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Canada Thistle (*Cirsium arvense*) Control with Aminopyralid in Range, Pasture, and Noncrop Areas

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Canada thistle is a serious weed of many crop, rangeland, pasture, and natural areas throughout North America. Aminopyralid is a new pyridine carboxylic acid herbicide that has activity on Canada thistle at lower use rates than current standard treatments. The objectives of this study were to compare aminopyralid efficacy, rates, and application timing with several commercial standards for Canada thistle control. Studies were conducted across the Great Plains at ten locations, which encompassed a wide range of environments. Aminopyralid provided Canada thistle control comparable to picloram, picloram + 2,4-D amine, and clopyralid and better control than clopyralid + 2,4-D amine, dicamba, dicamba + 2,4-D amine and dicamba + diflufenzopyr. Canada thistle control was similar when aminopyralid was applied between 0.08 and 0.11 kg ai/ha and application timing (spring bolting vs. fall rosette/regrowth) did not strongly influence control 1 yr after treatment (YAT). Aminopyralid provided effective Canada thistle control at lower use rates than current commercial standards and might be useful in areas where herbicides such as picloram and clopyralid are not recommended for use.

Nomenclature: Aminopyralid; clopyralid; dicamba; diflufenzopyr; picloram; 2,4-D amine; Canada thistle, *Cirsium arvense* L. Scop. CIRAR.

Key words: Application timing, rate-response.

Canada thistle is a deep-rooted perennial forb that is a serious weed in agronomic, pasture, riparian, and natural areas throughout North America (Moore 1975). Canada thistle is classified as a noxious weed in 43 states and much of Canada and is the most frequently listed noxious weed in both cropland and wild lands in the United States (Skinner et al. 2000). The weed is highly competitive, causes yield reductions in crops such as alfalfa grown for seed (Moyer et al. 1991) and barley (O'Sullivan et al. 1982), and can reduce forage availability (Haggar et al. 1986), production (Reece and Wilson 1983), and species diversity (Stachion and Zimdahl 1980) in grasslands. For wildlands and natural areas, the ecological and economic impacts of Canada thistle are still largely undocumented (Lym and Duncan 2005).

Control methods (beyond prevention measures) for Canada thistle in rangeland, pasture, and noncrop areas have included herbicides (Bultsma et al. 1992), mowing (Beck and Sebastian 2000), burning (Smith 1985), seeding competitive grasses (Wilson and Kachman 1999), and biological control (Piper and Andres 1995). All of these methods have merit and are frequently used in integrated strategies. Current chemical recommendations for Canada thistle control in range, pasture, and noncrop areas include picloram, clopyralid, dicamba, dicamba + diflufenzopyr, 2,4-D amine, triclopyr, chlorsulfuron, metsulfuron, glyphosate, and various combinations of these herbicides (Dewey et al. 2006; University of Nebraska 2006). Optimal treatment timings are generally split into two application periods: spring/early summer applications to plants in the late rosette/bolting/bud stages or in the fall to shoot regrowth or newly emerged rosettes. Although these timings are common current recommendations for Canada thistle treatment, few field studies have directly compared them. In addition, there are few published field studies that have examined the full range of registered rates for Canada thistle control in rangeland, pasture, and noncrop areas.

Aminopyralid is a pyridine carboxylic acid herbicide recently developed and registered for use in rangelands, pastures, and noncrop areas (Hare et al. 2005). Aminopyralid was granted reduced-risk classification in 2004 by the United States Environmental Protection Agency based upon a favorable toxicological, ecotoxicological, and environmental fate profile (Jachetta et al. 2005). Aminopyralid can control many broadleaf species in the families Asteraceae, Fabaceae, and Solanaceae (Carrithers et al. 2005); however, aminopyralid is selective among some dicot families and genera at registered use rates and can not control leafy spurge (*Euphorbia esula* L.; Lym 2005), Dalmatian toadflax [*Linaria dalmatica* (L.) P. Mill], tall larkspur [*Delphinium barbeyi* (Huth) Huth], houndstongue (*Cynoglossum officinale* L.), or common viper's bugloss [*Echium vulgare* L.; Enloe, unpublished data]. The efficacy and specificity across families and genera is still not clearly defined for aminopyralid. Due to a favorable environmental fate profile, aminopyralid can be used in riparian areas up to the water's edge and can provide a control option where other treatments such as clopyralid and picloram are not recommended for use.

The objectives of this study were to evaluate Canada thistle control with aminopyralid applied at several rates and

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Table 1. Study locations, mean annual precipitation, temperature, and site descriptions for Canada thistle study locations.

Location	Mean annual precipitation[a] (mm)	Mean annual temperature (C)	Site type and associated species present
Brookings, SD	571	6.2	CRP; smooth brome (*Bromus inermis*)
Cheyenne, WY	391	7.6	Rangeland; needle and thread grass (*Hesperostipa comata*), western wheatgrass (*Pascopyrum smithii*), smooth brome
Fargo, ND	531	5.3	Abandoned cropland; smooth brome, foxtail barley (*Hordeum jubatum*)
Fort Collins, CO	380	8.9	Abandoned cropland; kochia (*Kochia scoparia*), Russian thistle (*Salsola tragus*)
Hudson, CO (site 1)	310	9.6	Pasture; crested wheatgrass (*Agropyron cristatum*)
Hudson, CO (site 2)	310	9.6	Pasture; smooth brome
Jamestown, ND	470	4.4	Noncrop; smooth brome, absinth wormwood (*Artemisia absinthium*), field bindweed (*Convolvulus arvensis*)
Longmont, CO	340	9.4	Abandoned cropland; common wildrye (*Secale cereale*)
Scottsbluff, NE (2 sites)	388	9.2	Subirrigated pasture; needle and thread, sand bluestem (*Andropogon hallii*), Kentucky bluegrass (*Poa pratensis*)

[a] Mean precipitation and temperature are minimum 30-yr averages.

applications timings and compare aminopyralid efficacy to currently recommended treatments.

Materials and Methods

Studies were established in Colorado, Nebraska, North Dakota, South Dakota, and Wyoming in the late spring of 2004 at a total of ten locations (Table 1). Annual precipitation ranged from 310 mm (Hudson, CO) to 571 mm (Brookings, SD) and mean temperature ranged from 4.4 C (Jamestown, ND) to 9.6 C (Hudson, CO). Soil textures varied from sandy loam (Cheyenne, WY) to clay (Longmont, CO) and soil organic matter content ranged from 3.0 (Brookings, SD) to 10.8% (Hudson, CO, site 2) (Table 2).

At each location, aminopyralid was compared to several other commercial standards that varied among sites (Table 3). Herbicides were broadcast applied using a CO_2-pressurized backpack boom sprayer delivering 140 L/ha at 276 kPa. Plot size was 3.3 by 9 m. Treatments were applied when Canada thistle was in the spring bolting stage (late May to early June in 2004) or to fall rosette/regrowth in September 2004. Fall treatments were applied after the first frost for the Nebraska, North Dakota, and Wyoming locations but before the first frost at the Colorado and South Dakota locations. Herbicide treatments included aminopyralid at 0.08, 0.09 and 0.11 kg ai/ha; picloram at 0.42 kg ai/ha; clopyralid at 0.42 kg ai/ha; picloram + 2,4-D amine at 0.28 + 1.12 kg ai/ha; clopyralid + 2,4-D amine at 0.32 + 1.68 kg ai/ha; dicamba at 1.12 kg ai/ha; dicamba + 2,4-D amine at 0.56 or 1.12 + 1.12 kg ai/ha; and dicamba + diflufenzopyr at 0.14 + 0.06 or 0.2 + 0.08 kg ai/ha. A nonionic surfactant[1] was added to each treatment at 0.25% v/v. The experimental design was a randomized complete block with three or four replications at all locations.

Canada thistle control was visually evaluated 1 yr after treatment (YAT) for each treatment timing. Plots treated at the bolting stage were evaluated 1 YAT the following late spring or early summer and plots treated at the fall rosette regrowth stage were evaluated 1 YAT the following fall. Visual evaluations were made by comparing each treated plot to the nontreated control using a rating scale of 0 (no control) to 100 (complete absence of living Canada thistle shoots) percent control. Because the objective was to test for differences among treatments and between treatment timings, location was used as random effect. Visual evaluation data were subjected to analysis of variance using the mixed procedure in SAS.[2] The two Hudson, CO locations were combined for the analysis. Five locations had 1 YAT efficacy data for both treatment timings. These included Fargo, Jamestown, Hudson (when sites were pooled), Fort Collins, and Cheyenne. Four additional locations had 1 YAT efficacy data for only the spring bolting treatment timing. These included Scottsbluff, NE (two study sites), Longmont, CO, and Brookings, SD. To incorporate these additional data, a second ANOVA was conducted using the mixed procedure in SAS and included only the spring bolting treatment timing 1 YAT. For both analyses, post-hoc comparisons were done using Fisher's protected LSD at $P = 0.05$ level of significance. Sample size

Table 2. Soil characteristics of Canada thistle study locations.

Location	Soil series	Taxonomy	Sand	Silt	Clay	OM	pH
			%				
Brookings, SD	Hamerly loam	Fine-loamy, mixed, superactive, frigid Aeric Calciaquolls	26	37	37	3.0	6.5
Cheyenne, WY	Evanston loam	Fine-loamy, mixed, superactive, frigid Aridic Argiustolls	67	18	15	8.9	7.4
Fargo, ND	Silty clay	Fine, smectitic, frigid typic, Epiaquerts	2	45	53	4.3	7.8
Fort Collins, CO	Garrett clay[a]	Fine-loamy, mixed, superactive, mesic Pachic argiustolls	20	38	42	6.6	8.2
Hudson, CO (site 1)	Weld clay loam	Fine, smectitic, mesic Aridic Argiustolls	30	42	28	6.5	8.0
Hudson, CO (site 2)	Colby loam	Fine-silty, mixed, superactive, calcareous, mesic Aridic Ustorthents	34	41	25	10.8	7.9
Jamestown, ND	Loam	Fine-loamy, mixed, superactive, Frigid, Calcic Hapludolls	37	42	21	8.9	6.4
Longmont, CO	Heldt clay	Fine, smectitic, mesic, ustertic, Haplocambids	29	30	41	5.6	8.0
Scottsbluff, NE (both sites)	Valent loamy fine sand	Mixed, mesic Ustic Torripsamments	70	25	5	6.0	8.0

[a] Atypical texture for the Garrett series.

Table 3. Canada thistle control in pasture, rangeland, and noncrop areas 1 yr after treatment across the Great Plains.

Herbicide	Rate	Combined spring bolting and fall applications[a]			Spring bolting applications only[b]		
	kg ai/ha	% control [c]	Std. error	Sample size (*n*)[c]	% control[d]	Std. error	Sample size (*n*)[c]
Aminopyralid	0.08	90 a	6	38	88 a	5	33
Aminopyralid	0.09	93 a	6	40	90 a	5	35
Aminopyralid	0.11	95 a	6	39	93 a	5	35
Picloram	0.42	97 a	7	12	92 a	6	15
Picloram + 2,4-D amine	0.28 + 1.12	89 ab	7	12	83 a	6	20
Clopyralid	0.42	81 b	7	32	86 a	5	28
Clopyralid + 2,4-D amine	0.32 + 1.68	70 c	7	24	64 b	5	23
Dicamba	1.12	54 d	8	8	52 bc	8	7
Dicamba + 2,4-D amine	0.56 + 1.12	34 e	7	16	30 d	7	8
Dicamba + 2,4-D amine	1.12 + 1.12	56 d	7	20	36 d	6	20
Dicamba + diflufenzopyr	0.14 + 0.06	38 e	7	24	30 d	7	11
Dicamba + diflufenzopyr	0.2 + 0.08	52 d	8	16	44 cd	6	19

[a] Locations included Fargo, ND; Jamestown, ND; Hudson, CO; Fort Collins, CO; and Cheyenne, WY. These sites had 1 YAT data for bolting and fall regrowth application timings.

[b] Locations included Longmont, CO; Scottsbluff, NE (two sites); Brookings, SD; and all sites used in analysis one with 1 YAT data for the spring bolting timing only.

[c] Sample size equals the total number of observations used in the analysis.

[d] Means within columns followed by the same letter are not different at P = 0.05.

(*n*) is listed for each treatment and represents the number of observations used in each analysis (Table 3). To determine if there was an aminopyralid rate response, the regression procedure was used in SAS to analyze the rate response separately for each application timing using the five locations that had comparable 1 YAT data for both application timings.

Results and Discussion

Herbicide treatment was highly significant ($P < 0.0001$) for the five locations with comparable 1 YAT data for each application timing; however, application timing ($P = 0.36$) and the treatment by application timing interaction ($P = 0.54$) were not significant and data were then combined over application timing. Canada thistle control ranged from 34 to 97% across herbicide treatments 1 YAT (Table 3). Canada thistle control with aminopyralid was 90% or higher regardless of application rate and was comparable to picloram applied alone (97% control) and picloram + 2,4-D amine (89% control). Control with clopyralid was lower (81% control compared to 90%) than with aminopyralid but was similar to picloram + 2,4-D amine. Clopyralid + 2,4-D amine provided less Canada thistle control (70%) than clopyralid applied alone, possibly due to a slightly lower concentration of clopyralid in the treatment. Dicamba and dicamba + 2,4-D amine or dicamba + diflufenzopyr combinations averaged 34 to 54% control, which is commercially unacceptable.

Four additional locations provided 1 YAT data for the bolting timing. Canada thistle control with aminopyralid applied at bolting ranged between 88 to 93% and was comparable to picloram, picloram + 2,4-D amine, and clopyralid (Table 3). All other treatments provided less than 70% control 1 YAT. These treatments included clopyralid + 2,4-D amine, and all dicamba and dicamba + 2,4-D amine or diflufenzopyr applications. Canada thistle control with these treatments ranged from 30 to 64%.

Linear regression of the aminopyralid rate response (0, 0.08, 0.09, and 0.11 kg /ha) was significant for bolting applications ($P = 0.03$); however, the linear rate response could only account for a small percentage of the variation ($R^2 = 0.07$), probably due to the fact that control varied by only 5% across the three aminopyralid rates (data not shown). The aminopyralid rate response for the fall rosette/regrowth timing was not significant ($P = 0.28$, $R^2 = 0.02$) with Canada thistle control between 89 to 97% (data not shown).

Based upon these studies, we conclude that Canada thistle control 1 YAT was not different among any of the aminopyralid rates and that application timing (spring bolting vs. fall rosette/regrowth) did not strongly influence aminopyralid efficacy. Aminopyralid appears to provide comparable activity to picloram and picloram + 2,4-D amine applied at either bolting or fall timing. Canada thistle control at bolting was comparable for aminopyralid and clopyralid at the rates tested. Aminopyralid also provided better Canada thistle control 1 YAT than clopyralid + 2,4-D amine, dicamba, and all dicamba + 2,4-D amine or dicamba + diflufenzopyr treatments.

Aminopyralid rates used in this study were approximately two to four times lower on an active ingredient basis than the commercial standards used to control Canada thistle. This might be of interest to many land managers who are interested in reducing the amount of herbicides that need to be handled and stored. Although we did not see a difference in Canada thistle control between the low and high rates of aminopyralid, longer-term control data (2 to 4 YAT) would be very useful to determine if and when Canada thistle control begins to decrease relative to initial application rate. If there is significant decrease in control over time, this information would be useful for land managers with differing goals. For example, some managers might opt to apply the low rate in combination with other management strategies such as prescribed burning in a "many little hammers" approach (Liebman and Gallandt 1997); however, this approach has not yet been researched for aminopyralid. Conversely, they might want to apply the maximum registered rate to provide as many years of control as possible. This option could be highly desirable at sites with a sufficient grass understory. If there is no decline in Canada thistle control that correlates to initial application rate, then land managers will be able to utilize the lower registered rates even if management goals differ.

There have been very few published studies that have used these rates of picloram or clopyralid for Canada thistle control. Beck and Sebastian (2000) examined sequential applications of several rates of picloram, picloram + 2,4-D amine, and clopyralid + 2,4-D amine. They found that picloram + 2,4-D amine (0.28 + 1.12 kg/ha) applied over 2 yr in the fall eliminated Canada thistle in the third year. Alley and Humberg (1977) found clopyralid applied at 0.42 kg/ha to Canada thistle in the bud stage gave 90% control 1 YAT, which was similar to the results reported here. Bultsma et al. (1992) found clopyralid + 2,4-D amine applied at 0.21 + 1.1 kg ai/ha to Canada thistle in the bolting stage provided 63 to 65% control approximately 1 YAT. Lym and Diebert (2005) found clopyralid applied at 0.28 kg /ha provided 56% control 12 months after a June application, whereas Beck et al. (1989) reported that clopyralid applied at 0.28 kg ai/ha in the spring when Canada thistle was in the rosette stage provided only 24% control 1 YAT. Beck (1988) found clopyralid applied at 0.28 and 0.56 kg ai/ha to bolting plants provided 30 and 63% control 1 YAT, respectively. Currently, the lowest recommended registered rate of clopyralid for Canada thistle control in rangeland and pastures is 0.28 kg/ha (Anonymous 2005); however, the limited published literature suggests that rate might not provide consistent control 1 YAT.

In general, we observed that dicamba alone and the dicamba tank mixes did not adequately control Canada thistle. Dicamba applied at 1.12 kg/ha did not control Canada thistle 1 YAT (Beck 1988; Beck et al. 1989). Our results with dicamba + diflufenzopyr (0.28 + 0.11 kg ai/ha) were somewhat different than those of Lym and Diebert (2005). Canada thistle control 12 months after June application was only 11%, whereas our results for five locations averaged 58% control 1 YAT across spring and fall timings. Neither study demonstrated acceptable control despite these differences.

Few studies have compared the effect of Canada thistle growth stage on herbicide efficacy in rangeland, pasture, or noncrop settings. Sebastian et al. (1992) found no difference in Canada thistle efficacy 1 YAT when picloram was applied at 0.56 kg/ha in the bud stage or to fall regrowth; however, Wilson et al. (2006) found clopyralid applied at 0.28 kg/ha in September controlled Canada thistle better than when applied in June. They suggested the difference in control might be partially due to a timely disruption of seasonal changes of root carbohydrate levels by clopyralid with the fall application. Miller and Lym (1998) observed greater translocation to the roots of Canada thistle when clopyralid was applied at the rosette stage compared to the bolting stage, and a similar observation was made with glyphosate (Hunter 1995). Although not completely understood, the reason for these differences might be herbicide-dependent in regards to absorption and translocation, environmental conditions, and soil residual activity in the period following treatment. In our studies, control was similar when aminopyralid, picloram, and clopyralid were applied in the spring or fall where comparable 1 YAT data were available. Because we saw no difference in treatment timing, the fall timing does give land managers more flexibility in their Canada thistle control programs, allowing more time to focus management efforts on weed species that response better to spring and early summer treatments.

Sources of Materials

[1] Activator 90, Loveland Industries, Inc., P.O. Box 1289, Greeley, CO 80632.

[2] The SAS System for Windows, version 9.1. SAS Institute, Inc., SAS Campus Drive, Cary, NC 27513–8617.

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