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Postplanting Sprays of Dalapon and Atrazine to Aid Conifer Establishment

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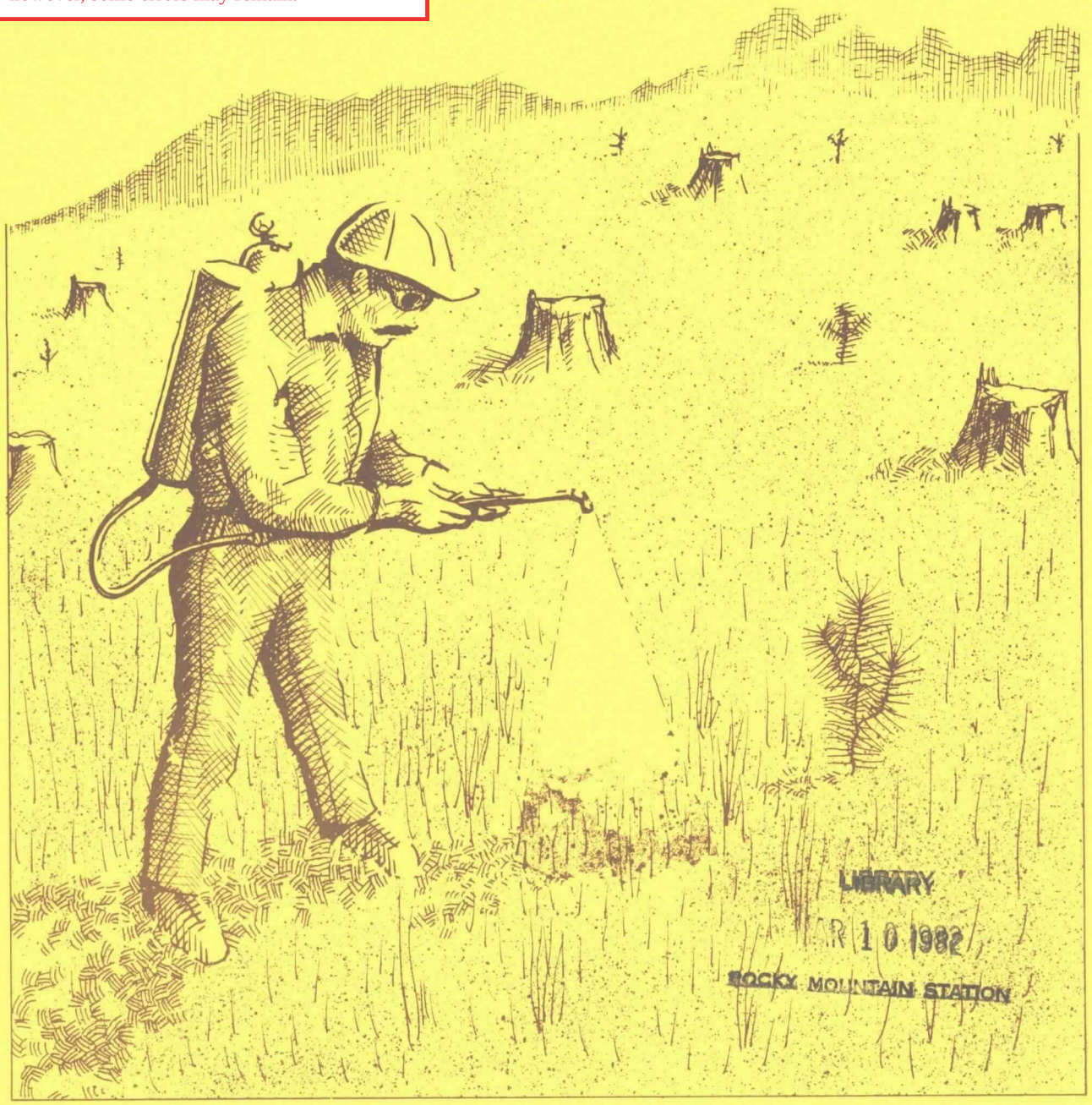

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Abstract

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A mixture of dalapon and atrazine consistently controlled grasses and forbs better than either herbicide used alone. Sprayed over and around newly planted ponderosa pine (Pinus ponderosa Dougl. ex Laws.) and Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco), the mixture doubled tree survival in one study, greatly enhanced height growth in another, but produced no significant gains in four studies. Protecting seedlings from herbicide sprays proved beneficial in two studies, but seemed unnecessary in four others.

Keywords: Herbicides (-regeneration, grass control, forbs, dalapon, atrazine.

Summary

Dalapon (2,2-dichloropropionic acid) and atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine], alone and in combination, were applied as postplanting sprays to control perennial grasses and forbs competing with newly planted seedlings of ponderosa pine (Pinus ponderosa Dougl. ex Laws.) and Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco).

In a series of four eastern Oregon studies, dalapon combined with atrazine at rates of 8 + 4 lb/acre (8.96 + 4.48 kg/ha) consistently controlled target species more effectively than dalapon alone at rates of 4 and 8 lb/acre (4.48 and 8.96 kg/ha). The combination reduced grass and forb cover the 1st year by averages of 80 and 58 percent, respectively, and effective control persisted for 2-3 years. Dalapon at heavier and lighter rates reduced grasses by 49 and 32 percent, respectively, during the 1st year, but effective control persisted no longer than 2 years. Dalapon alone was ineffective in controlling forbs. Covering seedlings during spraying somewhat reduced herbicide toxicity to conifers in one study, seemed unnecessary in two others, and actually reduced height growth in another. In no case was conifer survival reduced significantly below that of untreated seedlings. In one study, the dalapon-atrazine mixture doubled survival (49 vs. 25 percent) of ponderosa pine after 3 years.

A second series of two studies in both eastern Oregon and central Washington produced comparable results. Dalapon and atrazine mixed at the same rates as before reduced grasses by 82 percent and forbs by 48 percent the 1st year. Effective control of combined herbaceous species persisted 2-4 years. Dalapon at 8 lb/acre (8.96 kg/ha) reduced grasses 49 percent the 1st year but did not control forbs. Effective

control of all species combined persisted for 4 years in one study but no longer than 1 year in the other. Atrazine at 4 lb/acre (4.48 kg/ha) reduced grasses 47 percent and forbs 37 percent the 1st year, with effective control of all herbaceous species persisting only about 1 year in either study. Protecting seedlings from sprays did not benefit survival but, in one study, benefited height growth of both ponderosa pine and Douglas-fir after 3 years. Covered seedlings associated with the most effective treatment (dalapon + atrazine) averaged 86 and 60 percent taller than untreated trees in ponderosa pine and Douglas-fir, respectively.

Contents

Introduction

Resurgence and proliferation of herbaceous plants is normally rapid following forest disturbance by fire, windthrow, and logging on xeric sites east of the Cascade Range. Where disturbance is extensive or severe, land managers commonly seed annual and perennial grasses to hasten revegetation, lessen erosion, and improve forage for grazing animals. Reforesting such sites can be difficult. Delayed snowmelt necessitates planting conifers no earlier than late spring in most years; and to survive, young seedlings must compete successfully with established grasses and forbs that quickly deplete available soil moisture to critical levels with the onset of summer drought (Eckert 1979). Hence, control of competing vegetation--either before or concurrent with planting--is usually essential to minimize early mortality of young conifers in many parts of the West (Baron 1962, Christensen et al. 1974, Clark and McLean 1975, Cleary 1970, Foiles and Curtis 1973, Gratkowski et al. 1979, Hall 1971, and Heidmann 1969).

Herbicides of the *s*-triazine group have proven useful for chemically preparing reforestation sites in grassy plant communities. Atrazine, in particular, has shown notable success in substantially improving conifer survival in controlled studies (Crouch 1979, Eckert 1979, Gratkowski et al. 1979, Stewart and Beebe 1974). Certain perennial grasses and deep-rooted forbs, however, resist control by atrazine [2-chloro-4-(ethylamino)-6-(isopropylamino)-*s*-triazine] (Newton 1974); and effective treatment requires at least moderate precipitation shortly after application to leach the chemical into the rooting zone of target plants. These factors, combined with posttreatment restrictions on livestock grazing, suggest that foresters could profit from even more effective and flexible alternatives. Heidmann (1970) has posited an advantage for herbicide application simultaneous with tree planting. Dalapon (2,2-dichloropropionic acid), a translocated aliphatic acid, is one herbicide with considerable potential for this type of use. Effective on a broader spectrum of perennials than atrazine, dalapon can, nevertheless, injure conifers when sprayed directly over and around young trees (Gratkowski 1976). Though such injury does not always occur (Newton 1974), Newton and Overton (1973) report that harmful effects can be masked by adding atrazine to dalapon spray formulations.

We describe six studies aimed at evaluating dalapon and atrazine, used alone and in mixture, for controlling grasses and forbs in topical applications around newly planted ponderosa pine (Pinus ponderosa Dougl. ex Laws.) and Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco). Four of the above studies were begun in 1975 to test spot sprays around individual seedlings planted at normal density (500/acre or 1,235/ha). The remaining two studies were started in 1976 to test broadcast sprays on small plots with seedlings planted at higher density (3,000/acre or 7,415/ha).

1975 Spot Sprays
Study Areas

All four studies were located on the Wallowa-Whitman National Forest in eastern Oregon. One site (Camp Creek) is near Unity, two sites (Devils Run and Doe Creek) near Enterprise, and one site (Sheep Creek) near La Grande. Soils range from silt loams or loams of sedimentary origin with minimal ash components at Camp Creek to ash-characterized loams of varying texture and depth overlying basalt and pyroclastic rock at the other three locations. Topography is rolling to nearly level at Devils Run (elev., 4,900-ft or 1 490-m) and Doe Creek (elev., 4,600-ft or 1 400-m), but moderately steep with northwest exposures at Sheep Creek (elev., 5,700-ft or 1 740-m) and Camp Creek (elev., 5,500-ft or 1 680-m). Mean annual precipitation is: 22 in (56 cm) at Camp Creek, 20 in (51 cm) at Devils Run, 17 in (43 cm) at Doe Creek, and 28 in (71 cm) at Sheep Creek. Mean monthly precipitation during July, August, and September ranges from only 0.3 in (0.8 cm) to 0.8 in (2.0 cm) at all locations except Sheep Creek where it reaches 1.2 in (3.0 cm) during September.

History of forest disturbance before study installation differed on each area. Wildfire had destroyed the forest overstory at Camp Creek in 1969; and much dead timber, being small and unmerchantable, remained standing and unsalvaged. The Devils Run site previously supported larger trees that had been extensively windthrown in 1968 and subsequently salvaged. Timber at Doe Creek had been partially harvested in 1973 to leave a moderately stocked stand of large residual trees. Overstory on the Sheep Creek site had been completely harvested by clear cutting in 1973. On all sites, piling and burning of logging slash produced only minor disturbance.

Stand composition prior to disturbance included varying proportions of ponderosa pine, Douglas-fir, lodgepole pine (Pinus contorta var. latifolia Engelm.), grand fir (Abies grandis (Dougl. ex D. Don) Lindl.), and western larch (Larix occidentalis Nutt.). Apart from residual conifers, grasses and forbs dominated each site. Principal grasses included Idaho fescue (Festuca idahoensis Elm.), pinegrass (Calamogrostis rubescens Buckl.), intermediate wheatgrass (Agropyron intermedium (Host) Beauv.), orchard-grass (Dactylis glomerata L.), and timothy (Phleum pratense L.). Common forbs were heartleaf arnica (Arnica cordifolia Hook.), yarrow (Achillea millefolium L.), sedge (Carex spp.), clover (Trifolium spp.), and lupine (Lupinus spp.). Sparse shrub cover, composed chiefly of shiny-leaf spirea (Spiraea betulifolia Pall.), occurred only at Camp Creek.

Materials and Methods

Ponderosa pine was tested at Camp Creek and Devils Run; Douglas-fir at Doe Creek and Sheep Creek. Experimental design was identical on all sites. Each site supported an intact randomized complete block experiment with five blocks and seven treatments per block. Each treatment within a block was randomly assigned to a single row of 25 trees planted perpendicular to the land contour--providing 875 trees per experiment. Rows were spaced approximately 10 ft (3 m) apart, and 66 ft (20 m) or more separated each block. Treatments included two rates of dalapon and one rate of a dalapon-atrazine mixture. These were applied both with and without tree protection achieved by temporarily covering each seedling at time of treatment with an inverted, plugged funnel. An untreated check row completed the set:

Herbicide	Application rate [ai in lb/acre (kg/ha)]	Protection class
None (check)	--	--
Dalapon	4(4.48)	Covered
"	4(4.48)	Exposed
"	8(8.96)	Covered
"	8(8.96)	Exposed
Dalapon + atrazine	8(8.96) + 4(4.48)	Covered
Dalapon + atrazine	8(8.96) + 4(4.48)	Exposed

Ponderosa pine and Douglas-fir planting stock, grown in USDA Forest Service nurseries at Bend, Oregon, and Coeur d'Alene, Idaho, respectively, originated from seed sources local to each study area. All stock was of 2-0 class except for 525 3-0 ponderosa pine seedlings used in three blocks at Devils Run. Stock was lifted in either late March or early April, then stored at 2°C until planted in late May or early June. Where possible, each block of 175 seedlings was planted by a single worker.

Herbicides were applied by backpack sprayer to circular spots 5 ft (1.5 m) in diameter surrounding each tree about 1 to 2 weeks after planting. Dalapon used in these tests was a water-soluble powder formulation with active ingredients as sodium (72.5 percent) and magnesium (12.0 percent) salts; atrazine was an 80-percent wettable powder formulation. All herbicides were sprayed at specified rates of active ingredient in water carriers containing a non-ionic, polyglycol surfactant. Volume of carrier was 133 gal/acre (1 245 liters/ha with surfactant added at a ratio of 1:200 (v/v).

Each study was visited twice annually to evaluate target species control in early summer and conifer survival in early fall. Percentage control of herbaceous plants was based on two live crown-cover estimates made at each planting spot by adapting the method of Daubenmire (1959): 1) on the 5-ft (150-cm) treated circle, and 2) on a concentric 1-ft (30-cm) annulus immediately outside. The difference between the two was used to calculate negative or positive changes following treatment. Separate cover estimates were made for grasses and forbs. Conifer survival was the number of live trees expressed as the proportion of those originally planted. Stem heights were measured to the nearest centimeter immediately after planting and at study conclusion. All treatment means were tested by analysis of variance, and multiple comparisons were made according to Tukey's method. Camp Creek and Sheep Creek studies were monitored for two growing seasons; Devils Run and Doe Creek studies for three.

Results

Table 1--Grass control, forb control, and ponderosa pine survival and height at Camp Creek

Treatment	Grass control		Forb control		Tree survival		Stem Height
	1975	1976	1975	1976	1975	1976	1976
	- - - - - - - - - - - - - - Percent[1] - - - - - - - - - -						cm[1]
Untreated (Check)	0a	(8)a	0a	5	77	70	15.4
Dalapon, 4 lb/acre (trees covered)	31b	10ab	1a	2	75	61	15.4
Dalapon, 4 lb/acre (trees exposed)	28ab	9ab	1a	(6)	65	50	14.0
Dalapon, 8 lb/acre (trees covered)	47bc	22ab	8ab	(25)	59	45	14.6
Dalapon, 8 lb/acre (trees exposed)	47bc	28ab	4ab	(20)	74	54	14.7
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	71c	35b	54c	3	80	67	16.6
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	64c	27ab	29b	6	72	64	14.9

[1] Column means followed by the same letter or no letter do not differ significantly ($P > 0.05$). Control means not in parentheses indicate vegetation decrease; those in parentheses indicate vegetation increase. Control and survival means are based on 125 planting spots or trees; height means are for all trees surviving in 1976. 1.0 cm = 0.39 in.

Camp Creek (ponderosa pine).--Grasses, composed largely of pinegrass and fescue, were significantly reduced by all herbicide treatments the first season (table 1). Dalapon combined with atrazine clearly provided best results, but control did not significantly exceed that of dalapon used alone at the highest rate of 8 lb/acre (8.96 kg/ha). Recovery was rapid, and only one combined treatment controlled grass significantly through the 2d year. Forbs were not significantly reduced by dalapon alone at either low or high rates, but the dalapon-atrazine combination produced significant reductions. No forb control was significant the second season, though a slight increase in forb cover with dalapon at 8 lb/acre (8.96 kg/ha) probably occurred.

Ponderosa pine survived well on all treatments the 1st year and declined from an average of 72 to 59 percent the 2d. No treatments produced significant differences in survival during either year, or in stem height after 2 years. A definite confounding of treatment effects by planting procedures was observed at Camp Creek, as treatments within each block were not planted by one individual as originally prescribed. Obvious variation in planting quality probably nullified any significant survival effects. Observable damage to ponderosa pine from herbicides did not occur in this test, and covering seedlings at time of treatment produced no benefit.

Table 2--Grass control, forb control, and ponderosa pine survival and height at Devils Run

Treatment	Grass control			Forb control			Tree survival			Stem height
	1975	1976	1977	1975	1976	1977	1975	1976	1977	1977
	Percent[1]									cm[1]
Untreated (check)	0a	2a	3a	0a	(2)a	(15)	68	36ab	25ab	30.2
Dalapon, 4 lb/acre (trees covered)	24b	17b	5a	6a	(10)a	(8)	64	27a	15a	28.2
Dalapon, 4 lb/acre (trees exposed)	38bc	19b	7a	10a	(12)a	(9)	68	37ab	29ab	29.8
Dalapon, 8 lb/acre (trees covered)	54cd	44c	14a	14a	(25)a	(21)	80	51bc	28ab	28.0
Dalapon, 8 lb/acre (trees exposed)	62d	27b	9a	11a	(22)a	(15)	72	41abc	26ab	37.8
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	95e	74d	30b	88b	30b	(18)	80	59c	52c	32.2
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	94e	76d	35b	86b	23b	(26)	75	56bc	46bc	34.2

[1] Column means followed by same letter or no letter do not differ significantly ($P > 0.05$). Control means not in parentheses indicate vegetation decrease; those in parentheses indicate vegetation increase. Control and survival means are based on 125 planting spots or trees; height means are for all trees surviving in 1977. 1.0 cm = 0.39 in.

Devils Run (ponderosa pine).--All herbicides reduced grass cover significantly--an effect that extended through the second growing season for all treatments (table 2). Grasses included high densities of orchard-grass and intermediate wheatgrass but little pinegrass. Dalapon at 8 lb/acre (8.96 kg/ha) combined with atrazine at 4 lb/acre (4.48 kg/ha) reduced grass cover to nearly zero the 1st year, substantially inhibited its recovery, and maintained significant control through the 3d year. Dalapon used alone at either 4 or 8 lb/acre (4.48 or 8.96 kg/ha) was also effective through the second season but far less so than the combination treatment. All grass treated with dalapon alone had essentially recovered by the 3d year. Forbs were reduced only by combinations of dalapon and atrazine. Degree of control was high the 1st year and persisted at significant levels into the 2d. This result is notable because dalapon alone caused some increase in forb cover the 2d year, even though the increase was not significant.

Survival of ponderosa pine, like that at Camp Creek, was relatively high the 1st year but declined more rapidly from the same level of 72 percent in 1975 to 44 percent in 1976. More important, significant treatment-related differences, absent the 1st year, appeared in the 2d. Compared to the untreated check, dalapon used alone at low and high rates did not increase survival but the high rate combined with atrazine did. This result was significant for protected seedlings--i.e. 59 vs. 36 percent for treated and untreated trees, respectively. The margin widened to a significant doubling of survival for treated trees (52 vs. 25 percent) by the 3d year. Exposed trees treated with the same herbicide mixture survived almost equally well (46 percent), though not significantly better than the untreated check due to wide variation in treatment response.

Table 3--Grass control, forb control, and Douglas-fir survival and height at Doe Creek

Treatment	Grass control			Forb control			Tree survival			Stem height
	1975	1976	1977	1975	1976	1977	1975	1976	1977	1977
	Percent[1]									cm[1]
Untreated (check)	0a	3a	0a	0a	(2)a	(4)	90	70	49	21.8
Dalapon, 4 lb/acre (trees covered)	18ab	19b	9a	11a	(1)a	(3)	85	72	60	24.2
Dalapon, 4 lb/acre (trees exposed)	14ab	22bc	8a	9a	1a	0	90	64	50	20.6
Dalapon, 8 lb/acre (trees covered)	22b	33c	18a	11a	1a	(4)	89	79	62	22.6
Dalapon, 8 lb/acre (trees exposed)	32b	32bc	12a	15a	(3)a	(3)	86	75	56	23.0
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	92c	81d	51b	81b	59b	18	90	77	63	24.2
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	90c	84d	46b	79b	56b	8	88	68	54	20.8

[1] Column means followed by the same letter or no letter do not differ significantly ($P > 0.05$). Control means not in parentheses indicate vegetation decrease; those in parentheses indicate vegetation increase. Control and survival means are based on 125 planting spots or trees; height means are for all trees surviving in 1977. 1.0 cm = 0.39 in.

Visible damage to treated trees did not occur in this study. Furthermore, analysis of 3d-year tree height among all herbicide treatments (less the untreated check) disclosed an unexpected growth response associated with tree protection. Trees exposed at time of spraying averaged 4.4 cm (1.7 in) taller than covered trees. Moreover, this difference was significant ($P < 0.05$).

Doe Creek (Douglas-fir).--Herbaceous cover was similar to that at Devils Run but less dense and contained a higher proportion of forbs. During the 1st year, grass was reduced significantly only by treatments containing 8 lb/acre (8.96 kg/ha) of dalapon (table 3). Even this rate of dalapon, when used alone, reduced grass cover but little. The reduction persisted through the 2d year when control with the 4 lb/acre (4.48 kg/ha) rate of dalapon also became significant. Combining dalapon with atrazine, however, produced nearly total grass control the 1st year--an effect that diminished only gradually in the 2 years following. After 3 years, grass cover was still reduced by about 50 percent and significant control by the dalapon-atrazine combination could be expected for at least another year. Dalapon used alone was ineffective in reducing competition by forbs. The higher rate of dalapon combined with atrazine, however, produced a high level of forb control that remained significant throughout the first 2 years. By the 3d year, forb control was no longer significant.

Douglas-fir survival averaged 88 percent for all treatments the 1st year after planting. Mean survival declined to 72 percent in 1976, and to 56 percent in 1977. Though herbicide-treated seedlings survived consistently better than those on the untreated check after 3 years (58 vs. 49 percent, respectively), differences among all treatments were not significant. By eliminating the untreated check, however, we can compare common effects of herbicides and seedling protection. Survival differences associated with herbicides were not significant in any year; but by the 3d year, the difference between covered (62 percent) and exposed (53 percent) trees was ($P < 0.05$). Thus, seedling protection appeared to improve Douglas-fir survival by minimizing toxicity of herbicide treatment to trees while maximizing benefits of herbicide-reduced competition. At 3 years, stem height remained unaffected by treatment.

Sheep Creek (Douglas-fir).--Conditions on this site, more mesic than those on others, produced herbaceous cover dominated by grasses and sedges with a minimal component of forbs. Dalapon significantly reduced grass and sedge competiton the 1st year for all rates used either with or without atrazine (table 4), but the range of control was narrower (50 - 68 percent) than that achieved elsewhere (tables 1 - 3). A lack of difference between effects of dalapon used alone at 8 lb/acre (8.96 kg/ha), or at the same rate with atrazine added, was especially noticeable. The herbicide mixture was the only treatment that reduced forb cover significantly. No significant control of grasses or forbs persisted through the 2d year.

A high rate of Douglas-fir survival was attained the 1st year with all treatments, and no response to treatment could be detected. Survival declined from 93 percent the 1st year to 74 percent the 2d, when treatment-related differences again failed to appear. Future gains or losses as a consequence of herbicide applications also seemed unlikely in this test. As observed on site and reflected in the data, no injury to Douglas-fir due to herbicides occurred. Tree height at 2 years was neither increased nor decreased by treatment.

Table 4--Grass control, forb control, and Douglas-fir survival and height at Sheep Creek

Treatment	Grass control		Forb control		Tree survival		Stem height
	1975	1976	1975	1976	1975	1976	1976
	Percent[1]						cm[1]
Untreated (Check)	0a	17	0a	4	95	75	18.1
Dalapon, 4 lb/acre (trees covered)	50b	24	8ab	2	90	74	16.8
Dalapon, 4 lb/acre (trees exposed)	53b	24	4ab	0	90	72	18.6
Dalapon, 8 lb/acre (trees covered)	65b	36	8ab	3	93	71	17.5
Dalapon, 8 lb/acre (trees exposed)	62b	24	4ab	0	97	78	18.1
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	68b	31	23b	8	94	79	17.4
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	64b	24	20b	10	90	72	17.5

[1] Column means followed by the same letter or no letter do not differ significantly ($P > 0.05$). Control and survival means are based on 125 planting spots or trees; height means are for all trees surviving in 1976. 1.0 cm = 0.39 in.

Discussion

Weather was unusually favorable for conifer survival at all study locations in 1975. A cool, moist spring was followed by above-average precipitation in July and August at each site, as indicated by departures from long-term monthly averages:

Location	Precipitation		
	July	August	September
	Inches or (cm)		
Camp Creek	+ 0.7 (1.8)	+ 0.3 (0.8)	- 0.6 (1.5)
Devils Run	+ 2.3 (5.8)	+ 0.8 (2.0)	- 0.8 (2.0)
Doe Creek	+ 2.3 (5.8)	+ 0.9 (2.3)	- 0.7 (1.8)
Sheep Creek	+ 0.3 (0.8)	+ 0.2 (0.5)	- 1.2 (3.0)

Prolonged drought occurred only in September, and was soon relieved by above-normal October precipitation that ranged from a total of 1.3 in (3.3 cm) at Camp Creek to 3.4 in (8.6 cm) at Devils Run and Doe Creek. Though mean summer temperatures generally exceeded normal, drought conditions were undoubtedly abated.

Moisture stresses less than normal in 1975 probably reduced the likelihood of demonstrable benefits in terms of seedling survival. For example, large differences in relative survival were attained only at Devils Run, the site at which mortality of untreated seedlings was highest. Toxicity of herbicides to ponderosa pine was not evident at either Camp Creek or Devils Run. In fact, exposed trees at Devils Run were actually outgrowing covered trees by the 3d year. Though difficult to explain, this result at least indicates no adverse effects from herbicides. Marginal toxicity to Douglas-fir was suggested only at Doe Creek after 3 years, when survival of sprayed, covered trees exceeded that of sprayed, exposed and unsprayed trees by 9 and 13 percent, respectively. In this case, the only example of benefits associated with covering of seedlings, trees sprayed with dalapon-atrazine mixtures survived no better than those sprayed with dalapon alone. In our tests, atrazine did not appear to inhibit dalapon's phytotoxicity to conifers by the antagonistic mechanisms suggested by Newton and Overton (1973). Rather, cool storage of seedlings before planting delayed their emergence from dormancy and likely minimized adverse response to postplanting dalapon sprays. Damage by dalapon (with or without atrazine) to occasional natural seedlings, inadvertently sprayed on our study areas, reinforced this impression.

Though adding atrazine did not seem to reduce dalapon's toxicity to conifers, such toxicity was of little consequence. The combination did, however, provide high levels of lasting control of both grasses and forbs. Though dalapon alone effectively controlled grasses to a varying extent in all studies, the spectrum of grass species affected was narrower. Furthermore, dalapon did not control forbs. In fact, 2d-year increases in forb cover were suggested at Camp Creek and Devils Run--presumably in response to dalapon-caused decreases in grass competition the previous year. Only dalapon-atrazine mixtures consistently produced the degree and permanence of herbaceous control likely to benefit conifers substantially. Though obvious gains in survival with such mixtures occurred solely at Devils Run, they might have occurred elsewhere had competitive factors been more limiting. Northern pocket gophers (Thomomys talpoides) caused considerable damage to planted ponderosa pine at Devils Run, and damage was associated with 31 percent of the mortality occurring there over 3 years. No differences in damage were related to spot-spray treatments, though vegetation control with herbicides on even small plots has been shown to reduce damage by pocket gophers (Crouch 1979, Stewart and Beebe 1974).

1976 Broadcast Sprays

Study Areas

To retest dalapon and atrazine sprays, two studies were initiated in 1976 at widely separated locations. One experiment (TNT Gulch) was again sited on the Wallowa-Whitman National Forest near Enterprise, Oregon; the other (Entiat River) on the Wenatchee National Forest near Entiat, Washington. TNT Gulch is less than a mile (1.6 km) south of the 1975 site at Devils Run; and soils (ash), topography (level to rolling), and mean annual precipitation (20 in or 51 cm) are essentially identical. At Entiat River, soils ranged from residual, ash-characterized loams to light-textured pumice overlying gneiss and granodiorite. Topography is generally mountainous and steep near Entiat, and elevations of study plots varied from 2,700 to 3,300 ft (825 to 1 000 m). Mean annual precipitation at the various Entiat locations is 18 to 22 in (46 to 56 cm). During July, August, and September, mean monthly precipitation near Entiat is similar to that in northeastern Oregon and averages below 1 in (2.5 cm). Site history at TNT Gulch included 1968 blowdown and salvage of forest overstory--the same as that at Devils Run. The Entiat River experiment was divided between locations at Mosquito Ridge and Preston Creek, both ravaged by extensive wildfire in 1970. Only scattered patches of small, fire-killed timber remained at Entiat River plot locations. Herbaceous cover at TNT Gulch, similar to that at Devils Run, also included some Kentucky bluegrass (Poa pratensis L.). Sheep fescue (Festuca ovina L.) at Entiat River replaced Idaho fescue at TNT Gulch, but species composition of grasses and forbs in both experiments appeared otherwise much alike. Shrub cover was lacking at TNT Gulch and only sparse at Entiat River.

Materials and Methods

Experimental design was the same at TNT Gulch and Entiat Burn. Both ponderosa pine and Douglas-fir were tested at each location. Each experiment was a randomized complete block with three blocks of seven treatments per block. Each treatment was randomly allocated to one of seven square 1/100-acre (1/250-ha) plots. Fifteen ponderosa pine and 15 Douglas-fir seedlings were planted on each plot in six rows of alternating species with 5 seedlings per row (315 trees of each species per experiment). Untreated buffers minimally 10 ft (3 m) wide separated individual plots, and 1/2 mile (4/5 km) or more separated each block. Treatment variables in broadcast-spray studies differed in only one respect from those in spot-spray studies--i.e. substitution of atrazine for the lower rate of dalapon. Therefore, with two exceptions, the seven treatment prescriptions were identical and again included three herbicide treatments applied with and without temporary seedling protection:

Herbicide	Application rate ai in lb/acre (or kg/ha)	Protection class
None (check)	--	--
Dalapon	8(8.96)	Covered
"	8(8.96)	Exposed
Atrazine	4(4.48)	Covered
"	4(4.48)	Exposed
Dalapon + atrazine	8(8.96) + (4.48)	Covered
" + "	8(8.96) + (4.48)	Exposed

Results

USDA Forest Service nurseries at Coeur d'Alene, Idaho, and Wind River, Washington, provided Douglas-fir planting stock required at TNT Gulch and Entiat River, respectively. The nursery at Bend, Oregon, provided all ponderosa pine. All stock was of 2-0 class and originated from seed sources local to each area. Stock was lifted in late winter or early spring, stored at 2°C, and planted in late May at TNT Gulch and early June at Entiat River. Individual planters were employed for each species on each block. Herbicides were applied by backpack sprayer 1 to 4 weeks after planting. Powder formulations of herbicide, the same as used in 1975 spot sprays, were sprayed upon entire plots at specified rates of active ingredient without surfactant in water carriers at volumes of 200 gal/acre (1 870 liters/ha).

Control of target species was rated in midsummer; survival and height of conifers in early fall. Differences in herbaceous cover, estimated to the nearest 10 percent between plots and adjacent buffer strips, were used to calculate percentage control. As in spot-spray studies, analysis of variance was used to test treatment response in separate years, and multiple comparisons were made by the method of Tukey. Results at TNT Gulch were monitored for two growing seasons. At Entiat River, vegetation control was monitored for four seasons; survival and height of conifers for three.

TNT Gulch.--All herbicides reduced grass competition significantly the 1st year, and reductions attained with atrazine were somewhat greater than those attained with dalapon (table 5). Combining the two herbicides significantly increased levels of grass control beyond those produced by dalapon but did not significantly improve the performance of atrazine. Comparable to 1975 studies, dalapon did not significantly reduce competition by forbs. Atrazine, however, was successful in doing so, but the degree of control was erratic. Adding atrazine to dalapon was chiefly effective in widening the spectrum of forbs controlled--an effect observed on different blocks but not clearly reflected in treatment means. By the 2d year, combined reductions of grasses and forbs were significantly associated only with dalapon-atrazine mixtures and one of the atrazine treatments.

Ponderosa pine survived well the 1st year after planting and declined from 91 percent for all treatments to 62 percent by the 2d year. Though a survival advantage was apparent in 1977 for all herbicide treatments (64 percent) compared to the untreated check (49 percent), differences among individual treatment pairs were not significant. A much greater decline occurred between Douglas-fir survival in 1st and 2d years--82 to 20 percent; but survival differences were again not significant. Stem height of either species at 2 years remained unaffected by treatment. No observable toxicity to conifers resulted from herbicides, and no benefits from seedling protection emerged. During the 2d summer, range cattle used all parts of the study area heavily. The animals displayed a distinct proclivity for resting and bedding down on those plots where vegetation control had been most successful. Resultant damage to and mortality of seedlings on these study plots obviously confounded results. Accordingly, study evaluation was concluded after 2 years.

Table 5--Vegetation control, tree survival, and stem height at TNT Gulch

Treatment	Vegetation control			Tree survival				Stem height	
	Grass 1976	Forb 1976	Grass + Forb 1977	Ponderosa pine 1976	Ponderosa pine 1977	Douglas-fir 1976	Douglas-fir 1977	Ponderosa pine 1977	Douglas-fir 1977
	Percent[1]							cm[1]	
Untreated (check)	0a	0a	0a	91	49	87	31	19.2	16.6
Dalapon, 8 lb/acre (trees covered)	43b	10ab	13ab	96	56	67	16	20.0	14.8
Dalapon, 8 lb/acre (trees exposed)	50b	10ab	8ab	91	64	84	9	17.9	13.5
Atrazine, 4 lb/acre (trees covered)	67bc	60cd	30bc	84	58	82	16	16.8	14.8
Atrazine, 4 lb/acre (trees exposed)	57bc	37bc	11ab	93	69	89	18	20.6	12.2
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	87c	67d	30bc	98	73	84	29	20.7	12.2
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	87c	70d	48c	84	62	80	22	16.5	14.7

[1] Column means followed by the same letter or no letter do not differ significantly ($P > 0.05$). Control means are based on 3 replicates; survival means on 45 trees. Height means are for all trees surviving in 1977. 1.0 cm = 0.39 in.

Entiat River.--Pinegrass was present on the two study blocks at Mosquito Ridge, while orchard-grass, fescue, and timothy predominated on the single block at Preston Creek. Grass competition was reduced by all herbicides the 1st year, and control associated with only one atrazine treatment failed to differ significantly from the untreated check (table 6). Dalapon proved somewhat more effective than atrazine, but only the most effective dalapon treatment produced significantly greater control than the least effective atrazine application. As at TNT Gulch, dalapon-atrazine mixtures resulted in greatest control of grass. Some reduction of forbs was attained with all herbicides the 1st year, but wide data variations precluded significance. Combining evaluation of grass and forb cover facilitated treatment comparisons in subsequent years. Only treatments containing dalapon produced significant vegetation reductions the 2d year. Moreover, these reductions generally persisted through the 4th year. Though dalapon-atrazine mixtures continued to produce best control, dalapon alone was almost as effective.

Survival patterns were similar for both ponderosa pine and Douglas-fir throughout the 3-year period of evaluation (table 7). In ponderosa pine, percentage of live trees remaining after planting declined from 78 percent the 1st year to 69 percent the 3d. High 1st-year survival of Douglas-fir likewise declined from 92 to 77 percent after 3 years. Within both species, mortality was slight the 2d and 3d years. Analysis did not reveal any significant survival increases or decreases associated with treatment for any year within either species.

Table 6--Vegetation control at Entiat River

Treatment	Vegetation control				
	Grass	Forb	Grass + Forb		
	1976	1976	1977	1978	1979
	- - - - - - - - Percent[1] - - - - - - -				
Untreated (check)	0a	0a	13a	6a	(6)a
Dalapon, 8 lb/acre (trees covered)	57cd	27a	67b	40ab	21abc
Dalapon, 8 lb/acre (trees exposed)	47bc	10a	74b	64b	32bc
Atrazine, 4 lb/acre (trees covered)	40bc	17a	5a	(4)a	4ab
Atrazine, 4 lb/acre (trees exposed)	23ab	33a	6a	5a	2ab
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	83d	27a	81b	63b	39bc
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	70cd	30a	84b	63b	45c

[1] Column means followed by the same letter do not differ significantly ($P > 0.05$). Control means not in parentheses indicate vegetation decrease; those in parentheses indicate vegetation increase. All means are based on three replicates.

Table 7--Survival and height of ponderosa pine and Douglas-fir at Entiat River

Treatment	Ponderosa pine				Douglas-fir			
	Survival			Height	Survival			Height
	1976	1977	1978	1978	1976	1977	1978	1978
	- - - Percent[1] - - -			cm[1]	- - - Percent[1] - - -			cm[1]
Untreated (check)	82	82	78	16.7a	87	73	67	17.7a
Dalapon, 8 lb/acre (trees covered)	82	69	64	22.3ab	96	82	78	17.7a
Dalapon, 8 lb/acre (trees exposed)	76	60	60	13.7a	93	82	80	15.0a
Atrazine, 4 lb/acre (trees covered)	76	73	73	20.3a	96	75	69	18.7a
Atrazine, 4 lb/acre (trees exposed)	73	67	67	17.7a	91	76	75	17.7a
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees covered)	87	87	84	31.0b	93	86	86	28.3b
Dalapon, 8 lb/acre + atrazine, 4 lb/acre (trees exposed)	71	65	58	18.3a	91	82	82	18.3a

[1] Column means followed by the same letter or no letter do not differ significantly ($P > 0.05$). Survival means are based on 45 trees; height means are for all trees surviving in 1978. 1.0 cm = 0.39 in.

Discussion

Herbicide treatments containing dalapon produced some observable damage to conifer foliage when sprayed over exposed seedlings. No differences in damage could be detected between trees sprayed with either dalapon or dalapon-atrazine mixtures. Analysis of tree height at 3 years revealed a large and significant advantage for the dalapon-atrazine combinations if sprayed over covered seedlings (table 7). Ponderosa pine and Douglas-fir thus treated averaged 14.3 and 10.6 cm (5.6 and 4.2 in) taller, respectively, than untreated check trees. If check treatments are excluded, covered trees among all herbicide treatments averaged 8.1 and 4.6 cm (3.2 and 1.8 in) taller than exposed trees--again for ponderosa pine and Douglas-fir, respectively. Moreover, these differences were highly significant ($P < 0.01$).

Climatic factors generally favored conifers planted in 1976. Overcast skies were common during spring, and temperatures cooler than normal prevailed during summer months. Precipitation averaged near normal in spring and early summer, but monthly departures were well above normal in August as determined from locations near the study sites:

	Precipitation		
Location	July	August	September
	Inches or (cm)		
TNT Gulch (Enterprise)	+ 0.4 (1.0)	+ 2.2 (5.6)	- 0.1 (0.3)
Entiat River (Chelan)	- 0.1 (0.3)	+ 1.0 (2.5)	- 0.4 (1.0)

These departures, occurring near the midpoint of summer drought, combined with cooler weather to ameliorate factors critical to survival of newly planted conifers.

Little mortality of conifers occurred the first season at either TNT Gulch or Entiat River. Herbicide treatments aimed at enhancing survival are less likely to be effective if the factors they ameliorate are not limiting. First-year survival of untreated ponderosa pine and Douglas-fir seedlings at both locations ranged from 82 to 91 percent and left little margin for improvement. Therefore, reducing moisture stress on conifers by controlling competing grasses and forbs would likely have engendered more easily seen benefits in drier years.

Potential Application

Conifers at TNT Gulch displayed no toxic symptoms to herbicides applied either with or without seedling protection, and their survival was not significantly affected. Toxicity may have been minimized by rainfall shortly after spraying that diluted herbicide in contact with conifer foliage. At Entiat River, however, some injury to conifers was visible. Spraying dates were somewhat later than those at TNT Gulch, and conifers may have been less tolerant to herbicides. Benefits of seedling protection accrued gradually over time at Entiat River and produced gains in conifer growth but not in survival. The markedly superior growth of protected seedlings sprayed with a dalapon-atrazine mixture appears to be a net response relating to the combined effects of maximal control of target species and minimal toxicity to conifers. As in 1975 studies, adding atrazine to dalapon sprays did not appear to increase or decrease its toxicity to conifers.

Atrazine was somewhat more effective than dalapon in controlling plant competitors at TNT Gulch, but the reverse was true at Entiat River. The reversal was partly due to more efficient control of forbs with atrazine at TNT Gulch, but most likely reflected the net effect of differences in weather, soils, and species composition. Atrazine was ineffective on either forbs or grasses after 1 year at Entiat River, and most lasting control in both studies was attained with dalapon-atrazine mixtures.

Mode of action upon target plants was probably most responsible. Dalapon functions chiefly by direct translocation into foliage, while atrazine acts primarily through absorption by roots. Thus, combining the two herbicides more effectively exploited the properties of each to attain a broader spectrum of lasting response under a wider latitude of environmental conditions.

Postplanting sprays of dalapon combined with atrazine can safely and effectively control herbaceous species competing with newly planted conifers on dry, grassy sites. Postplanting sprays can be used with little or no injury to ponderosa pine and Douglas-fir, and seem a viable option to preplanting sprays that often require substantial delays between application and tree planting. The dormancy of planting stock taken from cool storage at forest nurseries can be effectively exploited in spring planting. If sufficiently prolonged, dormancy appears to provide latitude for topical applications of herbicides that might otherwise prove injurious. Chemically preparing sites in conjunction with the tree planting process has practical value for forest managers. Work scheduling can be simplified, opportunities for vegetation management expanded, and spot spraying used selectively to control herbaceous competitors only in the immediate vicinity of planted trees.

In our studies, a mixture of dalapon and atrazine (8 + 4 lb ai/acre, or 8.96 + 4.48 kg ai/ha) was the only spray treatment that significantly increased survival or growth of planted conifers. Temporary covering of seedlings at time of spraying provided some additional benefit but may not have been necessary in all cases. Covering seedlings added little to expense of treatment in our manual applications. Use of shielded spray nozzles or directed applications could also provide similar protection and decrease the possibility of conifer injury. High volumes of water carrier in our spray applications were aimed at enhancing thoroughness and uniformity of herbicide distribution. Lower volumes should differ little in effectiveness.

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Dimock, Edward J., II, and Ernest B. Collard.
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A mixture of dalapon and atrazine consistently controlled grasses and forbs better than either herbicide used alone. Sprayed over and around newly planted ponderosa pine (Pinus ponderosa Dougl. ex Laws.) and Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco), the mixture doubled tree survival in one study, greatly enhanced height growth in another, but produced no significant gains in four studies. Protecting seedlings from herbicide sprays proved beneficial in two studies, but seemed unnecessary in four others.

Keywords: Herbicides (-regeneration, grass control, forbs, dalapon, atrazine.

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