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Testing Control Options for Western Salsify (*Tragopogon dubius*) on Conservation Reserve Program Lands

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Western salsify has recently formed dense stands in Conservation Reserve Program (CRP) lands in north-central Montana. Our objective was to test the effects of various herbicide treatments and mowing on western salsify and associated vegetation in CRP lands. Six herbicide treatments and one mowing treatment were applied at three sites in 2010. Herbicide treatments included combinations of glyphosate, 2,4-D, dicamba, and/or metsulfuron-methyl applied when western salsify was either in the rosette or early flowering stage. Mowing was applied at the early flowering stage. Herbicide treatments reduced western salsify and increased perennial grass at one of the three sites, which was the site most dominated by western salsify. When dicamba (0.14 kg ae ha^{-1}) plus 2,4-D (0.48 kg ae ha^{-1}) was applied at the rosette stage, western salsify adult plant density and biomass were reduced to zero and perennial grass biomass increased by 108% in 2010. In 2011, western salsify adult plant density was lower across all herbicide treatments compared to the mowed and nontreated plots. Annual grass density increased by up to 400% when herbicide applications including metsulfuron-methyl were applied at the early flowering stage. Mowing did not control western salsify. Results suggest dicamba plus 2,4-D applied at the rosette stage can provide effective control of western salsify and increase perennial grasses without stimulating the emergence of annual grasses.
Nomenclature: Dicamba; glyphosate; metsulfuron-methyl; 2,4-D; western salsify, *Tragopogon dubius* Scop.
Key words: Annual grass, perennial grass, weed control.

Recientemente, *Tragopogon dubius* ha formado poblaciones densas en tierras del Programa de Reservas para la Conservación (CRP) en el centro-norte de Montana. Nuestro objetivo fue el evaluar los efectos de varios tratamientos de herbicidas y chapia sobre *T. dubius* y vegetación asociada en tierras de CRP. Seis tratamientos de herbicidas y un tratamiento de chapia fueron aplicados en tres sitios en 2010. Los tratamientos de herbicidas incluyeron combinaciones de glyphosate, 2,4-D, dicamba, y/o metsulfuron-methyl aplicadas cuando *T. dubius* estuvo en el estado de roseta o de floración temprana. La chapia fue aplicada en el estado de floración temprana. Los tratamientos de herbicidas redujeron *T. dubius* e incrementaron las gramíneas perennes en uno de los tres sitios, el cual fue el sitio dominado por *T. dubius*. Cuando se aplicó dicamba (0.14 kg ae ha^{-1}) más 2,4-D (0.48 kg ae ha^{-1}) en el estado de roseta, la densidad y biomasa de plantas adultas de *T. dubius* se redujeron a cero, y la biomasa de gramíneas perennes incrementó 108% en 2010. En 2011, la densidad de plantas adultas de *T. dubius* fue menor en todos los tratamientos de herbicidas en comparación con las parcelas con chapia o sin tratamiento. La densidad de gramíneas anuales incrementó en 400% cuando las aplicaciones de herbicidas incluyeron metsulfuron-methyl y fueron realizadas en el estado de floración temprana. La chapia no controló *T. dubius*. Los resultados sugieren que dicamba más 2,4-D aplicados en el estado de roseta pueden brindar un control efectivo de *T. dubius* e incrementar las poblaciones de gramíneas perennes sin estimular la emergencia de gramíneas anuales.

Western salsify, an exotic plant of the Asteraceae family native to Eurasia and northern Africa, was brought to North America by early settlers as a food plant and ornamental around the turn of the twentieth century (Clements et al. 1999). As a monocarpic perennial, western salsify relies on seed production to spread and maintain populations. Being a monocarpic perennial, the plant dies after seed production, which can happen in its first to 14th yr but usually after 2 to 4 yr (Clements et al. 1999). Rosettes have an erect growth form and can be mistaken for grass. Flowering occurs in early to mid-June and can extend into September. Western salsify seeds have a large, broad pappus that is ideal for long-distance dispersal (Clements et al. 1999). Gross and Werner (1982) measured wind dispersal of salsify seeds over distances exceeding 250 m.

Western salsify is widespread across North America and can be weedy in rangelands, pastures, Conservation Reserve Program (CRP) lands, and roadsides. It has been reported in every state except Alabama, Florida, Mississippi, and South Carolina; in every Canadian province except Newfoundland; and in 48 counties in Montana (Rice 2012). *Tragopogon* species are listed as noxious in Ontario, Canada, and meadow salsify (*Tragopogon pratensis* L.) is listed as a nuisance weed in Saskatchewan and Manitoba, Canada. Western salsify is not currently listed as a noxious weed in any state in the United States.

Western salsify will grow across a variety of vegetation zones and soil types (Upadhyaya et al. 1993). While frequently found in highly disturbed sites, it also occurs in less disturbed areas as well. Like other weeds, it can form dense stands (Novak et al. 1991) and may negatively impact desired vegetation. For example, research in British Columbia, Canada, by Upadhyaya et al. (1993) suggested that *Tragopogon* species reduced the leaf area and shoot-to-root ratio of bluebunch wheatgrass [*Pseudoroegneria spicata* (Pursh)

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Scribn. & Smith], an important component of native rangeland in western North America (Mueggler and Stewart 1980). At the same time, western salsify may be beneficial to wildlife (Crawford et al. 1986).

Recently western salsify has increased in rangeland and Conservation Reserve Program (CRP) lands in north-central Montana, where it has been observed to form dense stands with limited plant diversity. The Conservation Reserve Program, administered by the United State Department of Agriculture Farm Service Agency (USDA-FSA), is a voluntary program for landowners in which agricultural lands are converted to perennial vegetation in an effort to reduce soil erosion, increase quality of surface waters, and improve wildlife habitat. Landowners typically enroll in 10 to 15 yr contracts, receive annual rental payments, and must meet and follow specified management criteria (USDA-FSA 2012).

Weed management is a requirement of CRP contracts, and landowners who have experienced an increase in western salsify on their CRP acreages are being encouraged to implement control measures, especially since western salsify appears to be decreasing plant diversity and also because seeds of this plant can disperse to nearby CRP and crop fields. Minimizing disturbance during primary nesting or brood rearing season for wildlife is a priority for CRP lands (USDA-FSA 2012). However, spot treatments, if justified and approved, can be allowed during primary nesting or brood rearing season.

Unfortunately, research on western salsify control is limited. Anecdotal evidence suggested that intensive, short-term early season grazing could reduce western and meadow salsify density by 25 to 50% after 3 yr (Upadhyaya et al. 1993). In another study, picloram provided up to 4 yr of control of meadow salsify (Cranston et al. 1986). There is no other published research on western salsify management to our knowledge. In an effort to provide cost-effective western salsify control recommendations, this project was developed through a cooperative effort with USDA-FSA, USDA-Natural Resource Conservation Service (NRCS), and several landowners. The objective of this study was to test the effects of various herbicide treatments and mowing on western salsify and associated vegetation in CRP lands in north-central Montana. These treatments were applied one year and evaluated into the following year to determine if one-time applications would provide more than one season of control.

Materials and Methods

We selected three sites on CRP lands about 45 km north of Great Falls, Montana, where western salsify has been increasing over the previous two to three years (Bill Evans, personal communication). Distance between sites ranged from about 10 to 15 km. Western salsify density at the three sites ranged from about one to 34 flowering plants m^{-2}. All three sites had been seeded to CRP in 2000 to 2001 with a mix of species including thickspike wheatgrass [*Elymus lanceolatus* Scribn. & J.G. Sm.) Gould ssp. *Lanceolatus*], western wheatgrass [*Pascopyrum smithii*, (Rydb.) A. Love], slender wheatgrass [*Elymus trachycaulus*, (Link) Gould ex Shinners], Sherman big bluegrass (*Poa ampla*, J. Presl), Lewis blue flax (*Linum lewisii*, Pursh), alfalfa (*Medicago sativa*, L.), and yellow sweet clover [*Melilotus officinalis*, (L.) Lam.]. Site 1 was dominated by seeded grasses with western salsify plants mostly occurring as rosettes; Site 2 was codominated by seeded grasses and western salsify rosettes and adult plants; and Site 3 was dominated by western salsify.

Six herbicide treatments, a mowing treatment, and a nontreated control were applied to 3 m by 9 m plots arranged in a randomized complete block design (Table 1). Herbicide treatments were chosen based on experience and ideas presented by producers, crop consultants, and agency personnel during the planning phase of the study. The eight treatments were replicated three times at each site to encompass an area of approximately 0.1 ha site^{-1}. Treatments 1 to 3 and the first installment of treatment 6 were applied May 15, 2010 using a CO_2-pressurized backpack sprayer calibrated to deliver 157 L ha^{-1} water at 3 kg cm^{-2} pressure. All treatments were applied with a nonionic surfactant (Penetrator®) at 0.10% v/v herbicide and an ammonium sulfate water conditioning agent (BroncMax®) at 0.10% v/v herbicide. Conditions at the time of the first treatment application were 16 C, 49% relative humidity, and $<$ 8 km h^{-1} winds. Treatments 4, 5, 7 and the second installment of Treatment 6 were applied on June 20, 2010. Herbicide treatments were applied using the same methods as in mid-May. The mowing treatment was mowed to 10 to 15 cm stubble height using a push mower to remove bolting stems and flowers of western salsify. Conditions at the time of application were 14 C with calm winds. Relative humidity was not recorded at the time of the second application due to equipment failure.

Sites were sampled in early August 2010 and 2011. Density and biomass of western salsify adults (those plants that flowered summer 2010 and 2011), western salsify rosettes, annual grasses (downy brome (*Bromus tectorum* L.) and Japanese brome (*B. japonicus* Thunb)), perennial grasses, exotic forbs (excluding western salsify), and native forbs were collected using three, randomly located 20 by 50 cm frames per plot. Tillers were counted for grasses and plants were counted for forbs. Biomass was clipped at ground level, dried

Table 1. Management treatments and their timing of application (rosette = 15 May and early flowering = 20 June) to low, medium, and high density salsify infestation sites in north-central Montana. Treatment 6 had two application timings: glyphosate plus 2,4-D at rosette stage and dicamba plus 2,4-D, plus metsulfuron at early flowering. Numbers in parenthesis following the chemical name are the chemical rates in kg ai ha^{-1} or kg ae ha^{-1} (dicamba and 2,4-D).

Treatment		Timing
1	Glyphosate (1.4) + 2,4-D (0.14)	rosette
2	Dicamba (0.14) + 2,4-D (0.48)	rosette
3	Dicamba (0.07) + 2,4-D (0.48) + metsulfuron-methyl (0.07)	rosette
4	Dicamba (0.14) + 2,4-D (0.48)	early flowering
5	Dicamba (0.07) + 2,4-D (0.48) + metsulfuron-methyl (0.07)	early flowering
6	Glyphosate (1.4) + 2,4-D (0.14)	rosette
	Dicamba (0.07) + 2,4-D (0.48) + metsulfuron-methyl (0.07)	early flowering
7	Mowing	early flowering
8	Non-treated control	

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at 60 C for 48 h, and weighed. A 1-m border within each plot was avoided during sampling to reduce border effects.

Data were analyzed by site using a mixed model ANOVA with SAS® software (SAS 2010). Fixed effects included treatment and year. Random effects included replication. Effects of treatment and year on exotic and native forbs were not analyzed due to infrequent occurrence. When significant models were found ($P \leq 0.05$), means were separated using Tukey's honest significant difference (HSD).

Results and Discussion

Sites varied in their response to treatment and were therefore analyzed separately. Treatments affected most of the measured vegetative parameters at Site 3 (Table 2). Vegetative parameters were influenced only by year at Site 1 and 2 (Table 2). We present and discuss results from Sites 1 and 2 first because vegetative parameters were only influenced by year at these two sites. We then present and discuss results from Site 3 where vegetative parameters were influenced by treatment, year, and their interaction.

Sites 1 and 2. At Site 1, year influenced western salsify rosette density, perennial grass density and biomass, and annual grass density and biomass (Table 2). Western salsify rosette density was about four times higher in 2010 (4.6 $\pm$ 1.6 plants m^{-2}) than 2011 (1.1 $\pm$ 0.6 plants m^{-2}). Perennial grass density and biomass were higher in 2011 than in 2010. Perennial grass density was 755 $\pm$ 36.8 tillers m^{-2} in 2011 versus 629 $\pm$ 43.6 tillers m^{-2} in 2010; biomass was 171 $\pm$ 10.0 g m^{-2} in 2011 and 131 $\pm$ 10.4 g m^{-2} in 2010. In contrast to perennial grass, annual grass density and biomass were higher in 2010 than in 2011 (347 $\pm$ 43.4 plants m^{-2} versus 174 $\pm$ 45.3 plants m^{-2}, respectively; 16.4 $\pm$ 2.2 g m^{-2} versus 9.3 $\pm$ 2.4 g m^{-2}, respectively).

At Site 2, year influenced western salsify adult density and perennial grass density (Table 2). Western salsify adult density was about three times higher in 2010 (6.3 $\pm$ 2.0 plants m^{-2}) than in 2011 (2.2 $\pm$ 0.8 plants m^{-2}). Perennial grass density was higher in 2011 (646 $\pm$ 60.0 tillers m^{-2}) than in 2010 (458 $\pm$ 59.9 tillers m^{-2}).

At both sites, weedy species (i.e. western salsify and annual weedy grasses) declined while perennial grasses increased, but this response was not due to treatments and was likely not due to large differences in precipitation between 2010 and 2011. Precipitation for March through July was 223 mm for 2010 and 184 mm for 2011 (National Climatic Data Center 2013). Perennial grasses often increase in response to a decline in weedy forbs or annual weedy grasses (Sheley et al. 2000, 2004; Whitson and Koch 1998). Alternatively, high production by perennial grasses can competitively suppress weedy species (Rinella et al. 2012; Whitson and Koch 1998). It is impossible for us to know for sure what led to the shift in plant community composition between 2010 and 2011 in our plots at Sites 1 and 2, but it is not uncommon for plant community composition and productivity to vary from year to year in response to biotic and abiotic environmental variables (Haferkamp et al. 1993; Haferkamp 2001).

Site 3. Treatment and year interacted to affect western salsify adult density and biomass and western salsify rosette density (Table 2). For the remaining parameters, one or both main effects (treatment, year) were significant.

Western salsify. Density of adult western salsify plants was lowest in Treatments 2 (dicamba + 2,4-D) and 6 (glyphosate + 2,4-D followed by dicamba + 2,4-D + metsulfuron-methyl) in 2010 (Figure 1). The other treatments did not differ from the nontreated control. In 2011, all herbicide treatments (Treatments 1 to 6) resulted in similar densities, and all were lower than the mowing treatment (Treatment 7) and nontreated control (Treatment 8). Western salsify density decreased in Treatments 3, 4, and 5 from 2010 to 2011 while it increased in Treatments 7 and 8.

Biomass of western salsify adults followed a trend similar to density in that biomass was lowest in Treatments 2 and 6 in 2010, but by 2011 all herbicide treatments resulted in similar biomass (Figure 2). The mowed and nontreated control plots resulted in the highest western salsify biomass in 2011 at 94.1 $\pm$ 25.1 and 114 $\pm$ 33.8 g m^{-2}, respectively. Western salsify biomass increased in those two treatments between 2010 and 2011.

In 2010 western salsify rosette density was similar across herbicide treatments and highest in the mowed and non-treated plots (Figure 3). Rosette density generally remained constant across herbicide treatments from 2010 to 2011, but decreased in the mowed and nontreated control. Density was highest in the nontreated control at about 40 $\pm$ 17.3 plants m^{-2}. Western salsify rosette biomass was affected by treatment

Table 2. P-values for ANOVA for main effects (year (Y), treatment (T)) and interaction (Y x T) on western salsify adult plants (WSA), western salsify rosettes (WSR), perennial grass (PG), and annual grass (AG) density and biomass at three sites in north-central Montana. Significant P-values are shown in bold text ($P \leq 0.05$).

Source	Df	WSA density	WSA biomass	WSR density	WSR biomass	PG density	PG biomass	AG density	AG biomass
Site 1									
Y	1	0.1373	0.5383	**0.0470**	0.3315	**0.0222**	**0.0003**	**0.0068**	**0.0380**
T	7	0.1448	0.0838	0.3814	0.4628	0.2486	0.0790	0.1429	0.2660
Y x T	7	0.5779	0.0700	0.7953	0.4735	0.9649	0.6086	0.7860	0.9911
Site 2									
Y	1	**0.0464**	0.0621	0.5352	0.9412	**0.0407**	0.4869	0.5319	0.1037
T	7	0.0863	0.1271	0.0819	0.1310	0.8491	0.8318	0.1054	0.1941
Y x T	7	0.2215	0.1187	0.3095	0.2152	0.8109	0.5027	0.4284	0.6090
Site 3									
Y	1	0.4588	**0.0205**	**0.0060**	0.7349	**< 0.0001**	**< 0.0001**	0.0528	**0.0074**
T	7	**0.0003**	**0.0093**	**0.0008**	**0.0117**	**0.0086**	**0.0076**	**0.0099**	**0.0257**
Y x T	7	**0.0006**	**0.0081**	**0.0151**	0.8883	0.7651	0.2596	0.8716	0.0941

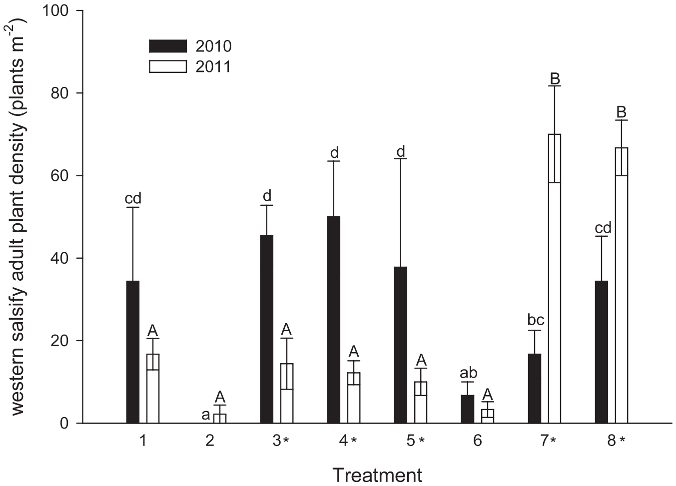

Figure 1. Influence of treatment across years on western salsify adult plant density at Site 3. Lower case and upper case letters separate means across treatments in 2010 and 2011, respectively ($\alpha = 0.05$). An asterisk (*) indicates a difference between means within a treatment and across years ($\alpha = 0.05$). Error bars indicate $\pm$ 1 standard error. Treatment 1 = glyphosate (1.4 kg ai ha^{-1}) + 2,4-D (0.14 kg ae ha^{-1}) applied at rosette stage; Treatment 2 = dicamba (0.14 kg ae ha^{-1}) + 2,4-D (0.48 kg ae ha^{-1}) applied at rosette stage; Treatment 3 = dicamba (0.07 kg ae ha^{-1}) + 2,4-D (0.48 kg ae ha^{-1}) + metsulfuron-methyl (0.07 kg ai ha^{-1}) applied at rosette stage; Treatment 4 = dicamba (0.14 kg ae ha^{-1}) + 2,4-D (0.48 kg ae ha^{-1}) applied at early flower stage; Treatment 5 = dicamba (0.07 kg ae ha^{-1}) + 2,4-D (0.48 kg ae ha^{-1}) + metsulfuron-methyl (0.07 kg ai ha^{-1}) applied at early flower stage; Treatment 6 = [glyphosate (1.4 kg ai ha^{-1}) + 2,4-D (0.14 kg ae ha^{-1}) applied at rosette stage] + [dicamba (0.07 kg ae ha^{-1}) + 2,4-D (0.48 kg ae ha^{-1}) + metsulfuron-methyl (0.07 kg ai ha^{-1}) applied at early flower stage]; Treatment 7 = mowing; Treatment 8 = nontreated control.

(Table 2). All treatments resulted in lower biomass than the nontreated control (0.4 g m^{-2} versus 4.6 g m^{-2}, respectively).

The decrease in western salsify adult plants across herbicide-treated plots in 2011 was likely a result of effectively controlling rosettes in 2010, preventing them from becoming adult flowering plants the following year. The decrease in western salsify adults was a function of herbicide treatment and not annual variation, because western salsify increased in the mowed and nontreated plots from 2010 to 2011. These results support the idea that herbicides that target the rosettes will effectively reduce salsify populations at least in the short term.

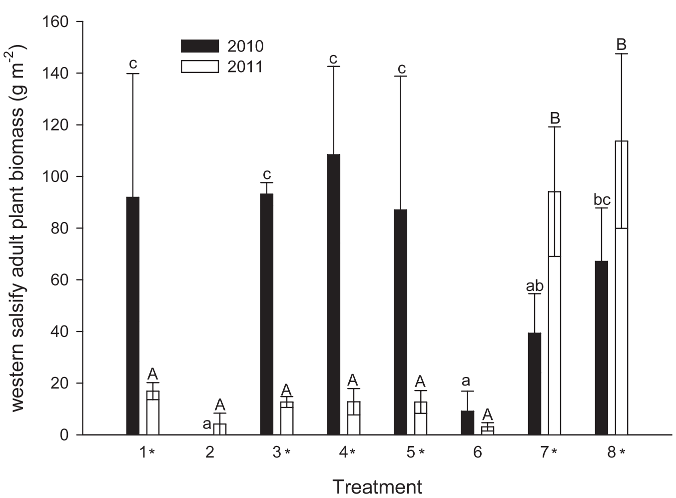

Figure 2. Influence of treatment across years on western salsify adult plant biomass at Site 3. Lower case and upper case letters separate means across treatments in 2010 and 2011, respectively ($\alpha = 0.05$). An asterisk (*) indicates a difference between means within a treatment and across years ($\alpha = 0.05$). Error bars indicate $\pm$ 1 standard error. See Figure 1 for explanation of treatments.

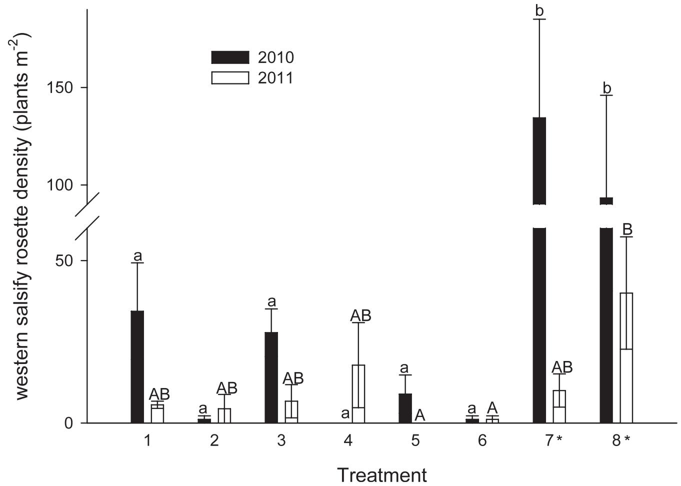

Figure 3. Influence of treatment across years on western salsify rosette density at Site 3. Lower case and upper case letters separate means across treatments in 2010 and 2011, respectively ($\alpha = 0.05$). An asterisk (*) indicates a difference between means within a treatment and across years ($\alpha = 0.05$). Error bars indicate $\pm$ 1 standard error. See Figure 1 for explanation of treatments.

We were encouraged by the decrease in western salsify across herbicide treatments from 2010 to 2011. In a study on meadow salsify in British Columbia, Canada, 2,4-D did not provide control beyond the year of application (Cranston et al. 1986). In the same study, however, a single application of dicamba provided two years of meadow salsify control. The difference in results between our study and that of Cranston et al. (1986) in the context of treatments that included 2,4-D could be due to us combining 2,4-D and dicamba (Treatment 2) and applying higher rates of each of those herbicides in our study versus the rates applied by Cranston et al. (1986). It should also be noted that we were attempting to control western salsify as opposed to meadow salsify, which was the species of concern in Cranston et al. (1986).

Timing of herbicide application appeared to influence efficacy. Treatment 2, which provided nearly 100% control of western salsify for two seasons, included dicamba and 2,4-D applied at the rosette stage. In contrast, Treatment 4, which included the same rate of dicamba and 2,4-D but applied at a later growth stage, did not reduce western salsify as effectively, especially for adult plants in 2010 and rosettes in 2011. While there are only a few studies specific to salsify management (Cranston et al. 1986; Upadhyaya et al. 2991), we can look to studies on other monocarpic perennial or biennial weeds for information on the influence of herbicide application timing. Timing of application played a role in control of the biennial weed houndstongue (*Cynoglossum officinale* L.) where 2,4-D applied to rosettes provided up to 97% control; application to flowering houndstongue plants provided only 77% control

(Dickerson and Fay 1982). Common mullein (*Verbascum thapsus* L.) is also best controlled when in the rosette stage (Knezevic 2009).

Timing of application is important, but western salsify rosettes can be difficult to distinguish from grass due to long, narrow, grass-like basal leaves. Producers and land managers should be encouraged to carefully survey early season vegetation in combination with standing litter (i.e. previous season's western salsify flowering stems) to gauge whether management is necessary and ensure appropriate timing of herbicide application.

Mowing reduced neither rosette nor adult western salsify density. From 2010 to 2011 there was a similar increase in adult plant density in the mowing and control plots (Figure 1), and a similar decrease in rosette densities (Figure 3). Although we did not take any measurements on light quantity, an increase in light from canopy removal through mowing may have resulted in more robust rosettes that flowered in 2011. This is supported by the large increase in the number of flowering plants from 2010 to 2011 in the mowing plots. We are not aware of any other studies that have tested mowing to control salsify, but some studies have tested mowing for control of biennial weeds like thistles. It was concluded from those studies that a single mowing will not satisfactorily control biennial thistles because of growth stage variability in natural populations, and seed will invariably still be produced (Beck 1999). Therefore, results from this research do not support mowing as a management strategy to reduce western salsify.

Perennial Grasses. Perennial grass density was affected by the main effects of treatment and year (Table 2). Treatment 2 resulted in the highest density at 1008 $\pm$ 190 tillers m^{-2} averaged across 2010 and 2011 (Table 3). Density in Treatment 2 was over two times greater than density in the nontreated control (Treatment 8, Table 3). All other treatments were similar to the nontreated control except for Treatment 1, which at 661 $\pm$ 137 tillers m^{-2} was about 200 tillers m^{-2} higher. Perennial grass density was higher in 2011 (798 $\pm$ 73.1 tillers m^{-2}) than in 2010 (422 $\pm$ 36.1 tillers m^{-2}).

Similar to density, perennial grass biomass was affected by treatment and year (Table 2). Biomass was highest in Treatment 2 at 181 $\pm$ 37.7 g m^{-2} followed by Treatments 6, 3, and 5, which were all similar to each other (Table 3). Treatments 1, 4, and 7 were all similar to each other and did not differ from the nontreated control (Treatment 8, Table 3). Perennial grass biomass was nearly three times higher in 2011 (177 $\pm$ 14.6 g m^{-2}) than in 2010 (60.8 $\pm$ 6.1 g m^{-2}).

Perennial grass density and biomass were highest when western salsify was most effectively controlled, especially with Treatment 2. Our results are consistent with other studies where perennial grasses increase in response to weedy forb control (Sheley et al. 2000. 2004). Once released from suppression, perennial grasses may be more effective at preventing re-invasion, and longevity of a one-time herbicide application may be increased (Sheley and Jacobs 1997).

Annual Grasses. Annual grass density was influenced by treatment (Table 2). Density was highest in Treatment 5 (270 $\pm$ 100 plants m^{-2}), followed by Treatment 6 (101 $\pm$ 46 plants m^{-2}) (Table 3). Annual grass densities in these treatments were about 45 and 17 times higher, respectively, than in the nontreated control (Treatment 8, Table 3). All other treatments were similar to the nontreated control.

Annual grass biomass was influenced by treatment and year (Table 2). Biomass was highest in Treatments 5 and 6 at 18.7 $\pm$ 10.4 g m^{-2} and 22.5 $\pm$ 13.5 g m^{-2}, respectively (Table 3). All other treatments were similar to each other and to the nontreated control. Biomass was higher in 2011 (12.2 $\pm$ 4.3 g m^{-2}) than 2010 (1.5 $\pm$ 1.1 g m^{-2}).

Annual weedy grasses such as downy and Japanese brome have been problematic in the western U.S. for decades (Mack 2011) and are increasingly problematic in Montana. Treatments that control a weedy forb like western salsify and result in an increase in annual weedy grasses may create additional weed management issues. Treatments 5 and 6, which included metsulfuron-methyl applied at the early flowering stage, led to an increase in annual weedy grasses. Metsulfuron-methyl can temporarily injure some grasses, especially when grasses are stressed by high soil pH or weather conditions such as drought (Anonymous 2001). We believe that the application of metsulfuron-methyl later in the season could have temporarily injured perennial grasses, allowing fall-emerging annual weedy bromes to increase, without impacts on density and biomass of perennial grasses the following year.

Table 3. Mean density and biomass of perennial and annual grasses as influenced by treatment at Site 3. SE = standard error. Means followed by a similar letter are similar to one another within a functional group and vegetative parameter ($\alpha = 0.05$).

Treatment[a]	Perennial grass		Annual grass	
	Density tillers m^{-2} (SE)	Biomass g m^{-2} (SE)	Density plants m^{-2} (SE)	Biomass g m^{-2} (SE)
1) glyphosate + 2,4-D (rosette)	661 C, (137)	110 A, (28.4)	60.6 AB, (33.6)	4.8 A, (2.5)
2) dicamba + 2,4-D (rosette)	1008 B, (190)	181 D, (37.7)	73.3 AB, (38.1)	0.7 A, (0.5)
3) dicamba + 2,4-D + metsulfuron-methyl (rosette)	554 A, (95.3)	128 C, (32.6)	18.3AB, (6.3)	0.8 A, (0.5)
4) dicamba + 2,4-D (early flower)	447 A, (109)	100 AB, (27.1)	86.1 AB, (34.3)	5.6 A, (2.6)
5) dicamba + 2,4-D + metsulfuron (early flower)	627 A, (100)	125 BC, (28.1)	270 C, (100)	18.7 B, (10.4)
6) treatment 1 + treatment 5	525 A, (166)	147 C, (51.7)	101 B, (46.0)	22.5 B, (13.5)
7) mowing (early flower)	602 A, (91.1)	74.5 A, (18.1)	40.6 AB, (17.1)	1.3 A, (0.8)
8) non-treated control	455 A, (112)	87.2 A, (23.7)	6.1 A , (3.4)	0.4 A, (0.3)

[a] See Table 1 for full description of each treatment.

Our results from the most heavily western salsify-infested site support a recommendation of dicamba at 0.14 kg ha^{-1} combined with 2,4-D at 0.48 kg ha^{-1} applied at the rosette stage (Treatment 2, Table 1). This treatment provided the most cost-effective control of western salsify and resulted in an increase of perennial grasses without stimulating annual grasses. For example, based on current herbicide prices, the cost of herbicides for Treatment 2 would be approximately \$10.25 ha^{-1} compared to about \$12.60 ha^{-1} for Treatment 6, and this cost does not include the expense associated with spraying more than once as would be the case with Treatment 6. This study supports management at sites where western salsify is dominating CRP lands. Adult plants increased from 2010 to 2011 in the mowed and nontreated plots, suggesting continued increase and spread if left untreated. Because treatment differences were not detected at the sites where western salsify was less dominant, a broadcast herbicide application to treat western salsify in such situations may not be warranted. Instead spot treatment of dense patches may suffice and prevent infestations from worsening.

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