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Response of montane tall-forb communities to 2,4-D and mixtures of 2,4-D and picloram

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Abstract

Tall-forb communities occur on deep soils of the upper montane and subalpine zones of the Rocky Mountains and extend from southwestern Montana to southern Utah. In the Centennial Mountains of Montana, forbs comprise >80% of the annual yields, including 30–35% sticky geranium *(Geranium viscosissimum)* and 20–25% *Potentilla* spp. Tall-forb communities are rich in species diversity and very productive, but many of the forbs are not palatable to grazing ungulates. Suppression of the less palatable species, like sticky geranium, would increase the forage value for grazing. In 1983 and 1984 adjacent plots were sprayed during weeks 1, 2, 3, and 4 in July, with 2,4-D[(2,4 Dichlorophenoxy)acetic acid, isooctyl ester] applied at 1.1 or 2.2 kg 2,4-D/ha or 2.2 kg 2,4-D/ha plus 0.6 kg/ha of the potassium salt of picloram (4-amino-3,5,6-trichloropicolinic acid). Forage yields were measured in August of 1984, 85, and 86. Total forage yields ranged from 2,700 to 3,000 kg/ha on the untreated areas. Forb yields were significantly reduced, especially by the 2,4-D + picloram treatment. Herbicide treatments applied during flower-stalk development to first fower of sticky geranium were most effective. Grass and sedge production partially compensated for reductions in forb yields. Interseeding of introduced species into herbicide treated plots in 1983 was unsuccessful. Forb and grass production is expected to return to levels similar to those on untreated areas after 5 years.

Key Words: herbicides, *geranium, potentilla,* subalpine vegetation types, *Elymus trachycaulus, Pachic cryoborall*

Tall-forb communities, found in the upper montane and subalpine zones, extend from the Centennial Mountains bordering Idaho and Montana in the north, eastward into Yellowstone National Park and the Big Horn Mountains. The type extends southward along the Idaho-Wyoming border, and into the Wasatch Mountains of Utah, terminating near Cedar City, Utah (Murray and Mayland 1990). Although not extensive in area, tall-forb communities are very important because of the forage produced, aesthetics provided, and for watershed protection. These plant communities are rich in species diversity, highly productive, and provide a nutritious diet for sheep (Buchanan et al. 1972). However, some sites support a high proportion of unpalatable forb species.

On the U.S. Sheep Experiment Station summer range in the Centennial Mountains of Montana, tall-forb communities comprise 29% of the usable area. In addition, the same species form the understory on a substantially larger area in open conifer and sagebrush (*Artemisia* spp.) types. At one intensively studied area, grass and forb composition (dry weight basis) was 12 and 88%, respectively. Sticky geranium (*Geranium viscosissimum* Fisch. & C.A. Meyer) contributed 34% of the total herbage weight. Buchanan et al. (1972) found this species contributed less than 2% of sheep diets, while grasses and northwest cinquefoil (*Potentilla gracilis* Dougl.) each make up 20% or more of the diet during the summer.

If the amount of sticky geranium and other unpalatable species could be reduced and replaced by species of greater palatability, then the type would have a much higher forage value. Many species of high palatablity occur in tall-forb communities. Therefore, it is essential that any method used that controlled the target species, would have a minimal effect on the desirable species.

Murray (unpublished) noted that growth of sticky geranium begins as soon as the snow has melted (in June or July). Sticky geranium grows rapidly and frequently provides a protective canopy over more palatable species like pale agoseris (*Agoseris glauca* [Pursh] Raf.) and leafybract aster (*Aster foliaceus* Lindl.). Because of the tendency of sticky geranium to overgrow other species, it was hypothesized that herbicide sprays might suppress sticky geranium without causing severe damage to palatable species in the lower strata.

Mueggler and Blaisdell (1951) found that dense stands of mulesear wyethia (*Wyethia amplexicaulis* Nutt.) were effective in shelter-ing other forb species from herbicide spray. Blaisdell and Mueggler (1956) reported that sticky geranium, western yarrow (*Achillea millefolium* L.), yampa (*Perideridia gairdneri* [H.&A.] Math.), and two larkspur species (*Delphinium* spp. L.) were unharmed by 2,4-D (2,4-Dichlorophenoxyacetic acid), while sticky cinquefoil (*Potentilla glandulosa* Lindl.), northwest cinquefoil, and one-flowered helianthella (*Helianthella uniflora* [Nutt.] T.&G.) sustained heavy damage, pale agoseris moderate damage, and groundsel (*Senecio integerrimus* Nutt.) light damage on areas sprayed for sagebrush control in eastern Idaho. Mead (1958), at the base of the Centennial Mountains on Crab Creek near Kilgore, Idaho, found that sticky geranium increased on sagebrush areas sprayed with 2,4-D and that cinquefoil was lightly damaged and fully recovered by the third year. Silvery lupine (*Lupinus argenteus* Pursh.), another prominent member of the tall-forb type on some sites in the Centennials, was severely damaged by 2,4-D (Mead 1958). On the Bighorn National Forest in northcentral Wyoming, Hurd (1955) reported that pale agoseris was heavily damaged and leafybract aster was moderately damaged by 2,4-D. In spite of reported results it was felt that not enough was known about rates and time of application to rule out use of 2,4-D in the tall-forb type.

The primary objectives of this study were to (1) evaluate the effects of applying herbicides during the early growth of tall-forb vegetation as a means of improving the overall forage value for sheep (specifically to determine effects on sticky geranium, the target species, and the more palatable forbs), and (2) evaluate effects of 2,4-D applied at 2 rates (1.1 and 2.2 kg/ha) and 2,4-D + picloram applied at a single rate (2.2 and 0.6 kg/ha, respectively), and most importantly (3) estimate the time required for the type to recover from herbicide treatment.

Study Area and Methods

The study was conducted during 1983–1986 on the U.S. Sheep Experiment Station summer range located in the Centennial

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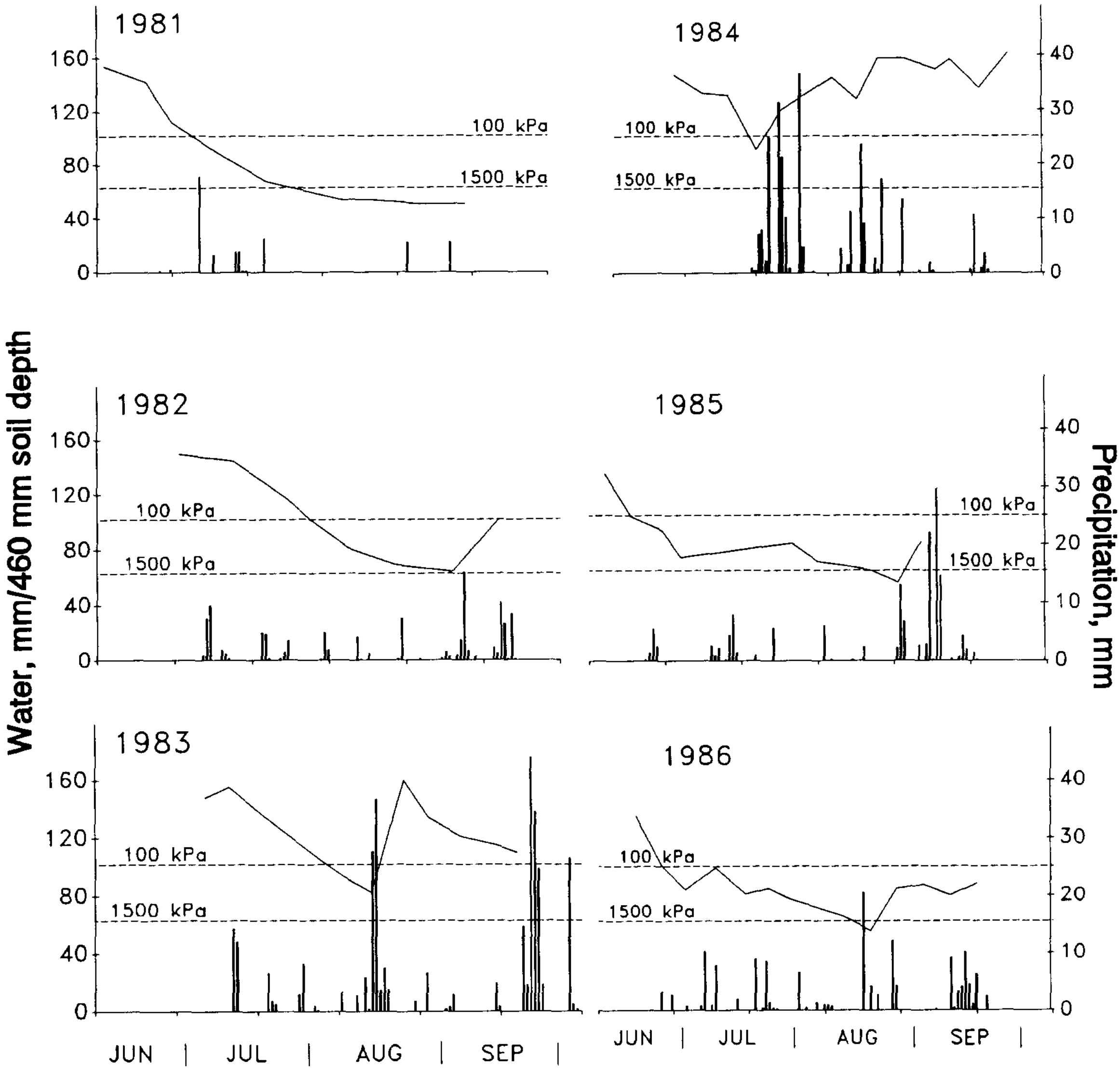

Fig. 1. Volumetric soil water (mm/460 mm depth) contents, 100 and 1,500 kPa tensions, and daily precipitation (mm) for the period June-September (1981-1986) at a site adjacent to herbicide research plots on the U.S. Sheep Experiment Station summer range, Centennial Mountains, Montana.

Mountains of southwestern Montana. The geographic description is 111° 46′ W, 44° 32′ N and legal description is T14N R2W Sec 13 in Beaverhead County, Montana. The study area faces northward, has a slope of 20%, and lies at an elevation of 2,380 m. Annual precipitation is estimated to be >750 mm with the majority occurring as snow. Summer precipitation during the study period is shown in Figure 1. Measured seasonal totals were 47, 115, 311, 254, 171, and 155 mm precipitation for the 1981 through 1986 summer periods. Air temperatures average less than 5° C annually, but average air temperatures over a 100-day summer period were about 12° C (Fig. 2).

Soils are of the Pachic Cryoborall, loamy-skeletal, mixed, 16 to 30% slope (Tippy et al. 1978). The upper surface horizon is a dark brown loam, black when moist, and is approximately 18-cm thick. The lower part is a very dark grayish brown moist loam, about 30-cm thick. The upper subsoil is a dark grayish brown moist loam, about 10-cm thick, and the lower part is a grayish brown moist loam, about 20-cm thick. The substratum is a pale brown or light gray moist loam at least 25-cm thick. Where Argic Cryoboralls are included, the substratum is usually a yellowish brown gravelly loam about 30-cm thick that grades into fractured bedrock of mixed sedimentary origin. Our data indicate the Pachic Cryoborall contains 45, 35, and 30 g/kg of organic carbon, and C:N values are 12.8, 12.5, and 11.5 for the 0 to 15, 15 to 30, and 30 to 45 cm depths, respectively.

Permeability of this soil is moderate and the available water holding capacity is high. The surface runoff is medium and the erosion hazard severe (especially when denuded of vegetation). The effective rooting depth is 73 to 79 cm, although some tap rooted species penetrate to a much greater depth. The compaction hazard is moderate. The potential plant community produces in excess of 2,000 kg/ha of dry forage in average years.

The principal grasses found on the study area are slender wheatgrass (*Elymus trachycaulus* [Link] Gould ex Skinners) (Dewey 1984), mountain brome (*Bromus carinatus* Hook. & Arn.), purple oniongrass (*Melica spectabilis* Scribn.), alpine timothy (*Phleum alpinum* L.), and spike trisetum (*Trisetum spicatum* [L.] Richter). Occasional grasses and sedges include nodding bluegrass (*Poa reflexa* Vasey & Scribn.), Letterman's needlegrass (*Stipa lettermannii* Vasey), western needlegrass (*Stipa occidentalis* Thurb.), and Raynolds sedge (*Carex raynoldsii* Dewey). The predominant desirable forbs include pale agoseris; asters (*Aster* spp. L.), which include Engelmann aster (*Aster engelmannii* (Eat.) Gray), leafy-bract aster, and thickstem aster (*A. integrifolius* Nutt.); stickseed (*Hackelia floribunda* [Lehm.] Johnst.); northwest cinquefoil; and groundsels (*Senecio* spp. L.), which include lambstongue groundsel

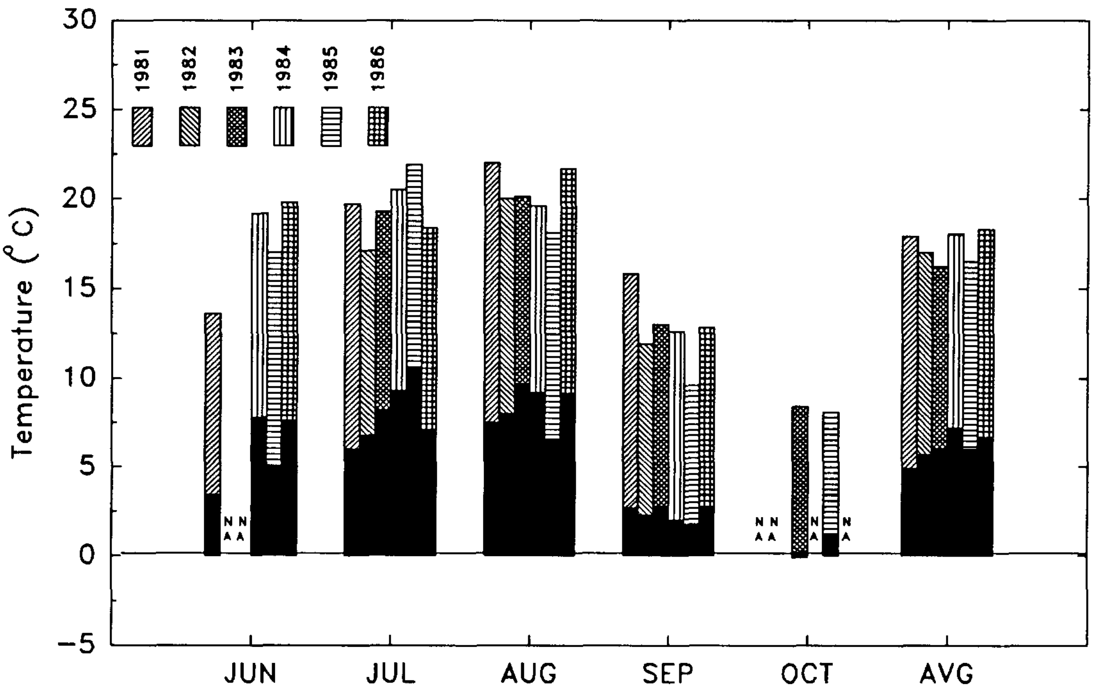

Fig. 2. Maximum and minimum (black-shaded) temperatures (° C) for the June-October period for 1981-1986 at the U.S. Sheep Experiment Station summer range, Centennial Mountains, Montana. Elevation 2,440 m. The NA notation indicates not available.

(*S. integerrimus* Nutt.), cutleaf groundsel (*S. serra* Hook.), and arrowleaf groundsel (*S. triangularis* Hook.). The less desirable species of forbs include western yarrow, duncecap larkspur (*Delphinium occidentale* Wats.), sticky geranium, silvery lupine, tarweed (*Madia glomerata* Hook.), sticky cinquefoil, and western coneflower (*Rudbeckia occidentalis* Nutt.). The more important annual forbs, aside from tarweed, include northern fairy-candelabra (*Androsace septentrionalis* L.), littleflower collinsia (*Collinsia parviflora* Lindl.), spring verna (*Draba verna* L.), thinleaf bedstraw (*Galium bifolium* Wats.), and mountain knotweed (*Polygonum douglasii* Greene). Although the latter species is not abundant, it is important in the sheep diet on this range (Buchanan et al. 1972).

The experimental design included 3 herbicide treatments applied at 4 weekly intervals in July, plus untreated checks. The 13 treatments were randomized on plots in each of 3 blocks. Herbicides[1] and rates were the isooctyl ester of 2,4-D at 1.1 kg/ha, 2,4-D at 2.2 kg/ha, and 2,4-D at 2.2 kg/ha plus the potassium salt of picloram (4-amino-3,5,6-trichloropicolinic acid) at 0.6 kg/ha. These were applied on 5, 13, 20, or 27 July 1983 and 5, 11, 18, or 25 July 1984. Areas treated in 1983 and 1984 were adjacent. The herbicides were applied in a total volume of 94 L/ha in a water carrier containing 0.2% non-ionic surfactant with a 6-nozzle backpack sprayer using carbon dioxide as a propellent.

[1]Mention of pesticides or proprietary products does not constitute an endorsement or recommendation for use by the USDA. Use of a restricted pesticide requires that the applicator have appropriate licensing.

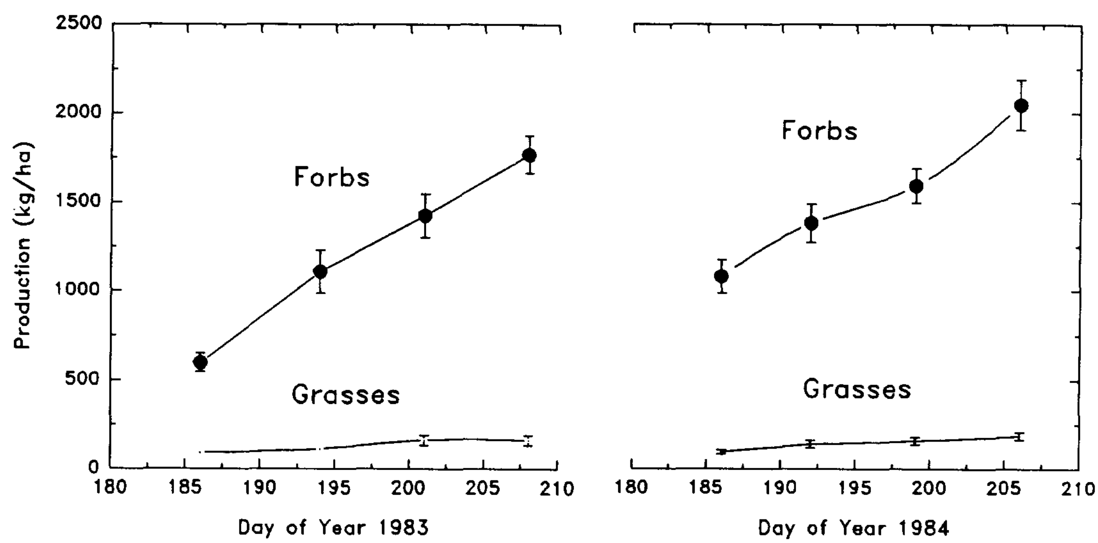

Fig. 3. Grass and forb production means ± SE (kg/ha) at time of herbicide applications in 1983 or 1984 on a tall-forb community, Centennial Mountains, Montana.

Table 1. Phenological stages of some principal grass[1] and forb[2] species in 1983 and 1984. Data from U.S. Sheep Experiment Station summer range, Centennial Mountains, Montana.

	1983							
	Jul 6	Jul 12	Jul 19	Jul 26	Aug 3	Aug 9	Aug 16	Aug 23
Elymus trachycaulus	1.0	1.0	1.3	3.0	3.8	4.5	5.0	5.0
Bromus carinatus	1.0	1.0	1.7	3.0	4.0	4.5	5.0	5.0
Melica spectabilis	2.7	2.9	4.0	4.8	5.0	5.0	6.2	7.5
Phleum alpinum	1.0	1.0	1.1	1.8	1.8	1.8	3.3	3.3
Trisetum spicatum	1.0	1.0	1.2	1.2	1.6	1.7	1.7	4.4
Agoseris glauca	1.0	1.0	1.0	1.1	1.5	1.5	2.9	2.9
Aster species	1.0	1.1	1.7	1.8	1.9	2.0	2.2	2.8
Delphinium occidentale	1.0	1.0	1.0	1.0	1.0	1.0	1.3	1.7
Geranium viscosissimum	1.7	1.8	2.0	3.0	4.0	4.0	4.7	5.0
Hackelia floribunda	2.2	2.5	3.6	3.6	5.0	5.0	6.1	6.2
Lupinus argenteus	1.6	1.6	1.6	1.7	1.7	2.5	2.5	2.5
Potentilla gracilis	1.0	1.2	1.6	2.5	3.1	4.0	4.5	5.0
Rudbeckia occidentalis	1.0	1.0	1.0	1.0	1.0	1.3	1.3	1.3
Senecio species	1.0	1.0	1.0	1.3	1.7	1.7	1.7	1.7

	1984					
	Jul 5	Jul 13	Jul 19	Jul 26	Aug 3	Aug 18
Elymus trachycaulus	1.5	1.5	2.3	3.5	4.0	5.5
Bromus carinatus	1.5	2.1	3.4	4.0	4.0	5.5
Melica spectabilis	2.8	3.5	4.3	4.8	5.3	5.5
Phleum alpinum	1.7	3.3	3.8	4.8	5.3	5.5
Trisetum spicatum	1.7	2.2	5.2	5.2	5.5	5.5
Agoseris glauca	1.5	1.5	2.1	2.6	2.6	3.3
Aster species	1.5	1.6	2.0	2.0	2.1	3.3
Delphinium occidentale	2.0	2.0	2.4	3.8	4.8	5.0
Geranium viscosissimum	2.0	2.1	3.1	3.1	4.1	4.8
Hackelia floribunda	2.5	3.6	3.9	4.5	5.2	6.5
Lupinus argenteus	1.9	1.9	2.5	2.9	4.0	4.0
Potentilla gracilis	1.5	1.5	2.1	2.2	3.1	4.9
Rudbeckia occidentalis	1.5	3.0	3.0	3.0	3.0	4.2
Senecio species	1.0	3.0	3.0	3.0	3.2	4.0

[1]Growth stage of grasses: 1, Growth started; 2, Flower stalks appear; 3, Heads showing; 4, Heads fully out; 5, Flowers in bloom; 6, Seed ripe; 7, Seed disseminating; 8, Seed 90% disseminated; 9, Plants drying.
[2]Growth stage for forbs: 1, Growth started; 2, Flower stalks showing; 3, 1st flowers in bloom; 4, In full bloom; 5, Blooming over; 6, Seed ripe; 7, Seed disseminating; 8, Seed disseminated; 9, Plant drying.

Individual plots were 5.5 by 9.1 m. The upper 5.8 m of each plot was used for collecting samples. The lower 3.3 m of each plot was used for a fall over-seeding trial in 1983 for the purpose of reducing erosion, should the herbicide kill most existing vegetation.

Ten to 20 circular 0.45-m^2 plots were clipped at ground level to estimate herbaceous standing production at each time of spray application. The plant material was first air-dried and then oven-dried at 70° C for 48 hr and weighed.

Soil samples collected from 0 to 15, 15 to 30, and 30 to 46-cm depths were air-dried and passed through a 2-mm sieve. Prewetted subsamples were subjected to matric suctions of 10, 100, 340, 1,070 or 1,500 kPa using a pressure plate apparatus (Klute 1982). Water retentivity was determined gravimetrically after drying at 106° C for 24 hr. Subsamples were also analyzed for organic carbon using the Walkely-Black procedure 9-57 (Jackson 1982) and total nitrogen using a micro-Kjeldahl procedure 31-3 (Bremner and Mulvaney 1982). Bulk density was determined on cores extracted at 6-cm increments to a depth of 48 cm. Soil water contents were determined gravimetrically each week from the adjacent growth study location during the summer (1983–1986) and were converted to volumetric water.

Average forb canopy height (cm) was determined by making 25 random measurements, to the top of each forb encountered, along each plot edge at approximately weekly intervals throughout the summers of 1983 through 1986 on areas treated in 1983; and 1984 through 1986 on areas treated in 1984. These data estimate the effects of treatment on the average growth of surviving forbs.

Stages of plant growth were recorded on untreated plots for 10 plants of slender wheatgrass, mountain brome, purple oniongrass, alpine timothy, spike trisetum, pale agoseris, asters, sticky geranium, stickseed, silvery lupine, northwest cinquefoil, western coneflower, and groundsels (if present) in the plot. The stages were developed by J.F. Pechanec (ca. 1935) and have been used extensively at the U.S. Sheep Experiment Station (see footnotes 1 and 2, Table 1 for growth stages of grasses and forbs). The stages were recorded periodically during the summers of 1983 through 1986 and 1984 through 1986 on plots treated in 1983 and 1984, respectively.

Unpalatable sticky geranium and palatable northwest cinquefoil plants, representing an undesirable and desirable species, were

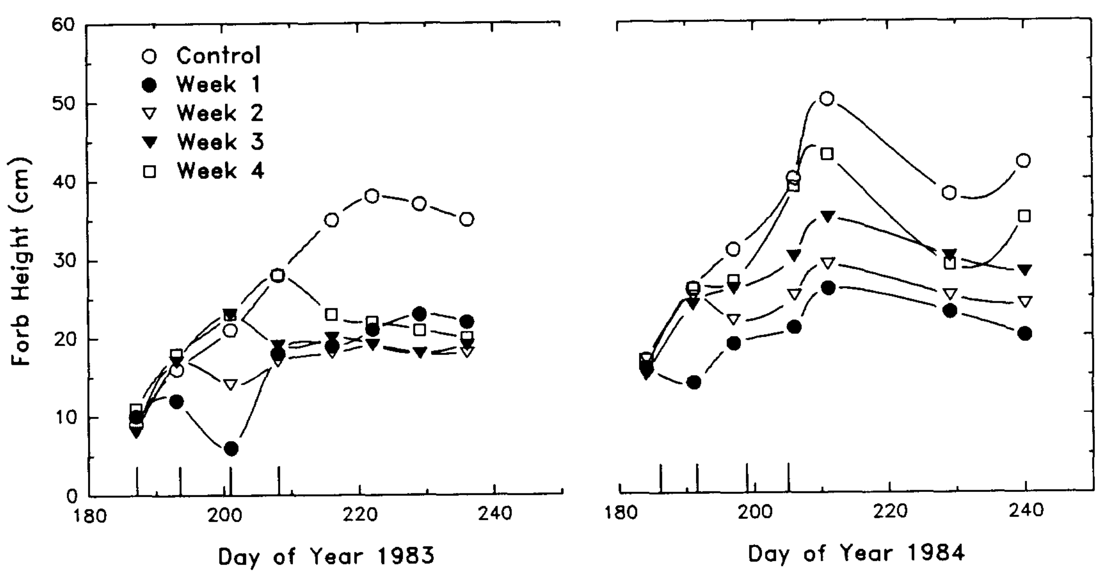

Fig. 4. Forb height growth (cm) in response to time of herbicide application in 1983 or 1984. Vertical lines designate date of application. The LSD for the last day of measurement was 2.6 cm in 1983 and 3.0 cm in 1984. Data from U.S. Sheep Experiment Station summer range, Centennial Mountains, Montana.

Table 2. Yields[1] by species averaged over 1984-1986 for untreated or herbicide sprayed plots in 1983. Data from U.S. Sheep Experiment Station summer range, Centennial Mountains, Montana.

		Week of Application[2]				Herbicide and Rate		
Species	Control	1	2	3	4	2,4-D 1.1 kg/ha	2,4-D 2.2 kg/ha	2,4-D + Picloram 2.2 + 0.6 kg/ha
	kg/ha							
Elymus trachycaulus	56 a	160 b	154 b	148 b	209 b	123 ac	152 bc	228 bd
Bromus carinatus	304 a	581 b	566 b	635 b	591 b	385 ac	510 ac	885 bd
Melica spectabilis	88 a	73 a	123 a	136 a	103 a	97 ac	96 ac	135 ad
Phleum alpinum	29 a	43 a	32 a	45 a	28 a	28 ac	32 ac	51 bd
Trisetum spicatum	10 a	20 a	21 a	29 a	17 a	14 ac	18 ac	33 bd
Other grasses and sedges	14 a	26 a	23 a	25 a	19 a	19 ab	25 ab	26 ab
TOTAL GRASS AND SEDGE	501 a	903 b	919 b	1018 b	967 b	666 ac	833 bc	1358 cd
Achillea millefolium	11 a	8 a	9 a	7 a	7 a	12 ac	9 ac	2 bd
Agoseris glauca	43 a	17 b	13 b	9 b	13 b	22 bc	16 bc	1 bd
Aster species	261 a	192 a	73 b	52 b	52 b	172 bc	85 bd	20 be
Geranium viscosissimum	559 a	409 a	524 a	499 a	400 a	583 ac	668 ac	123 bd
Hackelia floribunda	67 a	49 a	35 a	26 a	47 a	61 ac	49 ac	8 bd
Lupinus argenteus	11 a	12 a	6 a	5 a	2 a	10 ab	7 ab	1 ac
Potentilla gracilis	965 a	545 b	604 b	370 b	268 b	602 bc	527 bc	211 bd
Other annual forbs	196 a	126 a	163 a	209 a	189 a	161 ab	133 abc	221 abd
Other perennial forbs	101 a	75 a	131 a	95 a	91 a	143 ab	99 abc	51 ac
TOTAL FORBS	2214 a	1433 b	1558 b	1272 b	1069 b	1766 bc	1593 bc	638 bd
TOTAL VEGETATION	2715 a	2336 b	2477 a	2290 b	2036 b	2432 bc	2426 bc	1996 bd

[1]An orthogonal comparison technique (Steel and Torrie 1960) was used to compare untreated versus week of application and herbicide treatments. The first sequence of letters in a row compare the untreated and all others. Subsequent letters in the treatment section compare responses between treatments. If letters are not the same there is a significant difference at $P \leq .05$.
[2]Application was made in week 1, 2, 3, or 4 in July of 1983 (see text for actual day of year).

counted in 3 to 5 0.45-m^2 circular quadrats per plot during late August in 1983–1986 and 1984–1986 for 1983 and 1984 treatments, respectively.

Within the central section of each plot, herbage in four 0.45-m^2 circular quadrats was clipped at ground level during early to mid-August in 1984 on areas treated in 1983. Three subplots were clipped in subsequent years (1985 and 1986) on areas treated in 1983 and 1984. Individual species were separated and placed into paper sacks. After several days air-drying, the material was oven-dried at 70° C for 48 hours and weighed.

On 21 September 1983 in the lower section of each plot treated in 1983, 2 rows of smooth brome *(Bromus inermis 'Manchar'),* cicer milkvetch *(Astragalus cicer 'Lutana'),* reed foxtail *(Alopecurus arundinaceus 'Garrison'),* slender wheatgrass and single rows of RS-Hybrid *(Elytrigia repens* × *Pseudoroegneria spicata)* and intermediate wheatgrass (*Thinopyrum intermedium cv.* Green [Host] Barkworth & Dewey) (Dewey 1984) were drilled in rows 30 cm apart using a small tractor-mounted drill. Seedling establishment was measured in August 1984.

The yield data were analyzed using 3 different experimental models. The **first model** analyzed date of application, treatments, and year of treatment for each major species. The sources of variation and distribution of degrees of freedom were as follows: Block (2), Treatment (12), Error A (24), Year (1 or 2), Year × Treatment (12 or 24), Error B (26 or 52), and Total (77 or 116). The **second model** analyzed differences between treatment years for each species. The sources of variation and degrees of freedom were as follows: Treatment years (1), Blocks within treatment years (4), Treatments (2), Treatment years × Treatment (2), Treatment × Blocks within Treatment year (8), Dates (3), Treatment years × Dates (3), Dates × Blocks within Treatment years (12), Treatment × Dates (6), Error (30), and Total (71). The **third analysis** used a SAS (1987) general linear model procedure which analyzed species and treatments over all data sets within each treatment year. The data, to have homogeneous variance, were transformed to logarithms prior to analysis. The sources of variation and degrees of freedom were as follows: Species (19), Treatments (12), Blocks (2), Subplots (3), and Total (3,119 minus the number of zero plots).

Results and Discussion

Grass and forb aboveground standing crop (kg/ha), from untreated plots, at the time of each spray application is shown in Figure 3. Total standing crop was 32, 57, 74, and 90% of the maximum for the 4 spray dates in 1983, respectively. The values for plots treated in 1984 were 46, 60, 68, and 88%, respectively. By the first spray date in 1984 the vegetative development was more advanced compared to that in 1983. After the first date, production slowed—as evidenced by the lower maximum growth rate (52 kg ha^{-1} d^{-1} in 1984 vs 68 kg ha^{-1} d^{-1} in 1983). Although the percentages were similar after the first date, the actual maximum standing crop values were greater in 1984 compared to 1983 by about 16% (nearly 400 kg/ha). This difference in maximum standing crop is attributed to climatic differences between 1983 and 1984 since the standing crop was determined on the same location in the 2 years. Figure 1 shows that July 1984 was possibly wetter (only 19 days of record in 1983 compared to 31 in 1984) and warmer (Fig. 2) than July 1983. This is further supported by July precipitation records from nearby weather stations (Monida Pass, Lakeview, and Island Park) which show 63, 74, and 96 mm in 1983 and 80, 103, and 94 mm, respectively, in 1984. In spite of a saturated soil profile at the start of growth, the reduction in soil water was steady throughout the growth period in 1983, but was recharged in mid-July in 1984 (Fig. 1). In all years growth was completed before soil water tension reached or exceeded 1500 kPa.

Forb height growth (averaged over all treatments) was retarded following spray application (Fig. 4). At peak height (10 Aug. 1983, and 30 July 1984), forb heights on sprayed plots were 50 to 58% and 52 to 86% of untreated plots, respectively. By 2 years after treatment forb height was similar on both sprayed and untreated plots (data not shown).

Phenologically, most plants were more mature at time of treatments in 1984 compared to 1983 (Table 1). Species such as purple oniongrass, sticky geranium, and stickseed were generally more advanced than other species. Growth stages were similar among spray treatments within a date of treatment. Data for 2 years illustrate the marked dependence of plant development on seasonal temperature and soil moisture responses.

Densities of sticky geranium and northwest cinquefoil plants were determined in late August the year of application through 1986 (data not shown). Densities of these species were reduced in the year of treatment, only by the 2,4-D + picloram treatment in 1984. Phenology of plants sprayed in 1984 was 1 to 2 weeks ahead of those sprayed the previous year perhaps accounting for the greater phytotoxicity (Table 1). Sticky geranium densities were less ($P<.01$) on the 2,4-D + picloram treatment (2 plants/m^2) than on the untreated (8 plants/m^2) or the 2,4-D alone treatments (8 plants/m^2) on the year following treatment. Date of treatment within a year did not affect herbicide effectiveness on sticky geranium. Northwest cinquefoil densities on plots sprayed in 1983 or 1984 were less ($P<.05$) on 2,4-D + picloram treatments (6 plants/m^2) than on untreated plots (18 plants/m^2) or the 2,4-D alone treatments (13 plants/m^2) on the year following spraying. The greatest reduction in density caused by the 2,4-D + picloram treatment occurred from the third date of application in 1983 and second date of application in 1984 coinciding with preflowering stage (Table 1). These findings are similar to those by Mueggler and Blaisdell (1951), who reported that a more effective kill of mulesear wyethia was obtained by spraying 2,4-D before flowering.

Herbicides such as 2,4-D and picloram reduce yields of shrubs and forbs, while allowing for increases in grass yields. Thilenius et al. (1974) found that 2,4-D significantly reduced the standing crop of forbs, but not the total standing crop on alpine range in Wyoming. The increase in grass production usually does not make up for the loss in forb production. In this study total yields (Tables 2 and 3) on untreated plots were 2,720 and 2,950 kg/ha as averaged over 1984–1986 for 1983 treatments and 1985–1986 for 1984 treatments, respectively. The overall reduction in total yields as the result of herbicide application was 16 and 11% for 1983 and 1984 treatments, respectively. Grass and sedge yields were 19 and 16% of the total on untreated plots, compared to 42 and 41% of the total yields for plots receiving herbicide treatments in 1983 or 1984, respectively. It is clear that grass-sedge yields increased, forb yields decreased, but the overall yields were less than on untreated plots.

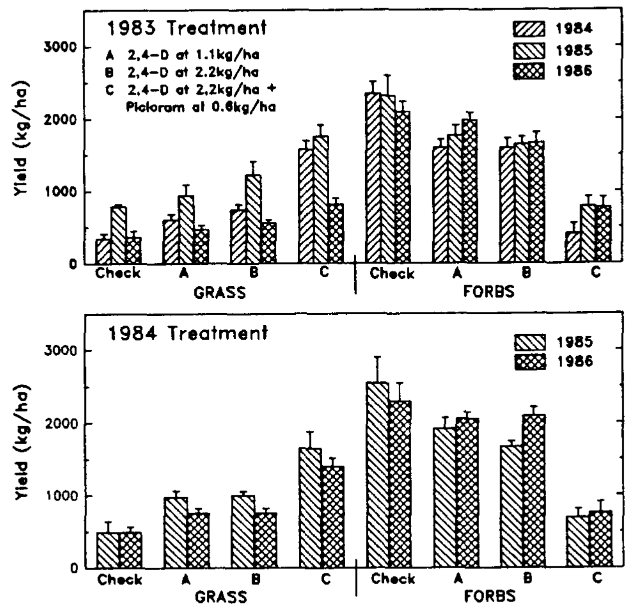

Fig. 5. Yields (kg/ha) of grass-sedges and forbs by years (1984–1986) for untreated plots and plots sprayed with herbicide in 1983 or 1984. Data from U.S. Sheep Experiment Station summer range, Centennial Mountains, Montana.

Table 3. Yields[1] by species averaged over 1985–1986 for untreated or herbicide sprayed plots in 1984. Data from U.S. Sheep Experiment Station summer range, Centennial Mountains, Montana.

Species	Control	Week of Application[2] 1	2	3	4	Herbicide and Rate 2,4-D 1.1 kg/ha	2,4-D 2.2 kg/ha	2,4-D + Picloram 2.2 + 0.6 kg/ha
	kg/ha							
Elymus trachycaulus	60 a	218 b	142 a	148 a	116 a	120 ac	122 ac	227 bd
Bromus carinatus	225 a	803 b	711 b	388 a	557 b	461 bc	488 bc	895 bd
Melica spectabilis	148 a	160 a	163 a	167 a	214 a	161 ab	166 ab	201 ab
Phleum alpinum	14 a	41 a	52 a	21 a	24 a	26 ab	35 ab	43 ab
Trisetum spicatum	15 a	41 a	30 a	36 a	28 a	27 ac	30 ac	44 bc
Other grasses and sedges	12 a	90 a	85 a	85 a	30 a	69 ab	33 ab	115 ab
TOTAL GRASS AND SEDGE	474 a	1353 b	1183 b	845 b	969 b	864 bc	874 bc	1525 bd
Achillea millefolium	14 a	17 a	8 a	9 a	6 a	15 ac	14 ac	2 bd
Agoseris glauca	47 a	10 b	6 b	16 b	18 b	20 bc	14 bc	3 bd
Aster species	228 a	102 b	58 b	140 a	53 b	172 ac	84 bd	8 be
Geranium viscosissimum	782 a	524 a	661 a	452 b	554 a	766 ac	725 ac	152 bd
Hackelia floribunda	178 a	55 b	98 a	107 a	99 a	106 ac	134 ac	29 bd
Lupinus argenteus	23 a	8 a	7 b	5 b	5 b	10 ac	6 ac	2 bc
Potentilla gracilis	860 a	498 b	329 b	426 b	579 b	589 bc	638 bc	148 bd
Other annual forbs	104 a	106 a	148 a	114 a	127 a	92 ab	114 ab	166 ac
Other perennial forbs	242 a	92 b	132 a	312 a	294 a	216 ab	164 ab	242 ab
TOTAL FORBS	2478 a	1412 b	1447 b	1581 b	1735 b	1986 bc	1893 bc	752 bd
TOTAL VEGETATION	2952 a	2765 a	2630 a	2426 b	2704 a	2850 ac	2767 ac	2277 bd

[1]See footnote 1 Table 2.
[2]Application was made in week 1, 2, 3, or 4 July of 1984 (see text for actual day of year).

A comparison of total yields of grass-sedges and forbs on untreated plots with herbicide treatments indicates grass-sedge production increases were greater from 1984 treatments than for 1983 treatments, but forb yield reductions were similar for both treatment years. There were no significant differences ($P<.05$) between grass-sedge or forb yields in plots treated with 2,4-D at 1.1 or 2.2 kg/ha, but both 2,4-D treatments were significantly different from 2,4-D + picloram treatment for both years of application. In every case grass-sedge yields increased and forbs declined significantly ($P<0.05$) regardless of time of herbicide application. However, grass-sedge yields increased most due to the third week of application in 1983 and due to the first week of application in 1984. Forb declines were greatest due to the fourth week of application in 1983 and the first week in 1984. Again, this may be related to the differences in phenological stages of plants on the 2 locations at the time of herbicide application and the subsequent responses of forbs to treatment.

For the most part, responses of individual species paralleled that of total grass-sedge or forb groups (Tables 2 and 3). Slender wheatgrass production was significantly ($P<.05$) greater compared to untreated plots in 2,4-D at 2.2 kg/ha and 2,4-D + picloram applied in 1983, but only in 2,4-D + picloram treatments applied in 1984. The most productive grass, mountain brome, increased significantly over the untreated plots due to 2,4-D + picloram applied in 1983 and all treatments applied in 1984. Purple oniongrass yields were not significantly greater than in untreated plots as a result of any treatment on either application year, but herbage response to 2,4-D + picloram applied in 1983 was significantly greater than to either 2,4-D alone treatments. Significant declines in average yields for all treatments compared to the untreated plots were evident for pale agoseris, aster species, and northwest cinquefoil for 1983 applications and for pale agoseris and northwest cinquefoil for 1984 applications. The 2,4-D alone treatments did not lower yields for the other forbs, but 2,4-D + picloram lowered yields for most forbs. Annual forb yields tended to increase as perennial forbs declined although the differences were not significant at $P<.05$. The plants grouped under perennial forbs were occasional species that did not appear in the majority of plots. This assemblage did not decrease significantly from the untreated plots on either year of application, but there were significant differences between treatments applied in 1983.

The relative difference between years for grass and forbs by treatments is shown in Figure 5 for 1983 and 1984 applications. It is clear from both figures that yield tended to be greater during 1985 for grass-sedges and during 1986 for forbs. However, when all data (grass plus forbs) were averaged over years there was a significantly ($P<0.05$) greater yield (2,700 kg/ha) during 1985 compared with 1984 (2,150 kg/ha) and 1986 (2,100 kg/ha) for 1983 herbicide applications. The total yields were not significantly different between 1985 (2,680 kg/ha) and 1986 (2,620 kg/ha) for 1984 herbicide applications. Growth curves for grasses and forbs (from a growth study, in progress) indicate a similar pattern in 1985 and 1986—growth beginning and reaching maximum production at about the same date. In that study total production was also greater in 1985 compared to 1986 by more than 50 g/m^2. Temperature records (Fig. 2) show a lower maximum and minimum temperature for July 1986 compared to July 1985. Precipitation was similar (Fig. 1). Soil moisture contents (Fig. 1) were above the 1,500 k Pa level throughout the entire growth period in both 1985 and 1986. Therefore, there does not appear to be an easy explanation for the yield differences between years.

Ratios of grasses to forbs on untreated plots varied from 13:87 (1984) to 26:74 (1985) and averaged 18:82. The year after herbicide application the proportion of grasses increased as forbs were reduced. Ratios were 13:87 (untreated), 27:73 (2,4-D at 1.1 kg/ha), 32:68 (2,4-D at 2.2 kg/ha), and 80:20 (2,4-D at 2.2 kg/ha + picloram at 0.6 kg/ha) for 1983 treatments and 15:85 (untreated), 34:66 (2,4-D at 1.1 kg/ha), 37:63 (2,4-D at 2.2 kg/ha), and 69:31 (2,4-D at 2.2 kg/ha + picloram at 0.6 kg/ha) for 1984 applications. The proportion of grasses decreased in subsequent years in 2,4-D + picloram treatments for both years of application. The proportion decreased linearly by an average of 14 percentage units per year, for treatments applied in 1983. On forb-dominated range in the Bighorn Mountains, Wyoming, Thilenius et al., (1975) found that 2,4-D applied at 2.2 kg/ha resulted in a large shift to grasses after the first year, but 3 years after treatment there was only a 12% decrease in the grass to forb ratio. The results from our study suggest that full recovery on tall-forb ranges in the Centennial Mountains might be achieved in 4 to 5 years after initial spraying with 2,4-D. Spraying with 2,4-D + picloram would further delay plant succession toward the untreated plant community.

Cicer milkvetch germinated and small seedlings appeared on 2 of the 2,4-D at 1.1 kg/ha treatments and 3 of the 2,4-D at 2.2 kg/ha plots (24 possible). No seedlings were evident in 1985 or in subsequent years. None of the other seeded species were present when plots were evaluated.

There were no visual signs of accelerated erosion from vegetation change in response to herbicide application. In the year of application the forbs provided cover although many plants were dead. In subsequent years the grass response largely replaced forb cover until forbs regained dominance. Snow usually covers the area in late fall before the forb cover has deteriorated sufficiently to pose a runoff problem.

Conclusions

Forb yields were significantly reduced by the 2,4-D plus picloram treatment. Applications made when the flower stalks of sticky geranium plants were elongating were most effective. Applying herbicides reduced forbs but did not specifically reduce the target species (sticky geranium). A wick applicator might have been more effective than broadcast spraying. Increases in grass and sedge production partially compensated for reductions in forb yields. Thus the range was more suitable for cattle than sheep following treatment. After 4 to 5 years, forb and grass production is expected to approach untreated levels.

Cicer milkvetch and several introduced grasses seeded into the 2,4-D treated areas did not establish. Under the conditions of this study it was found that native forbs in the tall-forb community have a great resiliency and attempts to suppress their growth by spraying 2,4-D or 2,4-D + picloram will have little long-term effect.

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