Weed Control in Spring and Summer After Fall Application of Sulfometuron

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ABSTRACT: *This study tested the residual spring and summer efficacy of sulfometuron after fall applications in forest regeneration settings in coastal forests of Oregon. This is the first reporting of results from what is becoming a more widely used silvicultural treatment. Sulfometuron alone (S) and sulfometuron plus imazapyr and glyphosate (SIG) were applied to vegetation on mechanically scarified sites and unscarified sites. The applications were replicated each month through fall 1994. Vegetation cover was assessed in mid-June and mid-August 1995. The SIG treatment controlled the vegetation more than the S treatment did, although cover was significantly lower for both herbicide treatments (9% to 54% for summed cover) compared to the control (64% to 104% for summed cover). On scarified sites, the month of application, early or late fall, did not significantly influence the efficacy of S or SIG treatments. On unscarified sites, however, later applications of the SIG treatment were less effective than earlier treatments were. These results suggest that fall applications of sulfometuron are still effective in spring and may eliminate the need to retreat sites in the spring to achieve effective weed control. West. J. Appl. For. 14(2):80–85.*

One of the reforestation techniques now being considered in the Pacific Northwest coastal region is the addition of a pre-emergent herbicide, sulfometuron (Oust®), to the fall site-preparation spray. The goal of a site-preparation treatment is to eliminate woody shrubs and perennial herbs prior to planting of crop trees. A common site-preparation herbicide prescription is a fall application of imazapyr (Arsenal®) and glyphosate (Accord®) followed by a spring application of sulfometuron. Imazapyr and glyphosate both have foliage activity; imazapyr also has some residual soil activity. Fall site-preparation treatments with these herbicides are generally applied from late August to early October. Timing of fall site-preparation treatments is important: too early and a new cohort of plant competitors can establish; too late and efficacy is reduced due to poor herbicide uptake by senescing foliage.

The addition of sulfometuron, a moderately persistent soil active herbicide, to the fall mix is expected to provide additional fall weed control and possibly residual impacts on weed emergence in the spring. Sulfometuron applied in the spring generally results in good to excellent control of a broad spectrum of herbaceous and some shrubby weeds (Newton and Cole 1989).

A typical half-life of sulfometuron in acidic soil is 4 wk (Harvey et al. 1985). Sulfometuron decomposition is quicker in acidic soils, at high soil moisture contents, and at warmer soil temperatures (Ahrens 1994, Anderson and Dulka 1985, Lym and Swenson 1991). It follows that if soil temperatures are cold enough to slow sulfometuron degradation there will be a corresponding decrease in sulfometuron lost through the winter months. The ability of this chemical to persist unchanged over winter is uncertain, but the possibility of overwintering is important enough to justify careful evaluation.

The addition of sulfometuron to the fall site-preparation mixture while still maintaining good control of grass and herbs in spring may reduce the costs of regenerating harvested sites by eliminating labor costs for the spring application. To date, this is the first study we are aware of in the Pacific Northwest to formally evaluate the spring and summer efficacy resulting from fall sulfometuron applications, a silvicultural treatment that has become more common in recent years.

Mechanical site preparation through scarification is another technique commonly used to reduce woody vegetation cover. There are several types of machines and techniques adapted for this work. All of these techniques generally result in the piling, breaking up, or burying of post-harvest organic material while also uprooting established potential shrub competitors. The early successional plant communities that result from scarification are different from those that occur on

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sites that are not scarified (Kelpsas 1978, Malavasi 1978). Generally, invasive weedy herbaceous species and grasses quickly dominate scarified sites, while unscarified sites result in plant communities with larger holdover shrub components. The effectiveness of sulfometuron alone or with imazapyr and glyphosate may vary on scarified and unscarified sites because different plant communities result.

The objective of this study is to determine the residual effect of fall applications of sulfometuron alone and in combination with imazapyr and glyphosate on target vegetation on both scarified and unscarified ground in the following spring and summer. The null hypotheses are as follows: (1) Vegetation cover after fall applications of sulfometuron does not differ from that in the controls (no chemical application). (2) There is no difference in weed control the following spring and summer between sulfometuron applied alone and sulfometuron applied in combination with imazapyr and glyphosate. (3) Timing of sulfometuron application in the fall does not influence efficacy the following year.

Materials and Methods

Site Descriptions

The experiment was repeated on two separate sites in the central Coast Range of Oregon, near Eddyville and near Falls City. The study sites were harvested the summer of 1994, immediately prior to the first fall treatments. The Eddyville site is about 40 km east of the coast and is representative of a high site in the Coast Range. Prior to harvest, the stand consisted of a mixture of 60-yr-old second growth Douglas-fir (*Pseudotsuga menziesii*) and a smaller component of red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*). The understory was dominated by a combination of vine maple (*Acer circinatum*), red elderberry (*Sambucus racemosa*), and sword fern (*Polystichum munitum*). Soils are in the Apt soil series and consist of deep to well-drained silty clay loam formed in colluvium weathered from sedimentary rocks. The site receives 150–200 cm/yr of rain and is on a 5% to 20% westerly slope. The Falls City site is on the fringe between the Coast Range and the Willamette Valley. Prior to harvest, the stand consisted of a monoculture of 60- to 80-yr-old second-growth Douglas-fir. The understory was dominated by California hazel (*Corylus cornuta*), snowberry (*Symphoricarpos albus*), sword fern, bracken fern (*Pteridium aquilinum*), and salal (*Gaultheria shallon*). Soils consist of a gravelly silty clay loam in the Kilowan series on a large, relatively flat bench. The site receives 15–200 cm/yr of rain. At both sites 80% or more of the rainfall occurs from October through April.

Study Design

The experiment was a randomized block design. Within each site, we established four experimental blocks on scarified ground and four on unscarified ground. Scarification consisted of removing woody debris from the study area with a Caterpillar tractor fitted with a brush blade. Within each block, we set up nine treatment units that were 30.5 m long by 4.5 m wide. The nine treatments [(2 herbicide treatments × 4 separate months of application) + 1 control (no herbicide)] were assigned randomly within each experimental block

We used two different herbicide treatments, one with sulfometuron alone (S treatment) and one with sulfometuron, imazapyr, and glyphosate (SIG treatment). The application rate of sulfometuron was the same for both treatments: 0.16 ai kg/ha (3 oz Oust®/ac). For the SIG treatment, imazapyr was applied at a rate of 0.035 ae kg/ha (2 oz Arsenal®/ac), and glyphosate was applied at a rate of 1.7 ae kg/ha (2 qt Accord®/ac). These application rates are typical for fall site preparation and spring treatments.

Herbicides were applied to treatment units during one of four consecutive months in the fall of 1994. The Falls City site received herbicide treatments from August to November. The Eddyville site was scheduled to receive herbicide treatments from September to December. Because of an application error, however, the Eddyville units that were treated with herbicide in November were treated again in December. Thus, the Eddyville site had no December treatment, and the November treatments received twice as much herbicide as all other treatments.

Data Collection and Analysis

Vegetation was sampled twice: June 10–15, 1995, and August 16–21, 1995. Percent cover was estimated visually for each plant species to a precision of 5% within five 1-m^2 quadrats. The quadrats were placed at regular 4.5 m intervals in the middle of each treatment unit (side to side).

Independent statistical analyses were performed for the Eddyville and Falls City study sites because the months of herbicide application were different between sites. Within each study site, independent analyses were performed for the scarified and unscarified sites. Scarification treatments were not replicated on each study site, thereby precluding any direct statistical comparisons of scarified versus unscarified treatments. Thus, a total of four independent analyses were conducted.

Cover values for all individual species within each quadrat were added together to yield a summed cover for each quadrat. A mean summed cover value was generated from the five quadrats sampled within each treatment unit. This value represents a measure of total leaf area (transpirational surface area). Summed cover can be greater than 100% due to the potential overlapping of individual plant canopies. In addition to total summed cover, total shrub and herb cover was also calculated. To accomplish this, individual species cover within each quadrat was separated into either shrub cover or herb cover. Again, a mean cover value for each treatment unit was calculated from the five sample quadrats. Values for summed cover, shrub cover, and herb cover were calculated for the June and August vegetation surveys.

Data analysis was performed in a two-step manner on cover data from both the June and August vegetation surveys. The first question of interest was whether cover in the herbicide treatments differed from the control treatment. Thus, the data were analyzed as a randomized block design with nine treatments by using an ANOVA procedure. Differences in treatment means were determined by Fisher's Protected Least Significant Difference (LSD) (Petersen 1985).

The second analysis step determined if there were differences in cover due to herbicide treatment or month of application and whether there was a significant interaction between these two factors. For this analysis, the control treatment was removed from the data set, and a two-way factorial analysis with herbicide treatment and month of application was performed, again by using ANOVA. Fisher's Protected LSD test was used to determine differences among treatments. For all analyses, residuals indicated that the data fit the assumptions inherent for ANOVA analyses.

Results

Control and Treatment Differences

Fall applications of S or SIG significantly impacted vegetation cover into the following year. On scarified and unscarified sites at both study sites, summed cover and herb cover were significantly less in most herbicide treatments than in the controls through the August vegetation survey of the following year (1995) (Table 1); the only two exceptions were at Falls City in the unscarified site during the August survey. On scarified ground at both study sites, shrub cover was not significantly different among the herbicide treatments and the controls. On unscarified ground in June, shrub cover was significantly less in the SIG treatments than in the controls The same was true for the S treatments except in the October treatment at Eddyville and the November treatment at Falls City. By August, shrub cover had increased such that the controls and most treatments were no longer significantly different. This was more common with S versus SIG treatments (Table 1). The double dose of herbicide applied accidentally to the Eddyville November treatment, surprisingly, did not result in additional weed control compared to the other months of application in the scarified sites. But, it did result in significantly less June cover in the unscarified site at Eddyville than the October application. This difference did not persist, however, into August.

Scarified Sites

Mechanical scarification successfully removed nearly all aboveground vegetation from both study sites. With the exception of a few remaining root clumps, nearly all preexisting shrubs were removed. Additionally, the scarified ground resembled a plowed field and contained few robust plants of any type prior to the first herbicide treatment.

On scarified sites, treatment and month of application did not significantly interact, and data were appropriately pooled to make comparisons of treatment and month of

Table 1. Mean summed cover, shrub cover, and herb cover in June and August 1995 for all treatments applied in 1994.

	Eddyville				Falls City			
	Scarified		Unscarified		Scarified		Unscarified	
Treatment[1]	June	August	June	August	June	August	June	August
				Summed cover (%)				
Control	69a	80a	104a	74a	64a	67a	86a	79a
Aug. S	—	—	—	—	28b	48b	47b	54b
Aug. SIG	—	—	—	—	18cd	41bc	12c	32bc
Sep. S	26b	32bc	22cd	35bc	22bc	45bc	24c	40bc
Sep. SIG	12b	29bc	15d	19c	13d	31c	10c	21c
Oct. S	23b	31bc	52b	44b	22bc	43bc	49b	49b
Oct. SIG	13b	23c	26cd	23c	12d	36bc	13c	35bc
Nov. S[3]	21b	38b	35c	48b	17cd	36bc	51b	54b
Nov. SIG[3]	15b	25bc	29c	52b	9d	29c	23c	35bc
				Shrub cover (%)				
Control	14a	17a	44a	31a	16a	17a	41a	36a
Aug. S	—	—	—	—	12a	18a	25b	34a
Aug. SIG	—	—	—	—	7a	17a	4c	7b
Sep. S	11a	17a	12c	22ab	9a	19a	12bc	21ab
Sep. SIG	5a	10a	7c	11b	3a	6a	4c	5b
Oct. S	9a	16a	39a	32a	9a	20a	25b	34a
Oct. SIG	5a	9a	17bc	16b	5a	10a	3c	7b
Nov. S	9a	22a	26b	38a	7a	11a	29ab	38a
Nov. SIG	5a	9a	23b	42a	3a	9a	16bc	23ab
				Herb cover (%)				
Control	56a	63a	60a	43a	49a	50a	45a	43a
Aug. S	—	—	—	—	16b	30b	22bc	20b
Aug. SIG	—	—	—	—	11bc	24bc	8c	25ab
Sep. S	16b	15b	10b	13b	13bc	26bc	13bc	19b
Sep. SIG	6b	18b	7b	7b	9bc	25bc	6c	16b
Oct. S	14b	15b	13b	12b	14bc	23bc	24b	15b
Oct. SIG	8b	14b	9b	7b	7c	27bc	11bc	29ab
Nov. S	12b	16b	10b	10b	10bc	25bc	22bc	16b
Nov. SIG	10b	16b	7b	10b	6c	20c	7c	12b

1 Control = no herbicide treatment. Aug. to Nov. = month of application. S = sulfometuron only. SIG = sulfometuron, imazapyr, and glyphosate.
2 Values followed by the same letter within a column for summed cover, shrub cover, and herb cover are not significantly different ($P \leq 0.05$).
3 All November applications were accidentally treated again in December at the Eddyville site, resulting in twice the rate of herbicide being applied.

Table 2. ANOVA results (P-values) for Falls City and Eddyville sites surveyed in 1995.

	June survey			August survey		
Source of variation	Summed cover	Shrub cover	Herb cover	Summed cover	Shrub cover	Herb cover
Eddyville–Scarified						
Herbicide treatment[1]	0.0063	0.0670	0.0213	0.0414	0.0551	0.8798
Month of application	0.9566	0.9310	0.9984	0.6328	0.9359	0.6381
Interaction[2]	0.5811	0.9598	0.4783	0.4284	0.5834	0.6699
Eddyville–Unscarified						
Herbicide treatment	NA[3]	0.0100	0.0166	NA	0.0736	0.1030
Month of application	NA	0.0008	0.2516	NA	0.0006	0.9381
Interaction	0.0374	0.0720	0.7919	0.0081	0.1296	0.4178
Falls City–Scarified						
Herbicide treatment	0.0002	0.0160	0.0010	0.0246	0.0214	0.4042
Month of application	0.0309	0.4022	0.0507	0.1453	0.2186	0.6040
Interaction	0.9791	0.9897	0.8329	0.8604	0.3121	0.4219
Falls City–Unscarified						
Herbicide treatment	0.0001	0.0007	0.0001	0.0042	0.0001	0.3461
Month of application	0.1145	0.1277	0.1516	0.3075	0.0935	0.2084
Interaction	0.5055	0.5127	0.6663	0.9635	0.6380	0.1894

1 S treatment (sulfometuron only) versus SIG treatment (sulfometuron, imazapyr, and glyphosate).
2 Herbicide treatment × month of application.
3 NA = not applicable.

application. The herbicide treatment, S or SIG, significantly influenced cover through August the following year (Table 2). In the June survey at both study sites, summed cover and herb cover were significantly less in the SIG treatment than in the S treatment (Table 3). In June, shrub cover was less than 10% in both S and SIG treatments and was significantly less in the SIG treatment at Falls City but not at Eddyville. By August, summed cover continued to be significantly less in the SIG treatment, but herb cover no longer differed between S and SIG treatments at either site. Shrub cover in August at both sites was significantly less, although marginally so at Eddyville, in the SIG treatment than in the S treatment.

The month of herbicide application did not significantly influence summed cover, shrub cover, or herb cover at the Eddyville site in either the June or August surveys (Table 4). At the Falls City site during the June survey, summed cover was significantly less in the November application than in the August application; by the August survey, there was no significant difference. Shrub cover and herb cover were unaffected by the month of herbicide application in the June and August surveys (Table 4).

Unscarified Sites

In the June and August surveys at Eddyville, the interaction between treatment and month of application was significant for summed cover (Table 2). Therefore, it is inappropriate to pool Eddyville summed cover values across either month of application or herbicide treatment, and results must be discussed for each month of application and herbicide treatment combination independently. For each month of application at Eddyville, summed cover was less in the SIG treatment than in the S treatment, although significantly so only in the October timing (Table 1). This pattern held for both the June and August surveys.

Herbicide treatment and month of application did not significantly interact to affect summed cover at Falls City or shrub cover or herb cover at either study site. Thus values can be pooled across month of application and herbicide treatment. In June, summed cover at Falls City and shrub and herb

Table 3. Mean cover in June and August 1995 by herbicide treatment (applied in 1994). Means were generated from data pooled across all months of application using a factorial model.

	Eddyville				Falls City			
Herbicide	Scarified		Unscarified		Scarified		Unscarified	
treatment[1]	June	August	June	August	June	August	June	August
	Summed cover (%)							
S	25a[2]	34a	NA[3]	NA	22a	43a	43a	49a
SIG	13b	25b	NA	NA	13b	34b	14b	31b
	Shrub cover (%)							
S	10a	18a	25a	31a	9a	17a	22a	32a
SIG	5a	9a	16b	23a	4b	10b	6b	10b
	Herb cover (%)							
S	14a	15a	20a	17a	14a	26a	11a	11a
SIG	8b	16a	8b	20a	8b	24a	8b	8a

1 S = sulfometuron only. SIG = sulfometuron, imazapyr, and glyphosate.
2 Values followed by the same letter within a column for summed cover, shrub cover, and herb cover are not significantly different ($P \leq 0.05$).
3 Due to a significant interaction between month of application and herbicide treatment, analysis pooled across month of application is not appropriate (NA).

Table 4. Mean cover in June and August 1995 by month of herbicide application (treated in 1994). Means were generated from data pooled across both herbicide treatments using a factorial model.

Month of herbicide application	Eddyville				Falls City			
	Scarified		Unscarified		Scarified		Unscarified	
	June	August	June	August	June	August	June	August
	Summed cover (%)							
August	—	—	—	—	23a	44a	29a	43a
September	19a[1]	30a	NA[2]	NA	17ab	38a	17a	30a
October	18a	27a	NA	NA	17ab	40a	31a	42a
November[3]	18a	31a	NA	NA	13b	32a	37a	44a
	Shrub cover (%)							
August	—	—	—	—	9a	18a	14a	20a
September	8a	14a	9b	16c	6a	12a	8a	13a
October	7a	13a	26a	24b	7a	15a	14a	21a
November	7a	15a	22a	40a	5a	10a	22a	30a
	Herbaceous cover (%)							
August	—	—	—	—	15a	27a	15a	23a
September	11a	16a	8a	9a	9a	26a	9a	17a
October	11a	14a	11a	9a	17a	25a	17a	22a
November	11a	16a	7a	7a	15a	23a	15a	14a

1 Values followed by the same letter within a column for summed cover, shrub cover, and herbaceous cover are not significantly different ($P \leq 0.05$).
2 Due to a significant interaction between month of application and herbicide treatment, analysis pooled across herbicide formulations is inappropriate.
3 All November applications were accidentally treated again in December at the Eddyville site, resulting in twice the rate of herbicide being applied.

cover at both sites were significantly less in the SIG treatment than in the S treatment (Table 3). In August, similar differences were still apparent for summed cover at Falls City. Shrub cover continued to be significantly less in the SIG treatment than in the S treatment at Falls City, but did not differ at Eddyville. By August, herb cover no longer differed at either site (Table 3).

The month of herbicide application had no influence on summed cover, shrub cover, or herb cover at Falls City (Table 4). At Eddyville, herb cover was unaffected by month of application, while shrub cover was significantly lower in earlier applications than later. These findings held for both the June and August surveys (Table 4).

Discussion

In June, weed cover in all herbicide treatments was significantly less than in the controls. Similarly in August, weed cover was significantly less in nearly all the treatments than the controls. It is unclear if this spring and summer effect was a result of good to excellent fall vegetation control or whether sulfometuron persisted in the soil at phytotoxic levels into the spring months. The plant community present prior to the fall sulfometuron site-preparation treatments appears to strongly influence the success of herbicide treatments

Influence of Plant Community

The timing of leaf senescence among different target plants plays a large role in the effectiveness of late fall herbicide applications. All the herbicides we used in this study effectively control a broad spectrum of plant species when absorbed through the foliage (Newton and Cole 1991, Cole et al. 1987, Cole et al. 1986). Due to the removal of most of the shrubs on scarified sites, no differences by month of application were observed. On unscarified sites, we would expect that as natural leaf senescence became more pronounced later in the fall, herbicide control of deciduous shrub species would decline with later months of application. Results from the Eddyville site support this conclusion, with herbicide applications later than October resulting in reduced shrub control. In fact, the November treatments at Eddyville received twice the desired dose because of an application error and still less shrub control was achieved than in earlier application timings. A similar pattern was not apparent at Falls City, where shrub cover was similar, regardless of the month of application. The difference in shrub species composition between the Eddyville (vine maple and elderberry) and Falls City (snowberry) sites is responsible for differences in efficacy associated with month of application. Vine maple and elderberry were ineffectively controlled by herbicide treatments later than September. Conversely, snowberry continued to be well controlled by the herbicide treatments through November. We were unable to determine whether October and November applications resulted in snowberry control because leaves were still on the plant or because of soil activity of either sulfometuron or imazapyr.

Scarification shifts the composition of the plant community and consequently influences the effectiveness of herbicides. The plant community composition dictates the success of any one herbicide. Scarification effectively removed woody species and increased the effectiveness of fall applications of sulfometuron by removing plant species poorly controlled by sulfometuron. The Eddyville plant community had a large vine maple and elderberry component. The Falls City site was dominated by a nearly continuous cover of snowberry. All three of these species were poorly controlled with the S treatment (sulfometuron by itself). However, if the site was scarified or if glyphosate and imazapyr were added to the tank mix (i.e., SIG treatment), these three species were well controlled. The influence of scarification can be expected to differ depending on the herbicides used in site preparation, and scarification could reduce herbicide effectiveness rather than enhance it.

Limitations of Study

Definitive conclusions about sulfometuron activity in the spring following fall applications cannot be drawn from our data. Direct correlation between spring efficacy and sulfometuron persistence requires knowledge of levels of sulfometuron in the spring soil solution, which we did not measure. In addition, we did not test a treatment of imazapyr and glyphosate without sulfometuron, which would have allowed us to make more definitive statements about the efficacy of adding sulfometuron to the imazapyr-glyphosate tank mix.

If fall site-preparation treatments result in adequate weed suppression through the following year, as was exhibited by nearly all of the treatments in this study, then the treatments are considered an operational success. From an operational perspective, whether spring efficacy results from sulfometuron activity in the fall/winter or in the spring is moot, as long as the desired effect is achieved.

In the Oregon Coast Range, fall site preparation with tank mixes of imazapyr and glyphosate generally removes most woody species, but herb and grass communities typically establish quickly the following spring. In August, the mean summed cover across all sites and herbicide treatments was 35%, which is 40% lower than the untreated control mean of 75%. This is considerably better weed suppression than would be expected with a one-time fall treatment of glyphosate and imazapyr. For example, Stein (1995) found that vegetation had rebounded to within 10% of untreated plots the summer after a fall site-preparation application of glyphosate.

Summary

Fall application of sulfometuron shows promise as a site-preparation tool especially with tank mixes of foliage active herbicides such as imazapyr and glyphosate. A single fall herbicide application represents a substantial financial advantage over the two-time (fall and spring) program often used for combined herb and shrub control Good planning and an understanding of succession dynamics, however, are the best tools a forester has in prescribing vegetation control measures. There is no single approach to vegetation control that will be successful in all sites. Each site should be screened independently to ensure that a fall application of single or combined herbicides is the correct choice. Choosing the best silvicultural approach will depend on the current and anticipated plant communities on the site.

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