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Control of Silky Crazyweed (*Oxytropis sericea*) with Aminopyralid + 2,4-D and Picloram + 2,4-D on Native Rangeland

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Techniques for preventing crazyweed toxicity in livestock have generally fallen into two categories: excluding livestock access to infested ranges during early spring and fall, and controlling crazyweed populations through herbicide application. Although picloram has been used to control crazyweed effectively in the past, aminopyralid has shown efficacy at lower application rates, exhibits less potential off-target movement, and has been classified as a reduced-risk product. Differences in the response of silky crazyweed and nontarget grasses and forbs to picloram + 2,4-D and aminopyralid + 2,4-D were investigated. Picloram + 2,4-D was applied at a rate of 0.3 kg ae ha^{-1} picloram + 1.1 kg ae ha^{-1} 2,4-D, and aminopyralid + 2,4-D was applied at a rate of 0.1 kg ae ha^{-1} aminopyralid + 1.2 kg ae ha^{-1} 2,4-D. Silky crazyweed canopy cover, number of flowering stalks, plant size, and biomass decreased 15 mo after herbicide treatments (MAT) with average percentage of relative reductions of 92, 95, 90, and 99%, respectively. Crazyweed density decreased by 1.5 $\pm$ 0.2 SE plants m^{-2} and 1.3 $\pm$ 0.2 plants m^{-2}, a relative reduction of 95 and 80%, 15 MAT in aminopyralid + 2,4-D– and picloram + 2,4-D–treated plots, respectively. Plots treated with aminopyralid + 2,4-D had 4% lower nontarget forb canopy cover than did picloram + 2,4-D plots 15 MAT. Grass biomass remained similar within treatments over time for control, aminopyralid + 2,4-D and picloram +2,4-D plots, and was similar in all plots 15 MAT. Plots treated with herbicides had, on average, 11% greater grass cover than did control plots 15 MAT (aminopyralid + 2,4-D: 89%; picloram + 2,4-D: 85%; control: 76%).

Nomenclature: 2,4-D; aminopyralid; picloram; crazyweed, *Oxytropis* spp., silky crazyweed, *Oxytropis sericea* Nutt.

Key words: Herbicide, nontarget, poisonous plant, reduced risk, silky crazyweed, white locoweed.

Locoweed, milkvetch (*Astragalus* spp.), and crazyweed (*Oxytropis* spp.) are among the most widely distributed (Kingsbury 1964) and economically damaging (James et al. 1992) poisonous plants on western rangelands. Although not the most toxic species, silky crazyweed or white locoweed (*Oxytropis sericea* Nutt.) is thought to be the most economically detrimental because of its wide distribution (James et al. 1991), ranging from southeastern Yukon Territory, AK, to Mexico (Welsh et al. 2007). The principal toxin in crazyweeds is swainsonine, an indolizidine alkaloid first isolated in spotted loco (*Astragalus lentiginosus* Dougl. ex Hook) by Molyneux and James (1982). Once ingested, swainsonine causes oligosaccharides and glycoproteins to build up in the cells, eventually causing their morphology to change (Molyneux 1999). Locoism (from *loco*, Spanish for crazy) occurs when enough of these cells are damaged and causes intoxicated animals to exhibit behaviors such as nervousness or startled reactions when stressed, staggering, and difficulty walking over obstacles, depression, emaciation, difficulty eating or drinking, abortion, and birth defects (Molyneux and James 1982). Locoism has been reported in horses, mules, donkeys, cattle, sheep, pigs, rabbits, hens, cats, hamsters, rats, elk, antelope, deer, and bees (Molyneux et al. 1985; Stegelmeier et al. 2007). Although

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Management Implications

Silky crazyweed is a widely distributed and economically damaging poisonous plant that contains the toxin swainsonine. When ingested, swainsonine causes emaciation, abortion, and birth defects in domesticated livestock as well as wildlife species. Typical toxicity prevention methods include limiting livestock access to infested ranges during early spring and fall and controlling silky crazyweed populations through herbicide application. Picloram + 2,4-D has been consistently effective in killing silky crazyweed, but a new herbicide, aminopyralid + 2,4-D, may be a better option because it is effective at lower rates, has a shorter average half-life, and has less potential for off-target movement. The effects of these two herbicides on silky crazyweed and nontarget forbs and grasses were compared at three sites in northern New Mexico. Picloram + 2,4-D and aminopyralid + 2,4-D had similar effects on silky crazyweed density, canopy cover, number of flowering stalks, plant size, and biomass. Nontarget vegetation also responded similarly to the two herbicides with grass biomass, canopy cover, and bare ground all having similar values following treatment. Forb canopy cover was lower in aminopyralid-treated plots than it was in picloram-treated plots, suggesting less selectivity with aminopyralid. This could have major implications for important wildlife forage species, but may be beneficial when multiple undesirable forb species are present. Overall, both herbicides effectively controlled crazyweed and increased grass cover.

toxic dose requirements differ, all animal species are apparently vulnerable to the effects of swainsonine if crazyweed is ingested (Stegelmeier et al. 2007).

Techniques for preventing crazyweed toxicity in livestock have generally fallen into two categories: excluding livestock access to infested ranges during early spring and fall (Ralphs et al. 1993, 1999) and controlling crazyweed populations through herbicide application (McDaniel 1999; Ralphs and Ueckert 1988). In some instances, these techniques are combined and crazyweed-free pastures for spring and fall grazing are created using herbicide treatment (Torell et al. 2000). Various herbicides have been tested on silky crazyweed with varying levels of success; among these, picloram + 2,4-D is the treatment that was most efficacious (McDaniel 1999; McDaniel et al. 2007; Ralphs et al. 1988; Ralphs and Ueckert 1988). Picloram was developed by Dow Chemical Company (1790 Building, Midland, MI 48667) in the early 1960s (Hamaker et al. 1963). It is a pyridine carboxylic acid herbicide, which is used for systemic, postemergent control of broadleaf weeds and woody plants. Its mechanism of action mimics the plant growth hormone auxin, indoleacetic acid (Retzinger and Mallory-Smith 1997). The recommended rate for early season application of Grazon P + D®, the commercial name of picloram + 2,4-D, is 2.3 L ha^{-1} (0.246 pints ac^{-1}) (Anonymous 2002).

Aminopyralid is also in the pyridine family, and, although it is structurally almost identical to picloram, it does not contain the chlorine molecule at the 5-carbon position on the picolinic acid ring. Aminopyralid is a relatively new herbicide that received the reduced-risk classification by the U.S. Environmental Protection Agency in 2004 (Jachetta et al. 2005) and was registered for use on rangelands, pastures, and noncrop areas in 2005 (USOPPEPTS 2005). Compared with picloram, aminopyralid is effective at lower rates (Hare et al. 2005) and has a shorter average half-life (Jachetta et al. 2005; Senseman 2007a, b) and a greater soil sorption that results in less potential off-target movement (Fast et al. 2010). This, as well as its low acute and chronic toxicity to fish, aquatic invertebrates, birds, and mammals, has earned it the status of a nonrestricted-use pesticide (Masters et al. 2005), which means that the applicator does not need to have a certified chemical applicator's license to purchase or apply this product. The recommended rate of GrazonNext®, the commercial name for aminopyralid + 2,4-D, is unknown because it has not been studied on crazyweed, to our knowledge, but other weed species application rates vary from 1.4 to 2.3 L ha^{-1} (Anonymous 2014).

Although aminopyralid is as effective as picloram at controlling tall ironweed [*Vernonia gigantea* (Walt.) Trel.], common ragweed (*Ambrosia artemisiifolia* L.) (Payne et al. 2010), Canada thistle [*Cirsium arvense* (L.) Scop.] (Enloe et al. 2007), and Russian knapweed [*Acroptilon repens* (L.) DC.] (Enloe et al. 2008), its efficacy at controlling silky crazyweed had not been previously reported. In addition, for a herbicide treatment to be economically feasible, it must control crazyweed populations for at least 2 yr (Torell et al. 2000). Therefore, the objective of this study was to assess the efficacy of aminopyralid + 2,4-D for controlling silky crazyweed for two growing seasons, compared with picloram + 2,4-D.

Materials and Methods

The study was conducted in 2009 and 2010 on three ranches in Union County, NM. Sites were selected for their similar silky crazyweed densities, ranging between 1.2 to 1.6 plants m^{-2} (0.11 to 0.15 plants ft^{-2}). Mean annual, spring, and summer precipitation for this area are 431, 118, and 272 mm (17, 5, and 11 in), respectively, based on 12 yr of records from the National Weather Service Cooperative Observation station in Capulin, NM (36°44′N, 103°59′W) (NOAA 2010). In 2009, precipitation was 81 mm (dry) in the spring (January through May) and 242 mm (average) in the summer (June through September). Spring precipitation, in 2010, was 212 mm (wet), whereas summer precipitation was 167 mm (dry).

Site 1 was located on Archuleta Ranch, 1.48 km (0.92 mi) southwest of Des Moines, NM (36°45′12.43″N, 103°51′00.99″W) at an elevation of 2,062 m (6,765 ft) above sea level. It had a moderate slope with northern exposure, and the soils consisted of cobbly loam and cobbly clay loam with basalt rock outcroppings. Basalt fragments

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Table 1. Application date, site, and weather conditions for herbicide spraying of silky crazyweed (*Oxytropis sericea*) in New Mexico.

Application Date	Site	Air temperature	Soil temperature	Relative humidity	Wind speed
		C		%	m s^{-1}
June 11, 2009	Archuleta ranch	19	18	16	2
June 11, 2009	Mondragon ranch	24	22	23	3
June 13, 2009	Capulin ranch	24	20	23	2

occupied 5% to 35% of the surface and soil at this site (USDA, NRCS 2007). Dominant grasses included blue grama [*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths], little bluestem [*Schizachyrium scoparium* (Michx.) Nash], western wheatgrass [*Pascopyrum smithii* (Rydb.) Á. Löve], sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], and hairy grama (*Bouteloua hirsuta* Lag.). Forbs consisted of silky crazyweed, globemallow (*Sphaeralcea* spp.), and prairie clover (*Dalea* spp.), with silky crazyweed being the most frequent. Fringed sagewort (*Artemisia frigida* Willd), skunkbush sumac (*Rhus trilobata* Nutt.), yucca (*Yucca* spp.), oneseed juniper [*Juniperus monosperma* (Engelm.) Sarg.], and twoneedle pinyon (*Pinus edulis* Engelm.) were common woody plants, while plains pricklypear (*Opuntia polyacantha* Haw.) was the predominant cactus.

Site 2 was located on Mondragon Ranch, 2.18 km northwest of Des Moines, NM (36°46′21.18″N, 103°51′32.13″W), at an elevation of 2,042 m above sea level. This area of open grassland had loam, clay loam, and gravelly loam soils. Dominant grasses were blue grama, James' galleta (*Pleuraphis jamesii* Torr.), tobosagrass (*Pleuraphis mutica* Buckl.), buffalograss [*Buchloe dactyloides* (Nutt.) J.T. Columbus], sideoats grama, sand dropseed [*Sporobolus cryptandrus* (Torr.) A. Gray], and western wheatgrass. Here, too, the most prevalent forb was silky crazyweed. Other forbs included globemallow and common sunflower (*Helianthus annuus* L.). Shrubs were rare, although winterfat [*Krascheninnikovia lanata* (Pursh) A. Meeuse & Smit] and groundsel (*Senecio* spp.) were present.

Site 3 was at the base of Capulin Volcano (36°45′22.87″N, 103°58′24.47″W), 2.34 km northeast of Capulin, NM, at an elevation of 2,099 m above sea level. Blue grama, western wheatgrass, squirreltail [*Elymus elymoides* (Rafin.) Swezey], sideoats grama, perennial threeawn (*Aristida* spp.), and buffalograss were common grasses. Again, the dominant forb was silky crazyweed, with western ragweed (*Ambrosia psilostachya* DC.), dotted gayfeather (*Liatris punctata* Hook.), upright prairie coneflower [*Ratibida columnifera* (Nutt.) Woot. & Standl.], sunflower, and globemallow also present. The only shrub present in the study plots was fringed sagewort, although skunkbush sumac, oneseed juniper, and twoneedle pinyon were nearby.

Experimental Protocol. At each of the three sites, three 200-m^2 plots (2,153-ft^2) (10 by 20 m) with similar (high) densities of crazyweed plants were established and randomly assigned to one of the following treatments: (1) control with no treatment, (2) aminopyralid + 2,4-D, or (3) picloram + 2,4-D as a positive control. Picloram + 2,4-D (Grazon P + D®, picloram: 65 g L^{-1} and 2,4-D: 240 g L^{-1} [2.002 lb gal^{-1}], Dow AgroSciences, 9330 Zionsville Road, Indianapolis, IN 46268) was applied at a rate of 0.3 kg ae ha^{-1} (0.268 lb ae ac^{-1}) picloram + 1.1 kg ae ha^{-1} 2,4-D and aminopyralid + 2,4-D (GrazonNext®, aminopyralid: 50 g L^{-1} and 2,4-D: 400 g L^{-1}, Dow AgroSciences) was applied at a rate of 0.1 kg ae ha^{-1} aminopyralid + 1.2 kg ae ha^{-1} 2,4-D. In June 2009, herbicides were applied using a six-nozzle boom sprayer with CO_2 cartridge delivering 200 L ha^{-1} (Spraying Systems Co., P.O. Box 7900, Wheaton, IL 60189-7900). Silky crazyweed was in the late-flowering stage at all sites when treated (McDaniel 1999, 2007). Weather at the time of herbicide application is listed in Table 1. Herbicide-treated plots were fenced during the summer following treatment to prevent cattle from grazing dead silky crazyweed plants.

Plant data were collected before treatment in May 2009, at the end of the growing season in September, and in the spring and fall of 2010. Plots were not measured immediately after treatment because of the expected time lag of 1 to 2 mo from treatment in plant response (McDaniel et al. 2007).

Canopy cover of silky crazyweed, perennial grasses, forbs, and litter, in addition to ground cover, were recorded in all plots using point intercept at 10-cm (3.9-in) intervals on four 20-m permanent transects per plot. Using the same transect, silky crazyweed density was recorded with a 1-m by 1-m square frame centered at each odd meter mark on the transect tape (40 frames $plot^{-1}$). Number of plants (plants m^{-2}) and plant vigor attributes—longest canopy diameter, perpendicular diameter, and number of flowering stalks—were recorded in each frame. The area of an ellipse was used to calculate plant canopy area (cm^2) and is hereafter referred to as *plant size*. Herbaceous biomass samples (g m^{-2}) were collected by clipping eight 0.25-m^2 (2.69-ft^2) frames at ground level in each plot. Samples were dried at 60 C (140 F) for 72 h, sorted into grass and silky crazyweed, and weighed.

Statistical Analysis. The experimental design used was a randomized complete block with herbicide treatment as the experimental unit and site as the blocking factor. The effect of site, date, treatment, and the interaction of treatment and date on all vegetation response variables listed below were analyzed with a repeated-measures mixed-model using version 9.1 of SAS software (SAS Institute Inc., 100 SAS Campus Drive, Cary, NC 27513-2414). Response variables considered were silky crazyweed density (plants m^{-2}), silky crazyweed cover (%), number of silky crazyweed flowering stalks, silky crazyweed plant canopy size (cm^2), silky crazyweed biomass (g m^{-2}), grass biomass (g m^{-2}), grass cover (%), forb cover (%), and bare ground (%). A subset (initial and final) of selected date by treatment comparisons of interest were conducted for each response variable using least-square means in the 9.1 version of SAS software. Covariance structures were tested for each variable, and residual plots were examined to detect outliers and violations of ANOVA assumptions (linearity, independence, normality, equal variances). No outliers were found, and ANOVA assumptions were met, except for a slight lack of independence of variances, but this was addressed using the appropriate covariance structures for each variable.

Differences were declared statistically significant at $P \leq 0.05$. Treatment by date interactions with $P \leq 0.10$ were further examined.

Results and Discussion

Effects of Herbicides on Silky Crazyweed. There were no site or treatment effects on all silky crazyweed responses, although a marginal treatment effect on silky crazyweed cover was detected (Table 2). Treatment by date interactions were detected for silky crazyweed cover, flower stalks, and plant size (Table 2).

Silky crazyweed density was similar in all plots before treatment (Table 3). In the control plots, density did not change from pretreatment to 15 mo after treatment (MAT) but decreased in aminopyralid + 2,4-D– and picloram + 2,4-D–treated plots by 1.5 ± 0.2 SE and 1.3 ± 0.2 SE plants m^{-2}, respectively (Table 3). McDaniel et al. (2007) reported comparable pretreatment densities, in northeastern New Mexico of 1.6 plants m^{-2}, which dropped to zero for 4 yr following picloram treatment. Densities then increased to 1 plant m^{-2} in the fifth year, presumably because of above-average rainfall. Silky crazyweed densities in our study did not drop to zero possibly because of the wet spring in 2010, which could have increased germination of new seedlings or, alternatively, because of lower-than-optimal humidity of $\geqslant 50\%$ recommended by McDaniel et al. (2007), when spraying was done. In picloram + 2,4-D–treated plots in northwestern Utah, the number of silky crazyweed plants was 0.05 plants m^{-2} 1 yr after treatment, vs. > 5.5 plants m^{-2} in control plots (Ralphs et al. 1988). Treated plots in that study had comparable densities to aminopyralid + 2,4-D plots in this study although density in control plots in the Ralphs et al. (1988)

Table 2. Fixed effects of site (df = 2), treatment (df = 2), date (df = 3), and treatment by date interaction on plant response variables collected from a herbicide experiment comparing picloram + 2,4-D and aminopyralid + 2,4-D treatment on silky crazyweed response variables in northern New Mexico.

Variable[a]	Site	Treatment	Date	Treatment × date
Locoweed density				
F	2.48	3.72	18.41	2.92
P value	0.20	0.12	< 0.01	0.04
Locoweed canopy cover				
F	4.95	7.30	25.79	4.62
P value	0.08	0.05	< 0.01	< 0.01
Flowering stalks				
F	4.98	0.12	15.58	4.76
P value	0.08	0.89	< 0.01	< 0.01
Plant size				
F	3.91	3.60	71.61	3.12
P value	0.11	0.13	< 0.01	0.03
Locoweed biomass				
F	0.28	0.10	5.93	1.94
P value	0.77	0.90	< 0.01	0.13
Grass biomass				
F	0.75	8.21	3.85	2.53
P value	0.53	0.04	0.03	0.06
Grass canopy cover				
F	38.88	4.65	19.46	4.13
P value	< 0.01	0.09	< 0.01	< 0.01
Forb canopy cover				
F	1.09	5.43	9.75	2.85
P value	0.42	0.07	< 0.01	0.04
Bare ground				
F	0.81	0.27	6.57	0.72
P value	0.51	0.77	< 0.01	0.64

[a] Data were analyzed using a mixed-model analysis of variance for repeated measures, testing the effect of site, treatment, date and their interaction.

study were considerably higher than in our study. Aminopyralid + 2,4-D achieved 95% control of silky crazyweed, and although not statistically different from 80% control by picloram + 2,4-D, these herbicides would have been categorized separately as excellent and fair in the categories of control for livestock producers described by McDaniel et al. (2007).

The same pattern was measured in crazyweed plant size, with similar pretreatment values (Table 3) and no change throughout the study in control plots, but there were decreases of 97.0 ± 19.4 and 99.3 ± 19.4 cm^2 (relative reductions of 96 and 85%) in aminopyralid + 2,4-D and picloram + 2,4-D plots 15 MAT, respectively. At the end

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Table 3. Date by treatment comparisons of silky crazyweed responses to the application of picloram + 2,4-D, aminopyralid + 2,4-D, or no treatment (control) at three sites in northern New Mexico. Option *pdiff* was used on a subset of preplanned comparisons. Values are least-square means.

		Date[a,b]			
Variable	Treatment	Pretreatment[c]	3 MAT	12 MAT	15 MAT[c]
Locoweed density (plants m^{-2})					
	Control	1.2 aA	1.0	0.9	0.8 aA
	Aminopyralid + 2,4-D[d]	1.6 aA	0.2	0.1	0.1 bB
	Picloram + 2,4-D[e]	1.6 aA	0.2	0.3	0.3 bB
Locoweed canopy cover (%)					
	Control	4.4 aA	2.5	3.5	2.6 aA
	Aminopyralid + 2,4-D	6.3 aA	0.2	0.3	0.2 bB
	Picloram + 2,4-D	5.7 aA	0.4	0.4	0.8 bAB
Flowering stalks (No. $plant^{-1}$)					
	Control	3.1 aA	1.2	1.6	0.6 bA
	Aminopyralid + 2,4-D	4.0 aA	0.2	0.0	0.4 bA
	Picloram + 2,4-D	4.2 aA	0.3	0.1	0.0 bA
Plant size (cm^2)					
	Control	83.2 aA	66.4	93.9	64.3 aA
	Aminopyralid + 2,4-D	100.8 aA	7.0	7.3	3.8 bB
	Picloram + 2,4-D	116.6 aA	8.9	20.8	17.4 bB
Locoweed Biomass (g m^{-2})					
	Control	2.8 aB	1.7	10.4	2.5 aA
	Aminopyralid + 2,4-D	19.6 aA	0.0	1.5	0.3 bA
	Picloram + 2,4-D	16.6 aAB	1.4	0.0	0.0 bA

[a] Pretreatment and 12 MAT measurements were taken in June; 3 and 15 MAT measurements were taken in September for both years.
[b] Abbreviation: MAT, months after treatment.
[c] Means with different lowercase letters indicate detectable differences ($P < 0.05$) by treatment between pretreatment and the final data collection at 15 MAT (i.e., within row; a). Means with different uppercase letters indicate detectable differences ($P < 0.05$) between treatments within dates (i.e., within column; A).
[d] Rate sprayed was 0.1 kg ae ha^{-1} aminopyralid + 1.2 kg ae ha^{-1} 2,4-D.
[e] Rate sprayed was 0.3 kg ae ha^{-1} picloram + 1.1 kg ae ha^{-1} 2,4-D.

of the study, silky crazyweed density and plant size were similar across herbicide treatments, which exhibited lower densities and smaller plants than the control did (Table 3).

Silky crazyweed canopy cover was similar in all plots before treatments (Table 3), remained unchanged in the control plots from pretreatment to 15 MAT but decreased in aminopyralid + 2,4-D– and picloram + 2,4-D–treated plots by 6 and 5% (relative reductions of 97 and 87%) of total cover, respectively, from the beginning to the end of the study. Conversely, although aminopyralid + 2,4-D–treated plots had 2% lower silky crazyweed canopy cover than did control plots 15 MAT, the picloram + 2,4-D–treated plots had intermediate cover levels, which were not different from either control or aminopyralid + 2,4-D–treated plots. Ralphs et al. (1988) reported a 19% decrease in silky crazyweed cover in northwestern Utah using picloram + 2,4-D, but that decrease may have been due to the higher initial silky crazyweed densities of 5.5 plants m^{-2}. This difference in cover between the two herbicides could have impacts on treatment longevity because the two most important factors influencing this variable are efficacy of initial herbicide treatment and frequency of environmental conditions that promote silky crazyweed germination (McDaniel et al. 2007).

Mean number of flower stalks in all plots was similar before treatment (Table 3), but decreased in control (81% relative reduction), aminopyralid + 2,4-D– (91%), and picloram + 2,4-D (100%)–treated plots after two growing seasons (Table 3). Timing of vegetation sampling 15 MAT was in the fall, when flowering stalks had senesced and broken off most plants. Additionally, unidentified larvae were feeding on flowering stalks at the Archuleta site, which may have confounded results.

Before herbicide application, control plots had less silky crazyweed biomass than did the aminopyralid + 2,4-D plots, whereas the aminopyralid + 2,4-D and picloram + 2,4-D plots were similar. Silky crazyweed biomass decreased in aminopyralid + 2,4-D (99% relative reduction) and

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Table 4. Date x treatment comparisons of nontarget vegetation responses to the application of picloram +2,4-D, aminopyralid +2,4-D, or no treatment (control) at three sites in northern New Mexico. Options *pdiff* was used on a subset of preplanned comparisons. Values are least square means.

Variable	Treatment	Date[a,b]			
		Pretreatment[c]	3 MAT	12 MAT	15 MAT[c]
Grass Biomass (g m^{-2})					
	Control	90.5 aA	84.5	115.7	85.5 aA
	Aminopyralid + 2,4-D[d]	106.8 aA	83.7	101.5	94.6 aA
	Picloram + 2,4-D[e]	109.2 aA	110.6	143.2	93.0 aA
Grass canopy cover (%)					
	Control	73.6 aA	78.6	72.9	76.0 aB
	Aminopyralid + 2,4-D	73.6 bA	83.4	83.4	88.7 aA
	Picloram + 2,4-D	70.8 bA	81.9	80.8	84.6 aA
Forb canopy cover (%)					
	Control	6.4 bA	6.7	7.9	11.7 aA
	Aminopyralid + 2,4-D	4.9 aA	3.1	2.6	3.8 aC
	Picloram + 2,4-D	3.8 aA	6.9	3.3	7.9 aB
Bare ground (%)					
	Control	5.0 aA	2.2	2.3	1.0 bA
	Aminopyralid + 2,4-D	5.7 aA	4.1	2.8	1.8 bA
	Picloram + 2,4-D	6.9 aA	2.5	2.8	1.8 bA

[a] Pretreatment and 12 MAT measurements were taken in June; 3 and 15 MAT measurements were taken in September for both years.
[b] Abbreviation: MAT, months after treatment.
[c] Means with different lowercase letters indicate detectable differences ($P < 0.05$) by treatment between pretreatment and the final data collection at 15 MAT (i.e., within-row; a). Means with different uppercase letters indicate detectable differences ($P < 0.05$) between treatments within dates (i.e., within-column; A).
[d] Rate sprayed was 0.1 kg ae ha^{-1} aminopyralid + 1.2 kg ae ha^{-1} 2,4-D.
[e] Rate sprayed was 0.3 kg ae ha^{-1} picloram + 1.1 kg ae ha^{-1} 2,4-D.

picloram + 2,4-D (100% relative reduction) plots from pretreatment to 15 MAT, and all treated plots had similar silky crazyweed biomass at 15 MAT (Table 3).

Effects of Herbicides on Nontarget Vegetation and Bare ground. Grass canopy cover was the only nontarget vegetation variable that was affected by the experiment site (Table 2). Treatment by date interactions were detected for grass biomass, grass canopy cover, and forb canopy cover (Table 2).

Grass biomass was unaffected by the herbicide treatments. All plots had similar grass biomass at the onset of the experiment, remained similar within treatments over time for control, aminopyralid + 2,4-D and picloram + 2,4-D plots, and was similar in all plots at 15 MAT (Table 4). This is consistent with results from a Missouri study in which picloram + 2,4-D and aminopyralid + 2,4-D were applied to control common ragweed and tall ironweed (Payne et al. 2010). Total biomass in that study was similar between the two herbicide-treated plots and the control plot at 12 MAT even though the most-prevalent forbs and all legumes were effectually eliminated from the treated plots, presumably from a flush of grass growth.

Grass canopy cover was similar in all treatments at the beginning of our study and control plots remained similar from pretreatment to 15 MAT (Table 4). Both herbicide treatments increased in grass cover from pre-treatment to 15 MAT with aminopyralid +2,4-D increasing by 15%, a relative increase of 21%, and picloram +2,4-D increasing by 14%, a relative increase of 19%. Herbicide treatments were similar to one another and had an average of 11% higher grass cover than control plots at 15 MAT. Ralphs et al. (1988) determined that grass cover increased by 10% 1 yr after picloram + 2,4-D treatment in northwest Utah. Samuel and Lym (2008) measured greater cover of western wheatgrass and blue grama, both dominant grasses in our plots, at 10 MAT in aminopyralid-treated plots vs. control plots in North Dakota. In Minnesota, the number of monocotyledonous species was similar between nontreated and aminopyralid-treated plots, whereas the cover of late-seral grasses increased after aminopyralid treatment (Almquist and Lym 2010). These increases in grass cover are most likely due to the decreased competition with the target plant for water and nutrients (Connell 1983) but may also be caused by decreased competition of grasses with nontarget forbs.

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All plots had similar forb cover before treatment (Table 4). Forb cover increased by 5% (a relative increase of 83%) in control plots but not in aminopyralid +2,4-D and picloram +2,4-D plots which remained unchanged throughout the study. All three treatments were different from each other at 15 MAT, with control plots having the greatest forb cover followed by the picloram + 2,4-D–treated plots, and the aminopyralid + 2,4-D–treated plots has lower forb cover percentages than the picloram + 2,4-D plots did (Table 4). This suggests that aminopyralid + 2,4-D may be less selective than picloram + 2,4-D. In North Dakota, aminopyralid reduced several native forbs at 10 MAT (Samuel and Lym 2008). One species determined to be susceptible in that study was scarlet globemallow [*Sphaeralcea coccinea* (Nutt.) Rydb.], a common forb in our plots and an important forage for pronghorn and deer (USDA-NRCS 2009). The greatest change in plant communities treated with aminopyralid in Minnesota was the decrease in the total number of late and early seral forbs (Almquist and Lym 2010), although plots treated with picloram + 2,4-D decreased forb cover by 7% at 1 yr after treatment in northwest Utah (Ralphs et al. 1988). Long-term impacts on desirable forbs are unknown, but decreased competition with silky crazyweed could allow these forbs to recover and increase to pretreatment levels or greater as determined with Canada thistle–infested plots treated with aminopyralid (Samuel and Lym 2008).

Bare ground values were similar among plots before and after treatments (Table 4). Bare ground decreased in the control, aminopyralid + 2,4-D–, and picloram + 2,4-D–treated plots (relative reductions of 81, 69, and 73%, respectively) from pretreatment to 15 MAT, most likely because of the timing of pretreatment and 15 MAT measurements (June vs. September).

Overall, these herbicide combinations showed similar efficacy in suppressing silky crazyweed. Silky crazyweed density, plant size, and biomass responded similarly to both herbicides. Our results suggest that aminopyralid + 2,4-D may be somewhat more effective in controlling silky crazyweed canopy cover than picloram + 2,4-D (difference in canopy cover) but may also be more-injurious to nontarget forb species. The application of synthetic auxin herbicides has been found to temporarily increase the palatability of some treated plants (Ralphs et al. 1998). When treating poisonous plants, grazing should be deferred until the plant has desiccated (Anonymous 2002). Grass increases after treatment can most likely be attributed to decreases in competition for nutrients and water, although further research is needed to examine this relationship. Aminopyralid's favorable toxicity profile, reduced risk of water contamination (Jachetta et al. 2005), low potential off-target movement (Fast et al. 2010), and reduce-risk status make it a favorable option for producers managing livestock on silky crazyweed–infested rangelands.

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