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INTRODUCTION

Western aspen (*Populus tremuloides* Michx.) forests are valued by resource managers for the multiple-use values of water, forage, wildlife habitat, and esthetics (DeByle 1981). Aspen stands are being managed by cutting and burning to rejuvenate aspen and to get a better age distribution of stands (Bartos 1981). Herbicide spraying (fig. l) is now beginning to be used on aspen in areas inaccessible or unsuited for cutting or burning. However, little information is available to the forest manager in the Western United States on what to expect from the use of herbicides or how they could be used to rejuvenate mature aspen stands.

Between 1965 and 1967 in central Utah, 470 acres (190 ha) were repeatedly sprayed with 2,4-D and 2,4,5-T (a total of six times during the growing season) in an attempt to convert the deep-rooted aspen and the associated communities to a more shallow-rooted grass type to increase water production (Robinson 1971). Aspen were virtually eliminated from the site immediately after spraying, and grass production increased approximately 10 times, in part because of aerial seeding. However, other problems arose such as mass slumping, accelerated erosion, and damage to big game habitat. Robinson (1971) indicated that "massive applications of herbicides to aspen and associated plant communities are not recommended at present since the full ecological impact of such treatment is not known." Several years after spraying, suckers 10 ft (3 m) tall were abundant.

In 1958, personnel at the Bridger-Teton National Forest sprayed 9,000 acres (3 645 ha) of sagebrush, which included aspen stringers, on the Upper Green River in western Wyoming. According to Lester (1972), the 2,4-D treatment "eliminated or injured" the aspen and some conifers. Bartos and Lester (1984) examined these aspen stands 22 years later and found abundant aspen trees on the sprayed areas. Forbs were still fewer in number of species, and there were no differences in grasses when compared to unsprayed aspen.

We decided to evaluate aspen stands that were accidentally or purposefully treated with herbicides by comparing the overstory and understory of treated and adjacent untreated stands throughout the Intermountain and Rocky Mountain area.

Figure 1.—Herbicide sprayed stand of aspen in southeastern Idaho after 1 year.

METHODS

National Forest personnel in the Western United States identified aspen stands treated with herbicides in conjunction with sagebrush, aspen, or conifer-release spraying projects. Stands were sampled if sprayed and unsprayed comparisons in proximity were about 1 acre (0.4 ha) and had information on the spray treatment. Spray information consisted of herbicide type, rate, carrier (water or diesel fuel), time of year, method of application, and treatment success on target species.

Stands were sampled at two levels of intensity. In stands selected for intensive sampling, 33- by 33-ft (10- by 10-m) plots were placed on the contour of the slope in relatively uniform and representative sprayed and unsprayed vegetation. Environmental attributes recorded were: elevation, aspect, slope percentage, and depth of soil organic layer, melanized layer, and parent material. Tree data determined by species on the entire

(d.b.h.) of live and dead trees over 2 inches (5 cm) d.b.h.; stem count of live and dead reproduction in classes of less than 20 inches (0.5 m) tall, 20 inches to 6.6 ft (0.5 m to 2 m) tall, and greater than 6.6 ft (2 m) tall up to 2 inches (5 cm) d.b.h., and number of stumps and diseased trees (primarily conks). Species numbers, composition, and frequency of the understory were determined by 33 nested frequency frames in each sample plot (U.S. Department of Agriculture 1983). Vegetation litter, rock, and bare ground were estimated from six points per frequency frame on the sample plot. Understory biomass was determined by both clipping and estimating current year's growth, up to 4.9 ft (1.5 m) high, by vegetation categories. Four sets of microplots, were distributed randomly on the 1,076 ft^2 (100 m^2) macroplot. Each set consisted of five circular 5.4 ft^2 (0.5 m^2) microplots clustered so that the biomass of four could be estimated as a percentage of the fifth, which was then clipped. The clipped vegetation was dried at least 48 hours in an oven at 158 °F (70 °C) and weighed for biomass. Percentages of the shrub, grass, and forb components were estimated on all five microplots. The dry weight biomass by vegetation categories is based on 20 microplots per stand. Photographs of the overstory and understory vegetation were taken on all plots.

On the plots sampled less intensively, the tree and environmental data were determined the same as on the more intensively sampled plots. The understory species cover was ocularly estimated on the entire 1,096 ft^2 understory biomass were estimated by vegetation categories.

More sprayed than unsprayed stands were sampled because variation was expected to be greater in the sprayed stands. All plots were used in an analysis using the one-tailed t-test for independent means.

RESULTS AND DISCUSSION

We sampled 17 sprayed areas that met our criteria in Idaho, Wyoming, Colorado, and Utah (fig. 2); 34 sprayed plots and 22 unsprayed plots for comparison were sampled (table 1). Sagebrush was the target species for most of the herbicide treatments (table 1). Aspen was sprayed for stand regeneration on four areas and for conifer release on two areas. The herbicide most commonly used was 2,4-D in high volatile butyl ester formulations mixed with water or diesel. The indicated rates of 2 lb/acre (2.2 kg/ha) are possibly higher than that actually applied in the aspen stands associated with sagebrush because of drift and volatilization. Quality control and equipment capabilities would also be factors in nontarget applications. Most of the sagebrush spray projects in which aspen was hit used fixed-wing aircraft in the late 1950's and early 1960's. The rarity of sprayed aspen stands in the 1970's when sagebrush was the target species coincides with the use of helicopter and low-volatile esters. Volatilization effects on nontarget species were reduced markedly when low volatile esters replaced the high volatile esters.

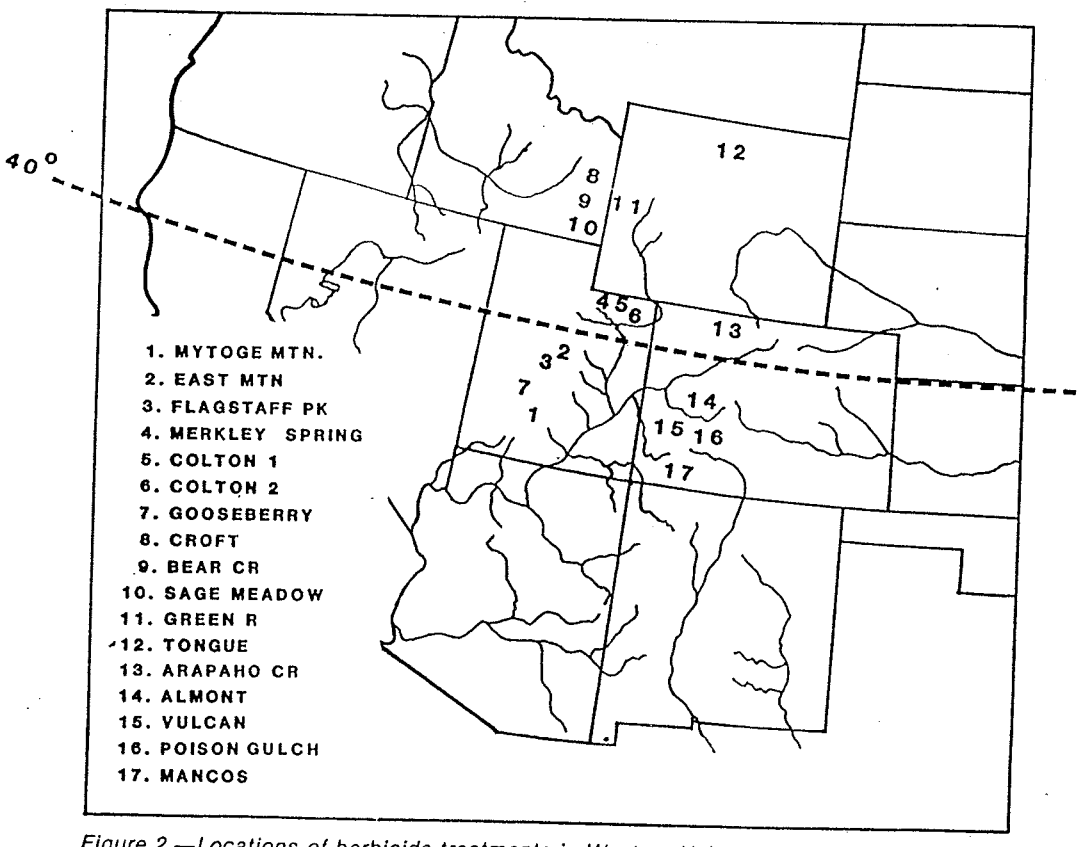

Figure 2.—Locations of herbicide treatments in Western United States.

Table 1.—Herbicide and plot information for 17 aspen stands sprayed with herbicides in the Western United States

Location	Month/year sprayed	Herbicide						Plot					
		Type	Rate[1]		Carrier[2]	Target[3]	Application[4]	Elevation		Slope	Aspect[5]	Spray	Unspr
			kg/ha	*Lb/acre*				*m*	*Ft*	*Percent*		*--Number--*	
1. Mytoge Mountain	6/80	2,4-D	2.2	2	W	SB	Heli	3 017	9,900	9-11	E	1	1
2. East Mountain	7/59	2,4-D	2.2	2	D	SB	FW	3 048	10,000	2-6	SW, NE	2	2
3. Flagstaff Peak	7/68	2,4-D	2.2	2	D	SB	Heli	2 926	9,600	12-14	E	1	1
4. Merkley Spring	6/58	2,4-D				SB	FW	2 621	8,600	2-8	SW	1	1
5. Colton 1	6/64	2,4-D	2.2	2	D	A	Heli	2 621	8,600	5	S	1	1
6. Colton 2	6/64	2,4-D	2.2	2	D	A	FW	2 590	8,500	7-9	SW	2	1
7. Gooseberry	/67	2,4-D/2,4,5T	2.2	2	D	A	Heli	2 621-2 865	8,600-9,400	11-18	All	9	1
8. Croft	6/65	2,4-D	2.2	2	D	SB/A	Heli	2 286	7,500	12-20	NE	1	1
9. Bear Creek	7/82	2,4-D	2.2	2	W	A	Heli	2 530	8,300	22-33	SW-SE	1	1
10. Sage Meadow	7/82	2,4-D	2.2	2	W	A	Heli	2 438	8,000	30-35	E	1	1
11. Green River	/58	2,4-D	2.2	2	D	SB	FW	2 743	9,000	5-17	E	4	3
12. Tongue	7/60/82	2,4-D	2.2	2	D	SB	Heli	2 377	7,800	18	W	2	1
13. Arapaho Creek	/62	2,4-D			W	SB	FW	2 621	8,600	27	NW	1	1
14. Almont	/68	2,4-D				SB	FW	2 865	9,400	37	NW	1	1
15. Vulcan	/81	2,4-D	2.2	2	W	SB	FW	2 895	9,500	24-27	NE	1	1
16. Poison Gulch	/63	2,4-D/2,4,5T	2.2	2	D	SB/A	Heli	3 017	9,900	4-21	SE	3	2
17. Mancos	/77	2,4-D	2.2	2		CR	Heli	2 499	8,200	2-5	N	2	2

[1]Acid equivalent.
[2]W = water, D = diesel.
[3]SB = sagebrush, A = aspen, CR = conifer release.
[4]Heli = helicopter, FW = fixed-wing.
[5]N = north, W = west, S = south, E = east.

unsprayed stands in the direction to be expected (table 2). Average number of live trees over 2 inches (5 cm) d.b.h., stand height, stand age, stand diameter, basal area, and disease incidence were higher in the unsprayed stands. Average number of suckers was generally higher in the sprayed stands, especially in the over 6.5-ft (2-m) category. The larger variation evident in the sprayed data is due partly to the variation in the number of years since spraying. The range in the unsprayed stands is about the expected range for aspen forests in the West (Baker 1925; Mueggler and Campbell 1982). However, average stand height, diameter, and basal area appear low for aspen. Perhaps most of the aspen stands associated with sagebrush spraying had drier site condition or poorer stand quality. Suckering on all sprayed stands was generally sufficient for rejuvenating the stand (fig. 3). The exception to sufficient suckering occurred in areas where the aspen clone was small

Table 2.—Tree and stand attributes for 34 sprayed and 22 unsprayed aspen stands

Variable	Units	Sprayed $\bar{x} \pm s$[1]	Unsprayed $\bar{x} \pm s$	t Prob	Range Sprayed	Range Unsprayed
Trees						
Live >5 cm	no/0.01 ha[2]	12.1 ± 13.0	21.0 ± 10.3	0.0046	0-53	9-50
Dead >5 cm	no/0.01 ha	9.0 ± 9.9	6.7 ± 4.3	.1608	0-42	1-16
Stumps	no/0.01 ha	14.5 ± 9.5	3.1 ± 4.2	.0000	0-33	0-14
Suckers						
Live <0.5 m	no/0.01 ha	32.4 ± 59.4	16.5 ± 19.0	.1155	0-212	0-80
Dead <0.5 m	no/0.01 ha	4.0 ± 14.0	1.0 ± 2.5	.1632	0-80	0-11
Live 0.5-2 m	no/0.01 ha	54.8 ± 99.4	23.0 ± 28.9	.0753	0-548	0-121
Dead 0.5-2 m	no/0.01 ha	11.0 ± 11.7	4.9 ± 8.3	.0200	0-37	0-34
Live >2 m-5 cm d.b.h.	no/0.01 ha	39.9 ± 45.1	5.2 ± 12.3	.0005	0-131	0-57
Dead >2 m-5 cm d.b.h.	no/0.01 ha	6.3 ± 9.6	2.1 ± 2.6	.0233	0-42	0-8
Stands						
Height	m	8.7 ± 5.7	12.6 ± 3.4	.0010	0-20	6-20
Age	years	47.7 ± 39.4	83.7 ± 21.8	.0001	0-129	38-117
Average d.b.h.	cm	7.9 ± 5.6	15.0 ± 3.3	.0000	0-19.6	8.4-20.8
Basal area	m^2/0.01 ha	0.102 ± 0.115	0.368 ± 0.161	.0000	0-0.4366	0.1208-0.7399
Disease	P/A[3]	0.029 ± 0.172	0.318 ± 0.477	.0010	0-1	0-1

[1]Average ± standard deviation.
[2]Multiply by 100 for numbers/hectare; 40.47 for numbers/acre.
[3]Presence or absence.

Figure 3.—Abundant regeneration of aspen 3 years after herbicide spraying.

Figure 4.—Isolated aspen stand treated with herbicide with no regeneration of aspen because of heavy grazing by deer and cattle.

(less than 1 acre [0.4 ha]), isolated, and grazed heavily by livestock or big game (fig. 4).

The understory composition had more grass and fewer forbs in the sprayed than in the unsprayed stands (table 3). Grass and total vegetation production was higher in the sprayed than in the unsprayed stands. Shrub numbers were slightly lower in the sprayed stands. Vegetation cover was greater on the sprayed plots, but the organic matter was deeper on the unsprayed plots, possibly due to undisturbed litter from aspen and understory categories. These results agree

decrease early while the grasses would increase after spraying. We found that these effects still show 20 or more years after treatment.

Based on the results of our observations and related literature, considerations for the use of herbicides on aspen that appear appropriate are:

1. The purpose for the herbicide treatment should be clearly identified. Aspen regeneration requires less herbicide and different timing than conifer site preparation and release.
2. The use of 2,4-D at a rate of 2 lb/acre (2.2 kg/ha) acid equivalent, low volatile mixed with a water carrier, kills most aspen overstory and initiates aspen regeneration. Lower rates of 1 to 1.5 lb/acre (1.1 to 1.6 kg/ha) may be effective in checking the aspen overstory and initiating suckering. However, this needs to be tested. Dicamba and 2,4-D mixtures have been recommended for *Populus* spp. control (Hamel 1983). These should be used mostly for conifer site preparations. Glyphosate (Roundup®) is being used experimentally in southern Utah in the fall for conifer release in stands with abundant aspen suckers, *Ribes* spp., or both.
3. Herbicides are most effective for stimulating aspen regeneration and conifer site preparation when applied soon after aspen reaches the full leaf stage. For conifer release, herbicides should be applied 1 to 3 weeks before aspen leaf fall to reduce herbicide damage to the conifer.
4. Spraying large openings in the aspen canopy should be avoided to reduce damage to shrubs and forbs, especially where aspen regeneration is the goal. Slight to moderate reductions of shrubs and forbs beneath the aspen should be expected when spraying aspen.

Table 3.—Understory vegetation and soil attributes for 34 sprayed and 22 unsprayed aspen stands

Variable	Units	Sprayed $\bar{x} \pm s$	Unsprayed $\bar{x} \pm s$	t Prob	Range	
					Sprayed	Unsprayed
Composition						
Shrub	Percent	22.5 ± 17.7	23.1 ± 14.3	0.4419	1.1-73.9	4.5-56.6
Grass	Percent	47.5 ± 21.3	33.9 ± 15.7	.0063	8.8-86.7	5.8-64.3
Forb	Percent	31.8 ± 17.9	43.0 ± 18.0	.0129	2.6-58.3	9.9-76.2
Weight						
Shrub	kg/ha	296.1 ± 303.1	284.0 ± 255.9	.4390	2.5-1,147.9	29.5-956.0
Grass	kg/ha	585.7 ± 471.3	400.8 ± 449.8	.0764	6.4-1,845.1	17.5-2,018.8
Forb	kg/ha	410.8 ± 343.8	393.4 ± 217.6	.4167	20.8-1,078.9	70.0-832.5
Total	kg/ha	1,292.9 ± 600.6	1,078.3 ± 548.7	.0925	241.9-2,351.2	211.2-2,539.4
Numbers						
Shrub	N/0.01 ha	4.0 ± 1.8	4.9 ± 1.4	.0287	2-9	3-8
Grass	N/0.01 ha	5.7 ± 2.0	5.9 ± 1.8	.4049	3-10	1-8
Forb	N/0.01 ha	11.0 ± 4.6	11.9 ± 4.9	.2354	2-22	4-20
Total	N/0.01 ha	20.6 ± 6.1	22.6 ± 5.7	.1111	12-31	12-34
Cover						
Vegetal	Percent	81.0 ± 16.8	73.6 ± 19.1	.0729	43-100	30-98
Litter	Percent	18.2 ± 16.5	24.4 ± 18.3	.1052	0-65	0-70.0
Rock	Percent	0.6 ± 1.6	1.7 ± 3.3	.0713	0-7	0-11.1
Bare ground	Percent	0.4 ± 0.9	0.8 ± 1.5	.1558	0-3.6	0-5
Soils						
Organic	cm	4.2 ± 1.6	5.8 ± 2.8	.0317	2-8	2-12
A	cm	25.1 ± 14.8	23.5 ± 11.8	.3650	3.8-60	3.8-53
B	cm	40.1 ± 17.4	32.4 ± 12.8	.1204	15-70	15-59

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Aspen stands sprayed with herbicides had higher numbers of aspen suckers than adjacent unsprayed stands. Understory production was higher due to more grass production in the sprayed stands. While the composition of forb species was lower, the number of grass species was higher on sprayed stands than on unsprayed stands. Vegetative cover was greater on the sprayed plots, but organic matter was deeper on the unsprayed plots. These results agree with expectations of broadleaf herbicide treatments.

KEYWORDS: *Populus tremuloides*, trembling aspen, spraying, understory, 2,4-D, management

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