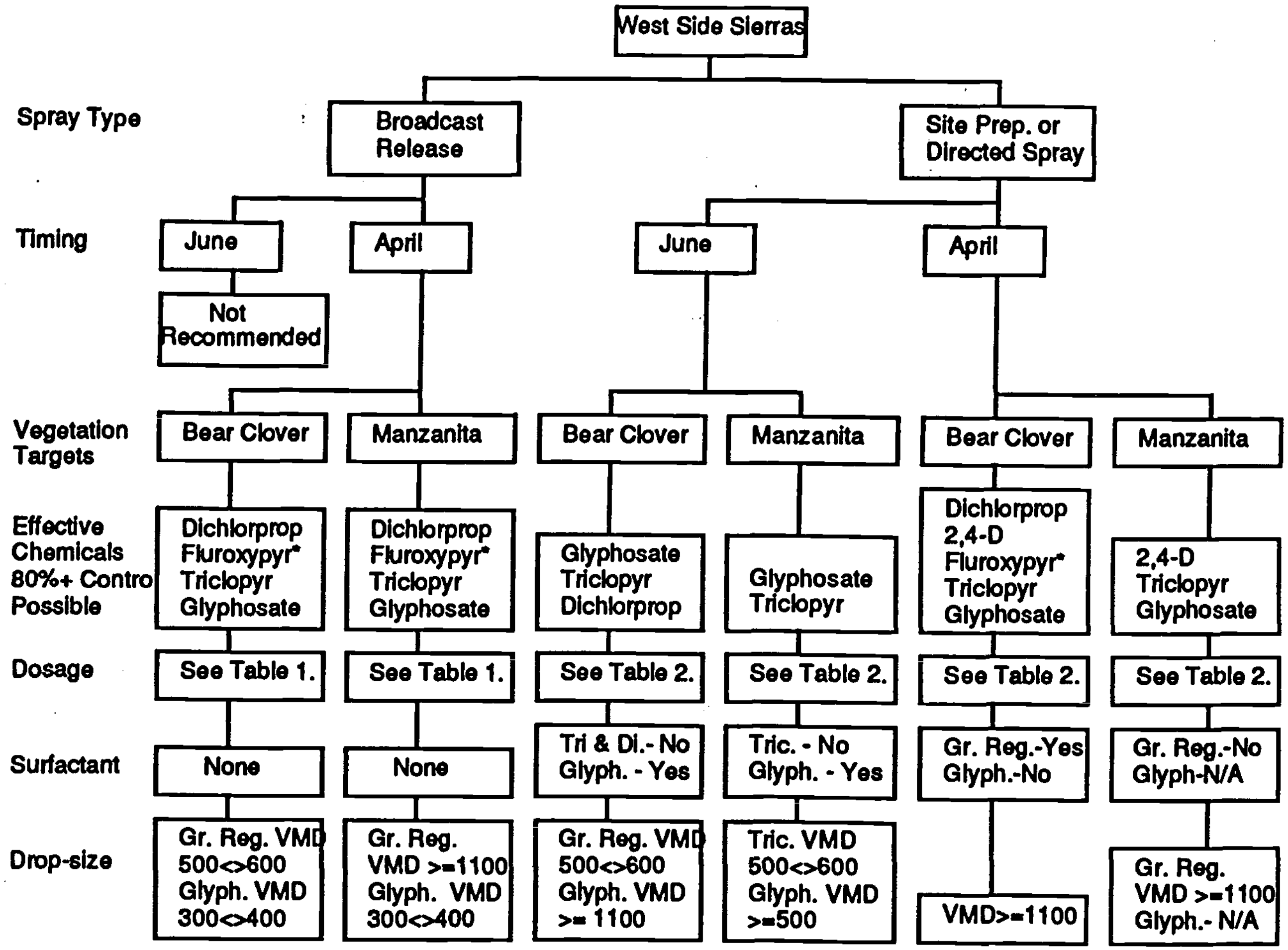

Figure 3.1 Foliage active herbicide decision tree for the west side of the Sierras. VMD's are in microns. VMD=volume median diameter--the dropsize at which 50% of the spray volume is contained in droplets larger or smaller than the VMD. * Not registered in California as of 7/93.

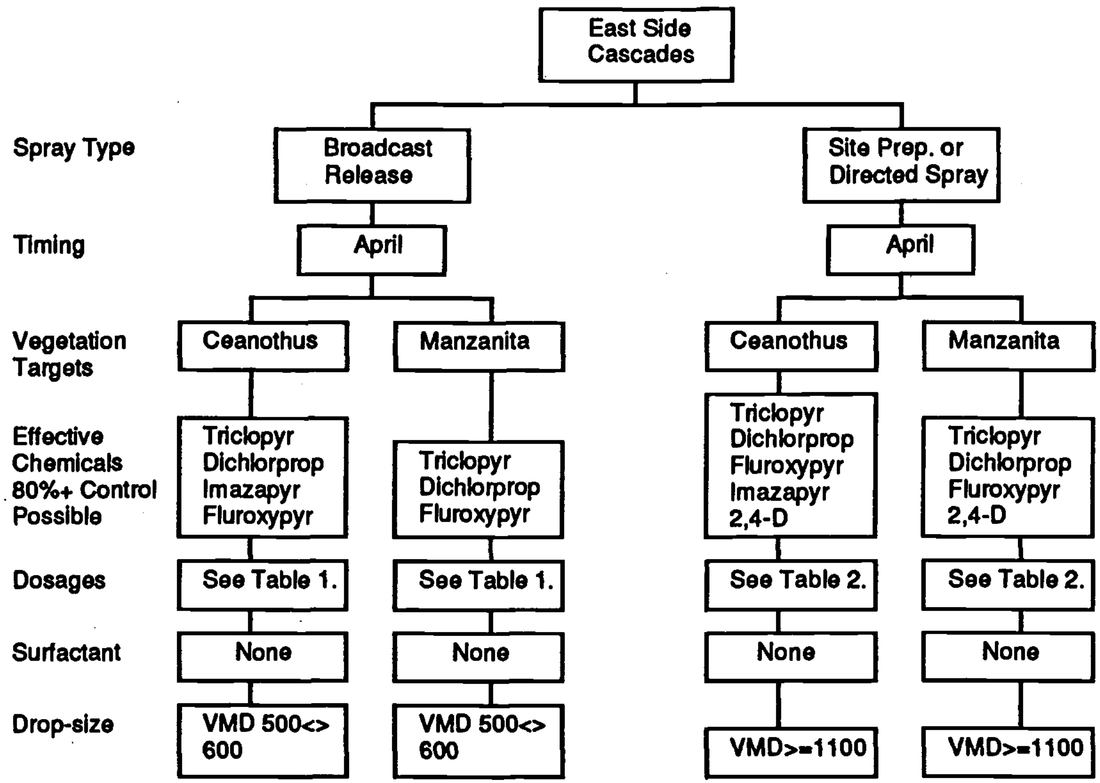

Figure 3.2 Foliage active herbicide decision tree for the east side of the Oregon Cascade Range. VMD's are in microns. See Figure 3.1 legend for definition of VMD.

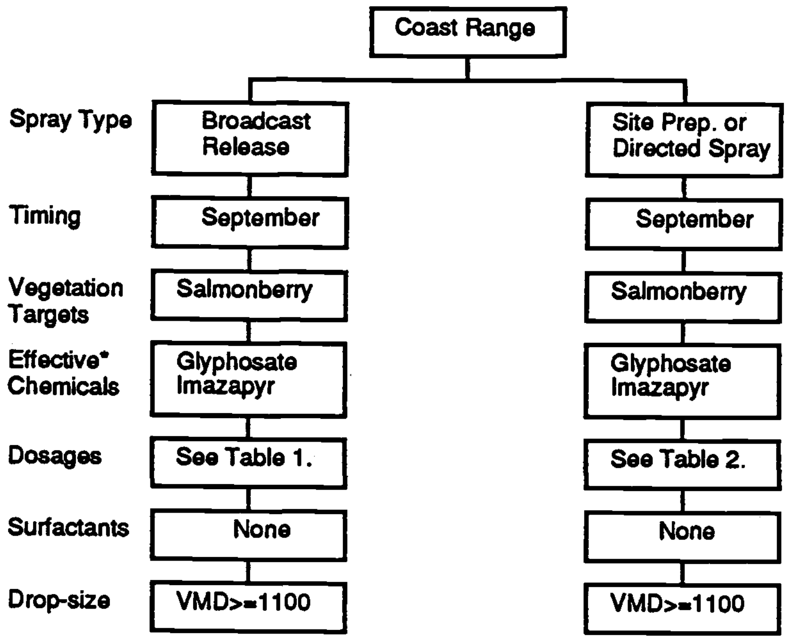

Figure 3.3 Foliage active herbicide decision tree for the Oregon Coast Range. VMD's are in microns. See Figure 3.1 legend for definition of VMD. * The treatments listed have the potential to produce 80%+ control.

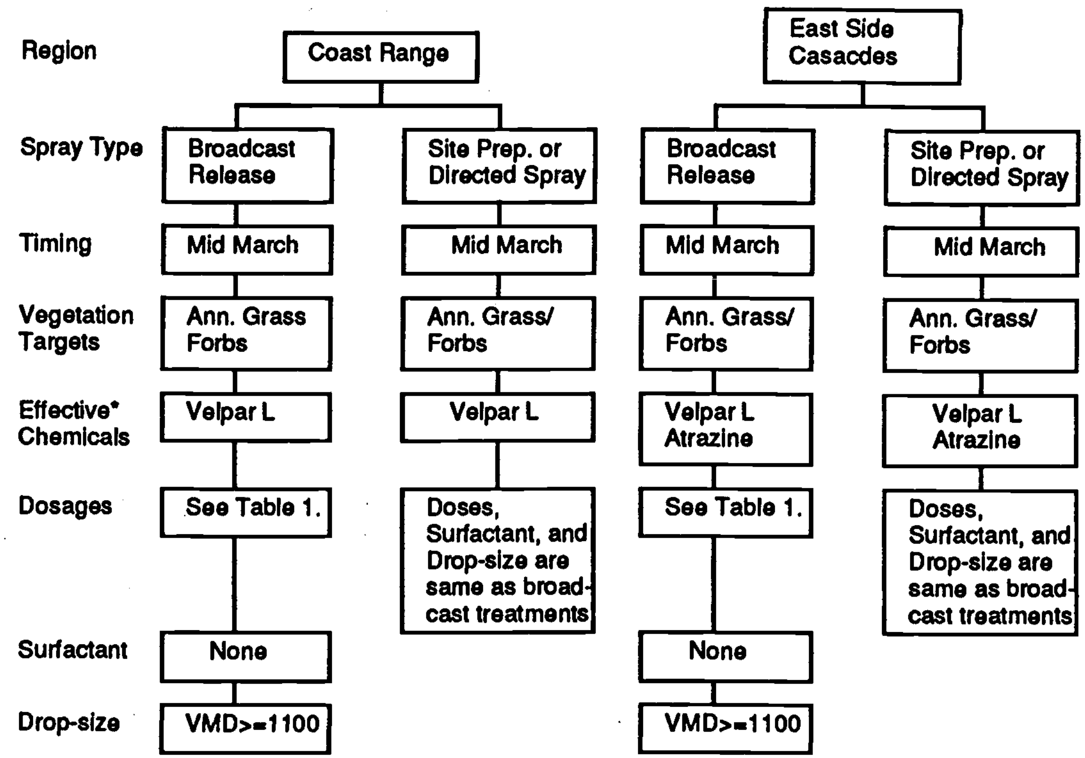

Figure 3.4 Residual herbicide decision tree. VMD's are in microns. See Figure 3.1 legend for definition of VMD. * The treatments listed have the potential to produce 80%+ control.

		Region			
	Dose	West Side Sierras Ponderosa Pine		East Cascades Ponderosa Pine	Coast Range Douglas-Fir
Chemical	**a.i./ac	April	June	April	September
Triclopyr	0.4#	1.2	N/A	0.8	N/A
	0.6#	1.3	N/A	2.2	N/A
	0.9#	2.9	2.7	N/A	N/A
	1.5#	N/A	3.5	N/A	N/A
Glyphosate	0.36#	N/A	N/A	N/A	<0.6a
	0.6#	N/A	N/A	N/A	<0.6a
	1.2#	0.0	1.6	N/A	N/A
	2.0#	0.5	2.8	N/A	N/A
	3.0#	0.6	N/A	N/A	N/A
Dichlorprop	1.2#	0.0	N/A	0.5	N/A
	2.0#	0.0	N/A	1.3	N/A
	4.0#	1.3	N/A	N/A	N/A
Fluroxypyr	0.5#	0.5	N/A	1.4	N/A
	0.75#	2.3	N/A	1.0	N/A
	1.0#	1.8	N/A	N/A	N/A
Imazypyr	0.2#	N/A	N/A	1.2	N/A
	0.4#	N/A	N/A	1.0	N/A
2,4-D	1.2#	N/A	N/A	4.5	N/A
	2.0#	4.0	N/A	4.9	N/A
	4.0#	4.7	N/A	N/A	N/A
Velpar L*	0.6#	N/A	N/A	0-1b	0.0c
	1.0#	N/A	N/A	0-1b	0.0c
Atrazine*	2.0#	N/A	N/A	0-1b	0.0c
	3.0#	N/A	N/A	0-1b	0.0c
Sulfometuron	0.7oz.	N/A	N/A	0-1b	N/A
	1.4oz.	N/A	N/A	0-1b	N/A

Table 3.1 Conifer damage data for recommended herbicides. Damage codes are on a scale from 0 to 5, with 0 being no damage and 5 dead. Coast Range glyphosate treatmtents and all Velpar L® and atrazine treatments pertain to Douglas-fir. All other treatments refer to ponderosa pine. All data is for no-surfactant applications except 2,4-D which includes Mor-act® at 5%. Damage ratings are averages of all nozzle types used. a-Data taken from Cole & Newton, (1989a). b-Data are estimated from O'Dea & Newton, unpublished data, (1993). c-Data taken from Cole & Newton, (1989b). * Velpar L® and atrazine treatments were applied in mid March. N/A=data not available. ** a.i./ac.=active ingredient per acre.

Region	Herbicide	Species	Timing	Rate # a.i./ac***
West Side Sierras	Glyphosate	Bear Clover	April	3-4
			June	> 2.0
		Manzanita	April	4.0a
			June	>2.0
	Triclopyr	Bear Clover	April	0.9-1.5
			June	0.9
		Manzanita	April	> 4.0a
			June	Poor Control
	Dichlorprop	Bear Clover	April	> 4.0
			June	4.0a
	Fluroxypyr	Bear Clover	April	1.0
			June	Unknown
	2,4-D l.v.e	Bear Clover	April	4.0
			June	2.0a
		Manzanita	April	> 4.0a
			June	Unknown
East Side Cascades	Triclopyr	Ceanothus	April	0.4
		Manzanita	April	0.6*
	Dichlorprop	Ceanothus	April	2.0
		Manzanita	April	2.0
	Fluroxypyr	Ceanothus	April	>=0.75
		Manzanita	April	0.5
	Imazypyr	Ceanothus	April	0.2
		Manzanita	April	Poor Control
	2,4-D	Ceanothus	April	1.2
		Manzanita	April	1.2
	Velpar L	Grass	Mar.-April	1.0
	Atrazine	Grass	Mar.-April	>=3.0
	Sulfometuron	Grass	Mar.-April	0.1b

Table 3.2 Rates which provide greater than or equal to 80% cover reduction. a-Data taken from Lanini, (1981). b-Data taken from Cole & Newton, (1988). c-Data taken from Cole & Newton, (1990). d-Data taken from PNW Weed Control Handbook, (1993). e-Data taken from Cole & Newton, (1989). * Provided large drops are used. ** Include 0.6# a.i./ac. of imazapyr. *** a.i./ac.=active ingredient per acre. Higher rates than were studied or could be found in the literature are required if doses are preceeded by a > or = sign. See label for timing and dosage for site prep vs. release.

Region	Herbicide	Species	Timing	Rate # a.i./ac.
Coast Range	Glyphosate	Salmonberry	Sept.	>0.6
		Red alder**	July-Sept.	1.1c
		Decid./ferns	Sept.	0.75-1.1d
	Velpar L	Grass/forbs	Mar.-April	1.0
	Atrazine	Grass (per.)	Mar.-April	Max. label dose
		Grass (ann.)	Mar.-April	4.0e
	Imazapyr	Red alder	August	<0.2c
		Vine maple	August	<0.2c
		Bigleaf maple	June	0.2-0.375c
	Triclopyr Ester	Bigleaf maple	April-Sept.	>4.0 Basal Spr.d
		Vine maple	April	1.5-2.0d
		Red alder	June	1.5b

Table 3.2 (continued)

BIBLIOGRAPHY

Ambach, R.M. and R. Ashford. 1982. Effects of variation in drop make-up on the phytotoxicity of glyphosate. Weed Science 30: 221-224.

Anderson, N.H. and D.J. Hall. 1987. Spray retention: effects of surfactant and plant species. Aspects of Applied Biology 14: 233-243.

Athins, R.L. et al. 1988. Hexazinone ultra low weight technology for forestry. Proc. of Southern Weed Sci. Soc. Jan. 18-20, 41: 233-239.

Babiker, A.G.T. and H.J. Duncan. 1974. Penetration of bracken fronds by asulam as influenced by the addition of surfactant to the spray solution and by pH. Weed Research 14: 375-377.

Baker, E.A. et al. 1983. Studies of plant cuticle spray droplet interactions: a fresh approach. Pesticide Science 14: 645-658.

Baker, E.A. and G.M. Hunt. 1985. Factors affecting the uptake of chlormequat into cereal leaves. Ann. Appl. Bio. 106: 579-590.

Balneaves, J.M. 1985. The effect of added surfactant on the performance of scrubweed herbicides. Proceedings of Scrubweed Herbicides pp.98-101.

Balneaves, J.M. 1986. Seasonal effects of glyphosate and Silwet M applied to mature gorse. Proc. 39th Ann. Weed and Pest Control Conf., New Zealand pp. 74-78;

Barry, J.W. 1984. Drop size: Drift and effectiveness of herbicide sprays. Forest Vegetation Management Workshop, Oregon State University. July 17-19 pp. 1-22.

Brady, H.A. 1979. Drop size affects absorption of 2-4-5, T by six hardwood species. Proc. Southern Weed Science Society. pp. 282-286.

Brewster, B.D. and A.P. Appleby. 1990. Effect of rate, carrier volume, and surfactant on imazamethabenz efficacy. Weed Technology 4: 291-293.

Buhler, D.D. and O.C. Burnside. 1987. Effects of application variables on glyphosate phytotoxicity. Weed Technology 1: 14-17.

Burrill, L. et al. 1990. Effect of three adjuvants on herbicide activity on gorse. Western Soc. of Weed Sci.. Res. Prog. Rep. pp. 129-131.

Burill, L. et al. 1990. Effect of two adjuvants on performance of five herbicides. Res. Prog. Rep. Western Soc. of Weed Sci. pp. 413-415.

Cantrell, R.L. 1985. Development of a herbicide data base for the southeastern U.S. forestry sector. Proc. Southern Weed Sci. Soc. pp. 257-262.

Cole, E.C. and M. Newton. 1987. Evaluation of herbicides for early season conifer release. Proc. Western Soc. of Weed Sci. 40: 119-128.

Cole, E.C. and M. Newton. 1988. Evaluation of herbicides for forest site preparation in coastal Oregon. Proc. Western Soc. of Weed Sci. pp. 86-88.

Cole, E.C. and M. Newton. 1989. Seasonal efficacy comparison of two glyphosate formulations. Proc. Western Soc. of Weed Sci. 42: 136-141.

Cole, E. C. and M. Newton. 1990a. Broadcast spraying of snowbrush ceanothus and greenleaf manzanita. Western Soc. of Weed Sci. Res. Prog. Rep. pp. 122-125.

Cole, E.C. and M. Newton. 1990b. Directed spraying of snowbrush ceanothus and greenleaf manzanita. Western Soc. of Weed Sci. Res. Prog. Rep. pp. 126-128.

Cole, E.C. and M. Newton. 1990c. Efficacy of control methods on shrubs on the Kenai Penninsula, Alaska. Western Soc. of Weed Sci. Res. Prog. Rep. pp. 132-135.

Cole, E.C. and M. Newton. 1990d. Glyphosate and imazapyr site preparation trials. Western Soc. of Weed Sci. Res. Prog. Rep.

Cole, E.C. and M. Newton. 1990e. Efficacy of different herbicides on bigleaf maple sprout clumps. Proc. Western Soc. of Weed Sci. 43: 37-42.

Coombes, D.E. and W.B. McHenry. 1983. Bear clover herbicide trials. Proc. 5th Ann. For. Veg. Mgt. Conf. Nov. 2-3, Sacremento, Cal. pp. 135-137.

Crammer, J.R. and D. L. Linscott. 1990. Droplet make-up and the effect on phytotoxicity in glyphosate. Weed Science 38: 406-410.

Fears, R.D. and S.A. McMaster. 1986. Evaluation of helicopter mounted application systems for potential spray drift. Proc. Southern Weed Sci. Soc. pp. 354-363.

Ferrell, M.A. and T.D. Whitson. 1989. Picloram and fluroxypyr with and without surfactant for leafy spurge control. Western Soc. of Weed Sci. Res. Prog. Rep. pp. 93-94.

Figueroa, P.F. 1989. Bigleaf maple control: Triclopyr thin-line and spot-foliar application treatments using imazapyr, metsulfuron, and glyphosate. Proc. Western Soc. of Weed Sci. March 13-16. 42: 104-119.

Figueroa, P.F. 1990. Sensitivity of actively growing Douglas-fir to selected herbicide formulations. Proc. Western Soc. of Weed Sci. 43: 45-53.

Fisk, J.N. 1984. Estimating effects of competing plants on conifer growth and yield, and determining release needs. Proc. 6th Ann. For. Veg. Mgt. Conf. Nov 1-2, Redding, Cal. pp. 129-143.

Fleming, R.A. and A. Sundaram. 1989. Evaporation of water from pesticide formulations and adjuvant solutions. J. Env. Sci. Health 24(3): 225-250.

Fowells, H.A. and G.H. Shubert. 1951. Natural reproduction in certain cutover pine-fir stands of California. J. For. Mar. 49(3): 192-196.

Gaskin, R.E. and J.A. Zabkiewicz. 1986. Comparison of effectiveness and persistance of three hexazinone formulations. Proc. 39th N.Z. Weed and Pest Control Conf. pp 81-84.

Goering, C.E. and B.J. Butler. 1975. Paired field studies of herbicide drift. Transactions of the Amer. Soc. Ag. Eng. pp. 27-34.

Haq, K., Akesson, N.B. and W.E. Yates. 1983. Analysis of droplet spectra and spray recovery as a function of atomizer type and physical fluid properties. Pesticide Formulations and Application Systems: Third Symposium pp. 67-82. Amer. Soc. for Test. and Mat. STP 828.

Heisey, R.M. et al. 1980. A new nitrogen fixing non-legume: *Chamaebatia foliolosa* (Rosaceae). Amer. Jor. Bot. 67(3): 429-431.

Hess, D. 1985. Herbicide absorption and their relationship to plant tolerances and susceptability. Weed Physiology pp. 191-214.

Hess, D. and R.H. Falk. 1990. Herbicide deposition on leaf surfaces. Weed Science 38: 280-288.

Hickson, Terry. 1976. Several benefits indicated for "prescribed burning." U.S. Dept. of Interior, BLM. California state office. BLM News Beat. June PP. 7.

Hogg, Edward H. 1991. The relationship between seasonal changes in rhizome carbohydrate reserves and recovery following disturbance in *Calamagrostis canadensis*. Can. J. Bot. 69: 641-645.

Holloway, P.J. and D. Stock. 1989. Rational approaches to selection of surfactants for optimizing uptake of foliage applied agrochemicals. Proc. of Brighton Crop Protection Conf. pp. 225-230.

Huang, W.Z., Hsiao, A.I., and Jordan, L. 1987. Effects of temperature, light, and certain growth regulating substances on sprouting, rooting and growth of single-node rhizome and shoot segments of *Paspalum disticum L.* Weed Research 27: 57-67.

Jackson, N.E. and M.D. Lemon. 1986. Timing of application studies with Roundup herbicide for control of bear clover *(Chamaebatia foliolosa).* Proc. 8th Ann. For. Veg. Mgt. Conf. Nov. 5-6, Sacremento, Cal. pp. 113-119.

Jackson, N.E. and M.D. Lemon. 1987. Roundup herbicide for control of bear clover *(Chamaebatia foliolosa)* in California forestry. Proc. 9th Ann. For. Veg. Mgt. Conf. Redding, Cal. pp. 59-65.

Johnson, S.A. 1987. Pronone herbicide: A granular hexazinone formulation for site preparation and conifer release. Proc. 9th Ann. For. Veg. Mgt. Conf. Nov. 3-5, Redding, Cal. pp.34-42.

King, Sandra P. and Radosevich, Steven R. 1985. Herbicide tolerance in relation to growth and stress in conifers. Weed Science 33: 472-478.

Lanini, W.T. 1981. Seasonal effectiveness of five herbicides on several Sierran brush species. M.S. Thesis. University of California, Davis.

Magill, A.W. 1974. Seeds of woody plants of the United States. USDA Forest Service Handbook #450. Washington D.C. p. 315.

May, K.R. 1950. The measurement of airborn droplets by the magnesium oxide method. J. of Sci. Instr. 27: 128-130.

McCann, A.W. and P. Whitehouse. 1985. More reliable herbicide performance. SPAN. 28(3): 98-99.

McHenry, W.B., N.L. Smith, and D. Irving. 1980. Bearmat control with five foliage applied herbicides. Proc. 2nd Ann. For. Veg. Mgt. Conf. pp.86-87.

McIntyre, Gordon I. and Hsiao, Andrew I. 1982. Influence of nitrogen and humidity on rhizome bud growth an glyphosate translocation in quackgrass *(Agropyron repens).* Weed Science 30: 655-660.

McWhorter, C.G. 1985. The physiological effects of adjuvants on plants. Weed Physiology vol 2 Herbicide Physiology CRC Inc. (Boca Raton Florida) pp. 141-158.

Miller, D. et al. 1983. The influence of spray altitude on shrub control. Forestry Research Note RN-83-1. Potlatch Corporation, Lewiston, Idaho.

Munns, E.N. 1922. Bear clover and forest reproduction. J. of For. 20: 745-754.

Munz, P.A. and D.D. Keck. A California Flora & Supplement. University of California Press. Berkley, Cal. p. 781.

Nelson, D.A. 1989. Effectiveness of a winged subsoiler for control of bear clover and reduction of soil compaction during site preparation. Proc. 11th Ann. For. Veg. Mgt. Conf. Nov. 7-9, Sacremento, Cal. pp. 59-64.

Newcomb, W. and R.M. Heisey. 1984. Ultrastructure of actinorhizal root nodules of *Chamaebatia foliolosa* (Rosaceae). Can. J. of Bot. 62: 1697-1707.

Newton, M. and F.B. Knight. 1981. Handbook of weed and insect control chemicals for forest resource managers. Timber Press. Beaverton, Oregon. 214p.

Parochetti, J.V. et al. 1979. Effect of different surfactants nozzles and liquid carriers on spray volume. N.E. Weed Sci. Soc. Proc. 33: 76-79.

Potter, D.A. 1984. Control of bear clover. Proc. 6th Ann. For. Veg. Mgt. Conf. Nov. 1-2, Redding, California. pp. 144-150.

Prasad, R. 1985a. Droplet size and efficacy of some forest herbicides. Expert Committee on Weeds. Res. Rep. Quebec, Que. October 29, 30 & 31. pp. 616.

Prasad, R. 1985b. Spray additives and their influence on herbicide efficacy. Expert Committee on Weeds. Res. Rep. Quebec, Que. October 29, 30 & 31. pp. 615

Radosevich, S.R. 1973. Woody plant control in California Wildlands. Univ. of Cal., Davis. Weed Control Research Report.

Radosevich, S.R., Roncoroni, E.J., Conard, S.G., and McHenry, W.B. 1980. Seasonal tolerance of six coniferous species to eight foliage-active herbicides. Forest Science. 26: 3-9.

Radosevich, S.R. 1984. Interference between greenleaf manzanita (_Arctostaphylos patula_) and ponderosa pine (_Pinus ponderosa_). Seedling physiology and reforestation success. Duryea, M.L. and Brown, G.N. editors. Martinus Nijhoff/Dr. W. Junk publishers. Boston. pp. 259-270.

Reichard, D.L. 1988. Drop formation and impaction on the plant. Weed Technology 2: 82-87.

Richardson, B. 1988. The role of droplet size, concentration, spray volume, and canopy architecture in herbicide application efficiency. Doctoral thesis. Oregon State University. 151 p.

Richardson, R.G. 1974. Control of spray drift with thickening agents. J. of Ag. Eng. 19: 227-231.

Richardson, R.G. 1983. Effect of droplet size on the control of weeds with 2,4-D. Annual Weed 2(4):133-136.

Richardson, R.G. 1987. Effect of drop trajectory on spray deposits on crops and weeds. Plant Protection Quarterly 2(3): 108-111.

Saunders, W.J. 1986. New spray tips for improved performance. Proc. of North Central Weed Science Society 41: 15-21.

Schubert, G.H. and R.S. Adams. 1971. Reforestation practices for conifers in California. California State Board of Forestry. State of Cal. The Resources Agency, Dept of Conservation, Division of Forestry. Sacremento, Cal. pp. 178-205.

Spillman, J.J. 1984. Spray impaction and adhesion: an introduction to basic characteristics. Pesticide Science 15: 97-106.

Stark, N. 1965. Natural regeneration of Sierra Nevada mixed conifers after logging. J. of For. June. 63: 456-461.

Stevens, P.J.G. and M.J. Bukovac. 1987. Effect of spray application parameters on foliar uptake and translocation of daminozide and 2,4-D in *Vicia faba.* Crop Protection. 6(3): 163-170.

Stout, G.J. 1981. How the experts control drift. AG Consultant and Fieldman. May/June pp. 18-24.

Sundaram, A. et al. 1987. Influence of adjuvants on physiochemical properties, droplet size spectra, and deposit patterns: Relevance in pesticide applications. J. Env. Sci. Health B 22(3): 319-346.

Sundaram, A. 1990a. Effect of NalcoTrol 11 on bioavailability of glyphosate in lab trials. J. of Env. Sci. Health B B25(#3): 309-332.

Sundaram, A. 1990b. Influence of two polymeric adjuvants on physical properties, droplet spreading and drying rates, and foliar uptake and translocation of glyphosate in Vision formulation. ASTMSTP 1086. American Society for Testing and Materials.

Sundaram, A. Effect of adjuvants on glyphosate wash-off from white birch foliage by simulated rainfall. J. of Env. Sci. Health B. In press. 29 pages.

Swietlik, D. 1989. Adjuvants affect the efficacy of glyphosate on selected perennial weeds. Hortscience 24(3): 470-472.

Tappeiner, J.C. and J.A. Helms. 1971. Natural regeneration of Douglas-fir and white fir on exposed sites in the Sierra Nevada of California. Amer. Mid. Nat. 86(2): 358-370.

Tappeiner, J.C. and S.R. Radosevich. 1982. Effect of bearmat (*Chamaebatia foliolosa*) on soil moisture and ponderosa pine (*Pinus ponderosa*) growth. Weed Science 30: 98-101.

Taylor, W.A. and G.B. Shaw. 1983. The effect of drop speed, size, and surfactant on the deposition of spray on barley and radish or mustard. Pesticide Science. 14: 659-665.

Teske, M.E. and J.W. Barry. 1990. FSCBG modeling comparisons with the heather seed orchard deposition area. USDA Forest Service. Forest Pest Mgt. Rep. Gen. Tech. Rep. pp. 90-5 May.

Valkova, O. 1989. Long-term study of hexazinone efficacy in pine plantations. Proc of Brighton Crop Protection Conf., Weeds 1: 361-362.

Weatherspoon, C.P., C.N. Skinner, and C.S. Simpson. 1991. Reducing bear clover by repeated growing-season prescribed burns: Preliminary test results. Proc. 12th Ann. For. Veg. Mgt. Conf. May 14-16, Redding, California. pp. 1-9.

Western, N.M. and S.E. Woodley. 1987. Influence of drop size and application volume on the effectiveness of two herbicides. Aspects of Applied Biology 14: 181-192.

Wyrill, J.B. and O.C. Burnside. 1977. Glyphosate toxicity to common milkweed and hemp dogbane as influenced by surfactants. Weed Science 25(3): 275-287.

Yates, W.E., N.B. Akesson, and D. Bayer. 1976. Effect of spray adjuvants on drift. Transactions of the Amer. Soc. of Ag. Eng. 19:41-46.

Yates, W.E., N.B. Akesson, and R.E. Cowden. 1978. Atmospheric transport of sprays from helicopter applications in mountainous terrain. Amer. Soc. of Ag. Eng. Meeting. Dec 18-20. Paper # 78-1504.

Yates, W.E., N.B. Akesson, and R.E. Cowden. 1985. Atomization of herbicide simulants with hollow cone and raindrop nozzles. USDA Forest Service. Forest Pest Management. Feb. FPM 85-1.

Young, B.W. and C.A. Hart. 1987. The use of dial-a-drop concept in the study of droplet impaction with leaf surfaces. Aspects of Applied Biology 14: 23-33.

Zabkiewicz, J.A., R.E. Gskin, and J.M. Balneaves. 1985. Effect of two additives on foliar wetting and uptake of glyphosate into gorse *(Ulex europaeus)*. Symp. on Application and Biology BCPC monograph No. 28: 127-133.

Zabkiewicz, J.A. et al. 1988. Effects of surfactants on droplet spreading and drying rates in relation to foliar uptake. Pesticide Formulations: Innovations and developments pp. 77-89.