Leafy spurge control with herbicide combinations that included imazapic, quinclorac, and diflufenzopyr. Rodney G. Lym. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Research at North Dakota State University has shown that long-term leafy spurge control can be improved when a mixture of herbicides are applied compared to a single herbicide applied alone. Also, both initial and long-term leafy spurge control was increased when diflufenzopyr, an auxin transport inhibitor, was applied with several auxin herbicides. The purpose of this research was to evaluate various combinations of imazapic, quinclorac, and diflufenzopyr for leafy spurge control.

The first experiment compared various mixtures of picloram, 2,4-D, imazapic, and quinclorac applied with diflufenzopyr for leafy spurge control on the Sheyenne National Grassland (SNG) and near Walcott, ND. Herbicides were applied on June 8 and 22, 2001, respectively, when the leafy spurge was in the true-flower growth stage and 14 to 28 inches tall using a hand-held boom sprayer delivering 8.5 gpa at 35 psi. The plots were 10 by 30 feet at Walcott and 8 by 25 feet on the SNG, and treatments were replicated four times in a randomized complete block design. Leafy spurge topgrowth control was visually evaluated based on percent stand reduction compared to the untreated check.

The combinations of picloram plus 2,4-D with imazapic or with imazapic plus diflufenzopyr provided better leafy spurge control than picloram plus 2,4-D applied alone (Table 1). For instance, leafy spurge control 12 MAT (months after treatment) averaged over both locations was 78% with picloram plus 2,4-D compared to 92% when picloram plus 2,4-D were applied with imazapic or imazapic plus diflufenzopyr. The addition of quinclorac or quinclorac plus diflufenzopyr to picloram plus 2,4-D only tended to increase control 12 MAT compared to picloram plus 2,4-D alone and averaged 84%. In general, leafy spurge control 12 MAT was similar when quinclorac was applied alone or with diflufenzopyr, dicamba, or dicamba plus diflufenzopyr and averaged 88% over both locations. The combination of picloram plus 2,4-D plus quinclorac plus dicamba plus diflufenzopyr tended to provide the best long-term control at the SNG and averaged 82% 24 MAT. However, the same treatment at Walcott only averaged 40% control 24 MAT.

The second experiment evaluated leafy spurge control with the commercial formulation of dicamba plus diflufenzopyr (Distinct) applied alone or with imazapic, quinclorac, or imazapic plus 2,4-D. Herbicide treatments were applied at the same locations and dates as the first experiment to leafy spurge in the true-flower growth stage, except the imazapic alone treatments were applied in mid-September 2001. Herbicides were applied as previously described, and plots at both locations were 10 by 30 feet with three replications.

In general, dicamba plus diflufenzopyr spring-applied provided similar leafy spurge control when applied alone or with imazapic or imazapic plus 2,4-D at comparable rates regardless of evaluation date (Table 2). Also, quinclorac alone spring-applied generally provided similar leafy spurge control compared to quinclorac applied with dicamba plus diflufenzopyr. Imazapic alone fall-applied provided the best long-term leafy spurge control, which averaged 99% over both rates 12 months after treatment. However, grass injury 9 MAT averaged over both locations was

11 and 22% with imazapic at 2 and 3 oz/A, respectively. Grass injury only slightly declined by 12 MAT. Leafy spurge control averaged of 85 and 98% 18 MAT when imazapic was applied at 2 and 3 oz/A, respectively. Leafy spurge control with imazapic at 3 oz/A averaged 94% 24 MAT at the SNG, but only 62% at Walcott, while imazapic applied at 2 oz/A averaged 71 and 55%, respectively (data not shown). Grass injury was not observed with either treatment 24 MAT.

The third and fourth experiments compared leafy spurge control with imazapic applied alone or with diflufenzopyr or diflufenzopyr plus dicamba or quinclorac and quinclorac plus diflufenzopyr. The experiment was established as previously described near Valley City on September 10, 2002 and on the SNG on September 11, 2002.

Leafy spurge control with imazapic was similar when applied at 1 oz/A alone or with diflufenzopyr or diflufenzopyr plus dicamba and averaged 92 and 73% at the SNG and Valley City 12 MAT, respectively (Table 3). Imazapic at 2 oz/A averaged 95% leafy spurge control 12 MAT regardless of location compared to 49% with picloram plus 2,4-D at 8 + 16 oz/A. Long-term leafy spurge control was similar whether imazapic was applied alone or with diflufenzopyr or dicamba plus diflufenzopyr and declined rapidly to less than 60% 24 MAT regardless of treatment.

Quinclorac applied with imazapic provided similar leafy spurge control to the herbicides applied alone (Table 4). For instance, imazapic applied at 1 oz/A provided an average of 92% leafy spurge control 12 MAT compared to 93% when applied with quinclorac. Also, the addition of diflufenzopyr with imazapic or quinclorac provided similar leafy spurge control to the herbicides applied alone regardless of rate or location. Quinclorac at 4 oz/A provided similar long-term leafy spurge control to imazapic at Valley City, but not on the SNG.

In summary, imazapic applied with picloram plus 2,4-D improved long-term leafy spurge control compared to the standard treatment of picloram plus 2,4-D. In general, imazapic fall-applied provided the best long-term leafy spurge control while imazapic applied with diflufenzopyr, dicamba, or quinclorac in various combinations provided similar leafy spurge control to imazapic applied alone at comparable rates. Dicamba plus diflufenzopyr did not provide long-term leafy spurge control.

Table 1. Leafy spurge control 3 to 24 months after treatment from various herbicide mixtures applied in June 2001 near Walcott and on the Sheyenne National Grassland (SNG) in ND.

		Location/months after treatment							
		3		12		15		24	
Treatment	Rate	Walcott	SNG	Walcott	SNG	Walcott	SNG	Walcott	SNG
	—— oz/A ——	——	——	——	%	——	——	——	——
Picloram + 2,4-D	4 + 16	68	82	79	77	19	12	31	41
Imazapic +MSO[a]+28%N	1 + 1 qt + 1 qt	45	93	89	70	42	0	35	31
Picloram+2,4-D+imazapic+MSO+28%N	4+16+1+1 qt +1qt	96	99	87	95	40	52	44	53
Picloram+2,4-D+imazapic+diflufenzopyr +MSO+28%N	4+16+1+2+1 qt+1qt	100	100	89	95	44	66	40	68
Picloram+2,4-D+quinclorac+MSO	4+16+8+1 qt	96	99	81	89	35	17	40	82
Picloram+2,4-D+quinclorac+diflufenzopyr +MSO	4+16+6+2.5+1 qt	97	95	79	85	22	27	43	64
Quinclorac+diflufenzopyr+MSO	6+1.2+1 qt	93	96	88	88	36	45	43	40
Quinclorac+dicamba+MSO	6+3+1 qt	90	92	89	83	35	51	41	51
Quinclorac+dicamba+diflufenzopyr[b]+MSO	6+3+1.2+1 qt	97	97	86	92	34	63	58	68
Quinclorac+dicamba+diflufenzopyr[c]+ imazapic+MSO	6+3+1.2+1+1 qt	97	96	92	96	51	88	26	22
LSD (0.05)		16	7	18	12	NS	29	NS	36

[a]Methylated seed oil was Scoil by AGSCO, Grand Forks, ND.
[b]Commercial formulation of dicamba plus diflufenzopyr - Distinct, by BASF Corp., Research Triangle Park, NC.

Table 2. Leafy spurge control from dicamba plus diflufenzopyr applied alone or with various other herbicides in June 2001 for leafy spurge control near Walcott and on the Sheyenne National Grassland.

		Location/months after treatment													
		Walcott							Sheyenne National Grassland						
		3	12/9		15/12		24/18		3	12/9		15/12		24/18	
Treatment	Rate	Cont	Cont	GI[a]	Cont	GI[a]	Cont	GI[a]	Cont	Cont	GI[a]	Cont	GI[a]	Cont	GI[a]
	– oz/A –	%													
Imazapic + picloram + 2,4-D+ MSO[b] + 28%N	1 + 4 + 16	97	95	3	68	0	58	0	97	83	0	33	5	32	0
Dicamba + diflufenzopyr[c]+MSO	3 + 1.2	73	69	0	13	0	27	0	72	68	0	22	0	8	0
Dicamba + diflufenzopyr[c]+MSO	4 + 1.6	86	79	0	37	0	28	0	58	63	0	15	0	3	0
Dicamba + diflufenzopyr[c] + imazapic+MSO	2 + 0.8 + 1	82	62	0	11	0	24	0	84	78	0	25	0	10	0
Dicamba + diflufenzopyr[c] + imazapic+MSO	3 + 1.2 + 1	82	64	0	7	0	20	2	89	89	0	22	0	20	0
Dicamba + diflufenzopyr[c] + imazapic+MSO	4 + 1.6 + 1	96	93	0	40	0	27	0	83	72	0	25	0	21	0
Dicamba + diflufenzopyr[c] + imazapic + 2,4-D[d]+MSO	2 + 0.8 + 1 + 2	95	92	3	35	0	38	3	93	80	0	20	0	9	0
Dicamba + diflufenzopyr[c] + imazapic + 2,4-D[d]+MSO	3 + 1.2 + 1 + 2	94	86	0	30	0	20	0	81	63	0	18	0	4	0
Dicamba + diflufenzopyr[c] + imazapic + 2,4-D[d]+MSO	4 + 1.6 + 1 + 2	92	86	0	45	0	51	0	97	79	0	23	0	30	0
Quinclorac+MSO	6	85	87	0	18	0	3	0	59	61	0	6	0	0	0
Dicamba + diflufenzopyr[c] + quinclorac+MSO	2 + 0.8 + 6	88	88	0	37	0	44	0	80	67	0	27	0	25	0
Imazapic+MSO - fall applied	2	••	100	17	99	11	80	1	••	99	5	98	4	89	5
Imazapic+MSO - fall applied	3	••	100	31	100	23	97	3	••	98	12	99	15	99	10
LSD (0.05)		10	14	8	28	4	38	NS	26	23	11	34	5	30	2

[a] Grass injury.

[b] MSO = methylated seed oil at 1 qt/A , Scoil by AGSCO, Grand Forks, ND for all treatments.

[c] Commercial formulation of dicamba plus diflufenzopyr - Distinct by BASF Corp., Research Triangle Park, NC.

[d] Commercial formulation of imazapic plus 2,4-D - Oasis by BASF Corp., Research Triangle Park, NC.

Table 3. Leafy spurge control with imazapic applied alone or with diflufenzopyr and diflufenzopyr plus dicamba on the Sheyenne National Grassland (SNG) and near Valley City, North Dakota in September 2002.

		Location/time after treatment								
		9 MAT[a]				12 MAT		21 MAT		24 MAT
		SNG		Valley City		SNG	Valley City	SNG	Valley City	SNG
Treatment	Rate	Control	GI[a]	Control	GI[a]	Control		Control		Control
	oz/A	%								
Imazapic + MSO[b]	1 + 1 qt	99	1	100	8	93	67	54	69	36
Imazapic + diflu[c] + MSO	1 + 0.2 + 1 qt	99	1	99	9	94	72	75	65	49
Imazapic + diflu + MSO	1 + 0.1 + 1 qt	94	2	100	6	92	76	76	73	50
Imazapic + diflufenzopyr + MSO	1 + 0.5 + 1 qt	96	1	99	5	93	81	68	63	34
Imazapic + dicamba + diflu[d] + MSO	1 + 0.6 + 0.2 + 1 qt	92	3	99	5	87	77	32	55	8
Imazapic + dicamba + diflu[d] + MSO	1 + 0.3 + 0.1 + 1 qt	98	1	100	17	88	82	65	65	37
Imazapic + dicamba + difluf[d] + MSO	1 + 0.5 + 0.15 + 1 qt	98	5	100	8	94	56	71	50	25
Dicamba + diflu[d] + MSO	3 + 1.2 + 1 qt	70	0	99	4	3	36	5	71	0
Dicamba + diflu[d] + MSO	0.3 + 0.1 + 1 qt	85	0	88	4	0	15	0	48	0
Imazapic + MSO	2 + 1 qt	99	6	100	24	96	94	74	73	57
Picloram + 2,4-D	8 + 16	99	2	99	9	41	56	8	78	3
LSD (0.05)		15	5	7	9	11	22	27	22	28

[a] Grass injury.

[b] MSO = methylated seed oil, Scoil by AGSCO, Grand Forks, ND.

[c] Diflu = difllufenzopyr.

[d] Commercial formulation - Distinct by BASF, Research Triangle Park, NC.

Table 4. Leafy spurge control with imazapic applied alone or with quinclorac or quinclorac plus diflufenzopyr on the Sheyenne National Grassland (SNG) and near Valley City, North Dakota in September 2002.

		Location/Time after treatment							
		9 MAT[a]				12 MAT		21 MAT	
		SNG		Valley City		SNG	Valley City	SNG	Valley City
Treatment	Rate	Control	GI[b]	Control	GI[b]	Control		Control	
	—— oz/A ——	—— % ——							
Imazapic + MSO[c]	1 + 1 qt	95	7	99	6	93	89	74	80
Imazapic + diflufenzopyr + MSO	1 + 0.1 + 1 qt	90	9	99	8	79	90	27	76
Imazapic + quinclorac + MSO	1 + 2 + 1 qt	96	3	100	9	94	91	68	85
Imazapic + quinclorac + MSO	1 + 4 + 1 qt	97	7	100	11	92	93	72	69
Imazapic + quinclorac + diflufenzopyr + MSO	1 + 2 + 0.1 + 1 qt	93	6	99	9	90	94	62	76
Imazapic + quinclorac + diflufenzopyr + MSO	1 + 4 + 0.1 + 1 qt	96	7	99	3	84	91	48	81
Imazapic + dicamba + diflufenzopyr[c] + quinclorac + MSO	1 + 0.5 + 0.15 + 3 + 1 qt	99	16	100	6	89	92	76	87
Quinclorac + diflufenzopyr + MSO	2 + 0.1 + 1 qt	71	0	99	1	68	72	35	62
Quinclorac + diflufenzopyr + MSO	4 + 0.1 + 1 qt	89	2	99	1	63	90	41	82
Quinclorac + MSO	4 + 1 qt	87	0	99	0	61	78	33	74
Quinclorac + dicamba + diflufenzopyr[d] + MSO	8 + 6 + 3 + 1 qt	98	2	99	1	64	97	28	83
Picloram + 2,4-D	8 + 16	99	4	99	2	72	74	37	73
LSD (0.05)		7[e]	6	NS	7	16	8	30	NS

[a] Months after treatment.
[b] Grass injury.
[c] Methylated seed oil was Scoil by AGSCO, Grand Forks, ND
[d] Commercial formulation - Distinct by BASF Research Triangle Park, NC.
[e] LSD (0.10).

Leafy spurge control with imazapic combined with picloram plus 2,4-D or at reduced rates. Rodney G. Lym. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Research at North Dakota State University has shown that imazapic fall-applied provides good leafy spurge control but can injure grass, especially cool-season species. Also, imazapic spring-applied with picloram plus 2,4-D generally provides better leafy spurge control than picloram plus 2,4-D applied alone. The purpose of this study was to evaluate the optimum rate of imazapic applied alone or with picloram plus 2,4-D for leafy spurge control.

The first study was established at the Albert Ekre Research Center near Walcott and near Valley City, ND on June 20, 2002 to evaluate leafy spurge control with reduced rates of imazapic plus picloram plus 2,4-D in the spring. Leafy spurge was in the true-flower growth stage when treatments were applied with a hand-held sprayer delivering 8.5 gpa at 35 psi. The experiment was a randomized complete block design with four replicates and plots were 10 by 30 feet at both locations. Control was based on a visual estimate of percent stand reduction as compared to the untreated check.

The combination treatment of imazapic plus picloram plus 2,4-D provided better leafy spurge control than the herbicides applied alone (Table 1). For instance, leafy spurge control with picloram plus 2,4-D 12 and 15 MAT averaged 81 and 36% at Walcott, but when applied with imazapic control averaged 96 and 69%. Control was similar whether or not 28% N or 2,4-D were included in the treatment. Previous research at North Dakota State University had shown leafy spurge control declined when the imazapic rate was reduced to less than 1 oz/A in combination with picloram plus 2,4-D. However, in this study control was similar regardless of the imazapic application rate. Leafy spurge began to increase in density at Walcott 24 MAT regardless of treatment and control was poor regardless of treatment 27 MAT. Leafy spurge control at Valley City was variable, not only between treatments but between observation dates, and may have been influenced by *Aphthona* spp. flea beetle biocontrol agents.

The second study was established at four locations in North Dakota to evaluate leafy spurge control and grass injury from imazapic at 1 to 3 oz/A applied in the fall. Herbicides were applied on September 10, 2002 at Jamestown and Valley City and on September 11, 2002 near Walcott and on the Sheyenne National Grassland (SNG). Leafy spurge was in the fall regrowth stage and 18 to 26 inches tall at all locations. Plots were 10 by 30 feet and replicated four times at all locations, plots at Valley City were 8 by 30 feet.

Leafy spurge control 9 MAT was 99% averaged across all locations regardless of imazapic rate (Table 2). However, grass injury increased as the imazapic rate increased and averaged 29% with imazapic at 3 oz/A. Leafy spurge control increased from 74 to 93% 12 MAT as the imazapic rate increased from 1 to 3 oz/A. Grass injury was negligible 12 MAT regardless of imazapic application rate. Leafy spurge control 12 MAT was similar when imazapic was applied at 2 or 3 oz/A at three of the four study locations but grass injury was much less at the lower rate.

Leafy spurge control averaged 76 to 85% 21 MAT with imazapic at 2 to3 oz/A but declined as the application rate declined at all locations (Table 2). Control varied by location. For instance, leafy spurge control with imazapic at 2 oz/A ranged from 91% 21 MAT at Walcott to 66% at the SNG. In general, long-term leafy spurge control was better with imazapic compared to picloram plus 2,4-D when imazapic was applied at 2 oz/A or more. No treatment provided acceptable leafy spurge control 24 MAT regardless of location.

In summary, long-term leafy spurge control from a June-applied treatment was improved when imazapic was applied with picloram. The addition of 28% N or 2,4-D to the imazapic plus picloram treatment did not affect leafy spurge control. In general, imazapic at 2 oz/A fall-applied provided similar leafy spurge control to imazapic at 2.5 and 3 oz/A but caused less grass injury and would be a more cost-effective treatment.

Table 1. Leafy spurge control with various combinations of imazapic plus picloram plus 2,4-D applied in June 2002 at Walcott and Valley City, ND.

		Location / time after treatment						
		2 MAT[1]		12 MAT		15 MAT	24 MAT	27 MAT
Treatment	Rate	Walcott	Valley City	Walcott	Valley City	Walcott	Walcott	Walcott
	——— oz/A ———	———	———	———	%	———	———	———
Picloram + 2,4-D	4 + 16	84	42	81	87	36	45	18
Imazapic + MSO[2] + 28% N	1 + 1 qt + 1 qt	69	26	92	74	50	68	35
Picloram + 2,4-D + imazapic + MSO[2] + 28% N	4 + 16 + 1 + 1 qt + 1 qt	96	58	98	59	71	73	41
Picloram + 2,4-D + imazapic + MSO[2]	4 + 16 + 1 + 1 qt	93	61	93	66	66	73	18
Picloram + imazapic + MSO	4 + 1 + 1 qt	98	72	98	94	70	76	41
Picloram + imazapic + MSO	4 + 0.75 + 1 qt	89	69	90	86	57	68	25
Picloram + imazapic + MSO	4 + 0.5 + 1 qt	97	56	95	93	69	80	44
Picloram + imazapic + MSO	2 + 1 + 1 qt	98	59	97	74	72	85	56
Picloram + imazapic + MSO	2 + 0.75 + 1 qt	85	53	88	90	54	66	21
LSD (0.05)		9	17	9	14[3]	21[3]	19[3]	NS

[1] Months after treatment.

[2] Methylated seed oil was Scoil by AGSCO, Grand Forks, ND.

[3] LSD (0.10).

Table 2. Leafy spurge control with imazapic at various rates applied in September 2002 at Walcott, Jamestown, Valley City, and the Sheyenne National Grassland (SNG), ND

		9 months after treatment										12 months after treatment						
		Walcott		Jamestown		Valley City		SNG		Mean[2]		Walcott	Jamestown		Valley City	SNG	Mean[2]
Treatment	Rate	Cont.[1]	GI[1]	Cont.	GI	Cont.	GI	Cont.	GI	Cont.	GI	Cont.	Cont.	GI	Cont.	Cont.	Cont.
	— oz/A —	%															
Imazapic + MSO[3]	3 + 1 qt	100	22	100	33	100	33	99	13	100	29	99	83	6	95	96	93
Imazapic + MSO[3]	2.5 + 1 qt	100	17	99	13	99	23	96	8	99	18	97	80	4	90	91	90
Imazapic + MSO[3]	2 + 1 qt	100	16	99	12	100	17	93	6	99	15	95	63	3	95	94	87
Imazapic + MSO[3]	1.5 + 1 qt	100	7	99	11	100	11	94	6	99	10	87	58	3	78	88	78
Imazapic + MSO[3]	1 + 1 qt	100	3	99	1	100	10	88	1	99	4	66	73	1	73	84	74
Picloram + 2,4-D	8 + 16	100	5	99	2	100	0	97	1	99	2	45	81	0	76	48	62
LSD (0.05)		NS	8	NS	12	NS	14	NS	4	NS	7	20	15	NS	15	20	8.5

[1] Cont. = control; GI = grass injury.
[2] Does not include the SNG data.
[3] MSO = Methylated seed oil, Scoil by AGSCO, Grand Forks, ND.

Table 2 cont. Leafy spurge control with imazapic at various rates applied in September 2002 at Walcott, Jamestown, Valley City, and the Sheyenne National Grassland (SNG), ND

		21 months after treatment					24 months after treatment		
		Walcott	Jamestown	Valley City	SNG	Mean	Walcott	SNG	Mean
Treatment	Rate	Cont[1].	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.	Cont.
	— oz/A —	%							
Imazapic + MSO[2]	3 + 1 qt	95	67	92	86	85	77	67	72
Imazapic + MSO	2.5 + 1 qt	88	90	82	67	82	49	50	49
Imazapic + MSO	2 + 1 qt	91	71	77	66	76	46	46	46
Imazapic + MSO	1.5 + 1 qt	85	76	71	58	73	42	19	30
Imazapic + MSO	1 + 1 qt	57	63	50	55	56	11	25	18
Picloram + 2,4-D	8 + 16	58	92	82	16	62	20	11	15
LSD (0.05)		28	29	14	29	14	37	32	23

[1] Control.
[2] MSO = Methylated seed oil, Scoil by AGSCO, Grand Forks, ND.

Canada thistle control with clopyralid applied alone or with 2,4-D or triclopyr in the spring or fall. Rodney G. Lym. (Plant Science Department, North Dakota State University, Fargo, ND 58105). Clopyralid is considered one of the best herbicides available for long-term Canada thistle control in pasture, rangeland, and wildlands. Until recently, clopyralid was only available pre-mixed with 2,4-D or triclopyr for non-cropland use in North Dakota even though clopyralid applied alone often provided better long-term Canada thistle control than the premixes. The purpose of this research was to evaluate clopyralid applied alone or with 2,4-D or triclopyr in the spring or fall for long-term Canada thistle control.

The experiment was established at two locations on non-grazed land managed by the U.S. Army Corp. of Engineers near Valley City and Jamestown, ND. Spring herbicides treatments were applied on June 25 and June 26, 2002 at Jamestown and Valley City, respectively when Canada thistle was in the rosette to early bolt growth stage. Fall herbicide treatments were applied in separate experiments on Sept. 25, 2002 at both locations after Canada thistle had flowered and rosettes were present. The herbicides were applied using a hand-held boom sprayer delivering 17 gpa at 35 psi. The plots were 10 by 30 feet and replicated four times in a randomized complete block design at both locations. Control was based on a visual estimate of percent stand reduction as compared to the untreated check.

Canada thistle control at Jamestown was better than at Valley City and data could not be combined over locations (Tables 1 and 2). Although not directly comparable, Canada thistle control 12 MAT (months after treatment) was much better when herbicides were applied in the fall (Table 2) compared to the same treatments applied in the spring (Table 1). Picloram applied at 6 oz/A in the spring tended to provide the best Canada thistle control at Jamestown compared to all other spring applied treatments and averaged 79% 12 MAT. The same treatment only averaged 10% control at Valley City (Table 1). No treatment provided satisfactory Canada thistle control 25 MAT although clopyralid applied alone at 6.4 oz/A tended to provide better control than clopyralid applied with 2,4-D or triclopyr.

Clopyralid applied alone or with triclopyr in the fall provided similar Canada thistle control, but control generally declined when clopyralid was applied with 2,4-D at comparable rates (Table 2). For instance, clopyralid applied alone at 4.8 oz/A provided 88 and 91% Canada thistle control at Valley City and Jamestown, respectively, 12 MAT, but control declined to 48 and 80%, respectively, when clopyralid at 4.8 oz/A was applied with 2,4-D. Control also tended to decline when clopyralid at 6.4 oz/A was applied with 2,4-D compared to clopyralid at 6.4 oz/A alone 12 MAT. The most cost-effective treatment evaluated ($16/A) was picloram at 6 oz/A which provided 98 and 76% Canada thistle control 12 and 21 MAT, respectively, averaged over both locations. Clopyralid plus triclopyr at 6 + 18 oz/A and clopyralid alone at 6.4 oz/A provided an average of 92 and 61% control 12 and 21 MAT, respectively, but cost about $33 to $43/A.

In summary, picloram at 6 oz/A applied in the fall is a cost-effective treatment for Canada thistle control. In areas where picloram cannot be used, clopyralid plus triclopyr provided acceptable Canada thistle control, but was twice as expensive as the picloram treatment. Clopyralid applied alone generally provided better long-term Canada thistle control than clopyralid applied with 2,4-D at comparable application rates.

Table 1. Canada thistle control with clopyralid applied alone or with 2,4-D or triclopyr in June 2002 at two locations in North Dakota.

		Location / time after treatment				
		2 MAT[a]		12 MAT		25 MAT
Treatment	Rate	Valley City	James-town	Valley City	James-town	James-town
	—— oz/A ——	——	——	%	——	——
Clopyralid	2.4	36	30	6	30	5
Clopyralid	4.8	75	80	10	48	0
Clopyralid	6.4	82	82	10	31	38
Clopyralid + 2,4-D[b]	4.8 + 25.5	85	82	8	58	19
Clopyralid + 2,4-D[b]	6.4 + 33.6	86	88	10	45	19
Clopyralid + triclopyr[c] + X-77	4.5 + 13.5 + 0.25%	74	74	8	25	8
Clopyralid + triclopyr[c] + X-77	6 + 18 + 0.25%	73	81	4	44	19
Picloram	6	89	90	10	79	33
LSD (0.05)		11	9	NS	29	NS

[a] Months after treatment.

[b] Commercial formulation - Curtail by Dow AgroSciences Indianapolis, IN.

[c] Commercial formulation - Redeem by Dow AgroSciences Indianapolis, IN.

Table 2. Canada thistle control with clopyralid applied alone or with 2,4-D or triclopyr in September 2002 at two locations in North Dakota.

		Location / time after treatment					
		9 MAT[a]		12 MAT		21 MAT	
Treatment	Rate	Valley City	James-town	Valley City	Jame s-town	James-town	Valley City
	oz/A	%					
Clopyralid	2.4	96	99	43	85	72	58
Clopyralid	4.8	98	99	88	91	65	75
Clopyralid	6.4	98	99	89	95	80	79
Clopyralid + 2.4-D[b]	4.8 + 25.5	96	99	48	80	43	66
Clopyralid + 2,4-D[b]	6.4 + 33.6	98	99	72	87	46	71
Clopyralid + triclopyr[c] + X-77	4.5 + 13.5 + 0.25%	97	99	80	94	67	71
Clopyralid + triclopyr[c] + X-77	6 + 18 + 0.25%	97	99	90	93	72	76
Picloram	6	98	99	97	99	92	76
LSD (0.05)		NS	NS	25	10	31	15

[a] Months after treatment.

[b] Commercial formulation - Curtail by Dow AgroSciences, Indianapolis, IN.

[c] Commercial formulation - Redeem by Dow AgroSciences, Indianapolis, IN.

Control of Canada thistle, perennial sowthistle, fringed sage and other troublesome weeds with metsulfuron. Rodney G. Lym. (Plant Sciences Department, North Dakota State University, Fargo, ND 58105). Previous research at North Dakota State University found that metsulfuron controls some troublesome weeds, such as scentless chamomile (*Matricaria chamomilla* L.) and fringed sage (*Artemisia frigida* Willd.), that are difficult to control with commonly used auxin-type herbicides in pasture and rangeland. Metsulfuron is a relatively low cost alternative to these auxin-type herbicides for weed control in pasture, rangeland, and wild lands. The purpose of this research was to evaluate metsulfuron applied alone and in combination with other herbicides for control of several noxious and troublesome weeds.

The first experiment was established on fallow cropland near Fargo to evaluate metsulfuron applied alone or with thifensulfuron plus tribenuron at cropland use rates for perennial sowthistle (*Sonchus arvensis* L.) and Canada thistle (*Cirsium arvense* L.) control. Treatments were applied on June 20, 2002, using a hand-held boom sprayer delivering 17 gpa at 35 psi. The plots were 9 by 25 feet and replicated four times in a randomized complete block design. Control was based on a visual estimate of percent stand reduction as compared to the untreated check. Perennial sowthistle and Canada thistle were in the rosette growth stage with 4 to 10 leaves.

Metsulfuron provided nearly complete control of perennial sowthistle through 27 MAT (months after treatment) regardless of application rate (Table 1). Metsulfuron at 0.06 oz/A costs less than $1.50/A and could be used in cropland to control perennial sowthistle. Canada thistle control was similar regardless of metsulfuron rate or the addition of thifensulfuron plus tribenuron and averaged 74% control 15 MAT compared to 43% control with clopyralid plus 2,4-D. Canada thistle control 24 MAT declined to 40% or less regardless of treatment.

The second experiment was established to evaluate long-term perennial sowthistle and Canada thistle control with metsulfuron applied alone. Metsulfuron rates were increased 10-fold compared to the first study. Herbicides were applied on June 2, 2003 as previously described except the plots were 10 by 30 feet. The weed species evaluated were in the rosette growth stage. Again, metsulfuron provided near complete control of perennial sowthistle but did not provide long-term Canada thistle control (Table 2).

The third experiment was established to evaluate common burdock [*Arctium minus* (Hill) Bernh.] control by metsulfuron. Herbicides were applied on June 11, 2003, when common burdock was 10 to 12 inches tall with 6 to 8 leaves. The experiment was located in a moist wooded area near Walcott, ND. The plots were 9 by 30 feet with three replicates.

Common burdock control only averaged 65% 1 MAT with metsulfuron and the commonly used combination of clopyralid plus 2,4-D, but by 3 MAT control improved to an average of 93% (Table 3). All treatments provided nearly complete control 12 MAT but only clopyralid plus 2,4-D controlled common burdock by the end of the second season after treatment (97%). Common burdock by 15 MAT was regrowing from seed with all metsulfuron treatments.

The fourth experiment was established to evaluate absinth wormwood (*Artemisia absinthium* L.) control with metsulfuron. The experiment was established in a very dense absinth wormwood stand near Jamestown, ND, on June 4, 2003. Herbicides were applied as previously described when absinth wormwood was beginning to bolt and 12 to 24 inches tall. The plots were 10 by 30 feet, and treatments were replicated four times in a randomized complete block design. Metsulfuron did not control absinth wormwood regardless of rate (Table 4). The standard treatment of picloram at 2 to 4 oz/A provided complete absinth wormwood control for 12 MAT.

In summary, metsulfuron alone controlled perennial sowthistle for several seasons and would be a very cost-effective treatment in pasture, rangeland, and cropland. Metsulfuron provided good common burdock control for 1 yr, but would need to be reapplied to control seedlings. Metsulfuron provided relatively short-term Canada thistle control but did not control absinth wormwood.

Table 1. Control of perennial sowthistle and Canada thistle by metsulfuron alone and with other herbicides applied in June 2002, at Fargo, ND.

		Time after treatment/weed species								
		1 MAT[1]		12 MAT		15 MAT		24 MAT		27 MAT
Treatment[2]	Rate	PEST[1]	CT[1]	PEST	CT	PEST	CT	PEST	CT	PEST
	oz/A	%								
Metsulfuron	0.06	100	87	99	84	98	80	96	40	93
Metsulfuron	0.075	94	83	97	71	99	74	95	39	93
Metsulfuron	0.15	98	91	97	81	95	75	97	33	86
Metsulfuron	0.3	100	94	96	85	99	78	96	38	96
Metsulfuron + thifensulfuron + tribenuron[3]	0.03 + 0.075 + 0.037	97	85	96	80	92	70	95	35	86
Metsulfuron + thifensulfuron + tribenuron[3]	0.06 + 0.15 + 0.074	99	81	98	68	99	68	95	28	89
Clopyralid + 2,4-D[4]	1.52 + 8	96	76	94	73	65	43	73	30	66
Glyphosate	6	65	24	55	10	43	0	82	8	79
LSD (0.05)		9	12	10	18	34	28	21	NS	17[5]

[1] Abbreviations: MAT = months after treatment; PEST = perennial sowthistle; CT = Canada thistle.
[2] Surfactant X-77 at 0.25% was applied with all treatments, Loveland Industries, Greeley, CO.
[3] Thifensulfuron + tribenuron was a commercial formulation - Harmony Extra by DuPont, Wilmington, DE.
[4] Commercial formulation - Curtail by Dow AgroSciences, Indianapolis, IN.
[5] LSD = 0.10.

Table 2. Control of perennial sowthistle and Canada thistle by metsulfuron applied in June 2003.

		2 MAT[1]		3 MAT		12 MAT	
Treatment[2]	Rate	CT	PEST	CT	PEST	CT	PEST
	—— oz/A ——	—————— % control ——————					
Metsulfuron + X-77	0.3 + 0.25%	99	99	60	93	23	83
Metsulfuron + X-77	0.45 + 0.25%	99	99	61	99	3	100
Metsulfuron + X-77	0.6 + 0.25%	99	99	80	99	16	80
Metsulfuron + X-77	0.9 + 0.25%	99	99	91	100	8	100
Metsulfuron + X-77	1.2 + 0.25%	100	100	98	100	46	99
Metsulfuron + X-77	1.8 + 0.25%	99	99	99	100	50	100
Clopyralid + 2,4-D[3]	3 + 16	96	98	63	95	83	80
LSD (0.10)		NS	NS	NS	NS	47	NS

[1] Abbreviations: MAT = months after treatment; PEST = perennial sowthistle; CT = Canada thistle.
[2] Surfactant X-77 at 0.25% was applied with all treatments, Loveland Industries, Greeley, CO.
[3] Commercial formulation - Curtail by Dow AgroSciences, Indianapolis, IN.

Table 3. Common burdock control with metsulfuron applied in June 2003 in a wooded area near Walcott, ND.

		Time after treatment			
Treatment[1]	Rate	1 MAT[2]	3 MAT	12 MAT	15 MAT
	—— oz/A ——	—————— % control ——————			
Metsulfuron	0.3	62	88	100	50
Metsulfuron	0.45	58	91	100	3
Metsulfuron	0.6	76	98	97	48
Metsulfuron	0.9	63	97	100	32
Metsulfuron	1.2	70	91	100	49
Metsulfuron	1.8	72	95	100	36
Clopyralid + 2,4-D[3]	3 + 16	53	88	100	97
LSD (0.05)		NS	NS	NS	52

[1] Surfactant X-77 at 0.25% was applied with all metsulfuron treatments, Loveland Industries, Greeley, CO.
[2] Abbreviation: MAT = months after treatment.
[3] Commercial formulation - Curtail by Dow AgroSciences, Indianapolis, IN.

Table 4. Absinth wormwood control with metsulfuron applied in June 2003 near Jamestown, ND.

		Time after treatment		
Treatment	Rate	1 MAT[1]	3 MAT	12 MAT
	—— oz/A ——	% injury	—— % control ——	
Metsulfuron + X-77[2]	0.6 + 0.25%	18	0	0
Metsulfuron + X-77	0.9 + 0.25%	23	8	0
Metsulfuron + X-77	1.2 + 0.25%	21	0	0
Metsulfuron + X-77	1.8 + 0.25%	29	0	0
Picloram	2	86	99	100
Picloram	4	96	99	100
LSD (0.05)		1	3	1

[1] Abbreviation: MAT = months after treatment.
[2] X-77 - Loveland Industries, Greeley, CO.

General pasture weed control with metsulfuron applied with dicamba plus 2,4-D. Rodney G. Lym. (Plant Sciences Department, North Dakota State University, Fargo, ND 58105). Many pastures in North Dakota are commonly over-grazed for at least a short time during the growing season. Overgrazing has led to invasion by both introduced and native weedy species that establish once grazing pressure is reduced. Most land managers do not commit much money to weed control in pasture and rangeland unless a portion of the cost is reimbursed by the state. However, the state cost-share program is usually confined to state-listed invasive weeds. Thus, a low cost-high return treatment program is required if non-noxious weeds are treated. The purpose of this study was to evaluated metsulfuron applied in combination with dicamba plus 2,4-D for general weed control in pasture.

The experiment was established on the Albret Ekre Research Station near Walcott, ND in a spring holding pasture. This pasture is heavily grazed for 2 to 3 weeks each May, then left idle the remainder of the year. A variety of weedy species were present in the pasture including bull thistle, Canada thistle, golden rod, horseweed, oxalis, sweet clover, green sage, vervain, and western snowberry (buckbrush). Treatments were applied on June 26, 2002 using a hand-held boom sprayer delivering 17 gpa at 35 psi. The plots were 15 by 40 feet and replicated four times in a randomized complete block design. Weeds were generally 6 to 12 inches tall and delayed in growth compared to those in non-grazed nearby pastures. Control was based on a visual estimate of percent stand reduction as compared to the untreated check. No single species was present in all plots, so a general weed control evaluation was made.

		2 MAT[1]		3 MAT		12 MAT	15 MAT
Treatment	Rate	General	Grass	General	Grass	General	General
	—— oz/A ——	% control					
Metsulfuron + dicamba + 2,4-D[2] + Premier 90	0.15 + 2 + 5.8 + 0.25%	95	9	99	10	100	93
Metsulfuron + dicamba + 2,4-D[2] + Premier 90	0.3 + 4 + 11.5 + 0.25%	97	6	99	11	98	87
Metsulfuron + 2,4-D + Premier 90	0.15 + 16 + 0.25%	94	4	99	11	100	95
Clopyralid + 2,4-D[3]	1.4 + 8	90	0.7	95	3	95	87
LSD (0.05)		NS	6	NS	NS	NS	NS

[1] Months after treatment.
[2] Commercial formulation - Range Star by DuPont, Wilmington, DE.
[3] Commercial formulation - Curtail by Dow AgroSciences, Indianapolis, IN.

Metsulfuron plus dicamba plus 2,4-D provided excellent general broadleaf weed control with an average of 92% 15 MAT (Table). Metsulufuron slightly injured smooth brome grass, but the injury was short-lived. Clopyralid plus 2,4-D also provided near complete weed control and did not injure bromegrass. Metsulfuron applied with dicamba plus 2,4-D at 0.15 + 2 + 5.8 oz/A would cost about $6.50/A and would be a cost-effective alternative to clopyralid plus 2,4-D at 1.4 + 8 oz/A which cost approximately $11/A.

Very late-season Russian knapweed control with various herbicides. Rodney G. Lym. (Plant Sciences Department, North Dakota State University, Fargo, ND 58105). Russian knapweed (*Acroptilon repens* L.) is an invasive perennial weed that is very difficult to control with herbicides. Recently, research in Wyoming and Colorado found that herbicides applied very late in the growing season to Russian knapweed following several hard frosts provided greater than 85% control for several seasons (Arnold et al. 2002, WSWS Res. Prog. Rep. p. 3; Whitson and Rose 1999, WSWS Res. Prog. Rep. p. 3; Whitson and Ferrell 2002, WSWS Res. Prog. Rep. p. 2). Similar treatments applied to Russian knapweed in September in North Dakota provided less than 40% control 1 yr after treatment (Lym and Christianson 2002, WSWS Res. Prog. Rep. p. 4-5). The purpose of this research was to evaluate Russian knapweed control with various herbicides applied after a killing frost in North Dakota.

The experiment was established in the South Unit of Theodore Roosevelt National Park near Medora, ND, on October 8, 2002. Russian knapweed plants were 24 to 30 inches tall, and the stems were yellow to grey in color and appeared dormant. The minimum air temperature had reached 29 F or lower five times prior to herbicide application, including three consecutive mornings immediately prior to treatment. The herbicides were applied using a hand-held boom sprayer delivering 8.5 gpa at 35 psi. The plots were 10 by 25 feet and replicated three times in a randomized complete block design. The air temperature was 48 F, with a 43 F dew point, and soil temperature at the 4 inch depth was 46 F.

Picloram at 6 oz/A provided near complete Russian knapweed control 21 MAT (months after treatment) with little to no visible grass injury (Table). Control declined to 76% by 24 MAT as Russian knapweed began to spread into the treated area from adjacent plots. Clopyralid applied alone or with triclopyr provided an average of 93% Russian knapweed control 12 MAT and control at 21 and 24 MAT gradually declined to 84 and 66%, respectively. Picloram plus clopyralid plus 2,4-D at 4 + 3 + 16 oz/A provided similar long-term Russian knapweed control to picloram at 6 oz/A applied alone. Imazapic at 3 oz/A provided 100% control through 10 MAT but suppressed grass production, and Russian knapweed control at 12 and 21 MAT declined to 79 and 15%, respectively. Metsulfuron applied with dicamba and 2,4-D did not provide season-long Russian knapweed control and grass injury 8 MAT averaged 30%. Quinclorac only provided short-term Russian knapweed control. Very late-season treatments that contained picloram or clopyralid cost approximately $15 to $30/A at the rates used in this study and could be used to control Russian knapweed in a variety of environments.

Table. Russian knapweed control with various herbicides applied after a killing frost in North Dakota.

		Control							
		8 MAT[1]		10 MAT		12 MAT		21 MAT	24 MAT
Treatment	Rate	RUKW[1]	GI[1]	RUKW	GI	RUKW	GI	RUKW	RUKW
	—— oz/A ——	—————— % ——————							
Picloram	6	100	0	100	0	91	3	99	76
Clopyralid	4	100	3	99	0	94	0	82	58
Clopyralid + triclopyr[2]	6 + 1.1	98	0	97	0	92	1	86	74
Picloram + clopyralid + 2,4-D[3]	4 + 3 + 16	100	13	100	7	96	3	98	72
Imazapic + MSO[4]	3 + 1 qt	100	27	100	21	79	3	15	38
Metsulfuron + dicamba + 2,4-D[5] + MSO[4]	0.6 + 8 + 23 + 1 qt	100	30	97	22	66	17	39	41
Quinclorac + MSO[3]	8 + 1 qt	97	0	30	0	30	0	0	15
LSD (0.05)		NS	19	36	17	29[6]	NS	30	32

[1] Abbreviations: MAT = Months after treatment, RUKW = Russian knapweed, GI = grass injury.

[2] Commercial formulation - Redeem by Dow AgroSciences, Indianapolis, IN.

[3] Commercial formulation - Curtail by Dow AgroSciences, Indianapolis, IN.

[4] MSO is methylated seed oil, Scoil by AGSCO, Grand Forks, ND.

[5] Commercial formulation - Range Star by DuPont, Wilmington, DE.

[6] LSD (0.15).

Evaluation of pre- and post-emergence herbicides for kochia control in non-cropland. Rodney G. Lym. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Kochia is a common weed problem on industrial sites such as railroad right-of-ways, electrical substations, and parking areas. Recently, kochia populations resistant to commonly used herbicides on railroad right-of-ways have rapidly increased. Kochia once easily controlled by diuron or fluoxypyr for instance, has become resistant to these and related herbicides. The purpose of this research was to evaluate herbicides commonly used in cropland to control kochia at increased rates for use on non-cropland sites.

The experiment was established near Fargo, ND on research land that had not been cropped for 8 yr. Paraquat at 1.5 lb/A was applied over the entire experiment site on April 29, 2004 to control a variety of broadleaf weeds including field pennycress, prickly lettuce, and some kochia which had emerged under a late-season snow cover. Pre-emergence herbicides were applied on May 1, 2004 to bare ground while post-emergent treatments were applied on July 1 when the kochia was 1 to 3 inches tall. The long delay between the pre- and post-emergent treatments was caused by much colder than average temperatures and frequent rainfall which delayed kochia emergence. Treatments were applied with a hand-held sprayer delivering 8.5 gpa at 35 psi. The experiment was a randomized complete block design with five replicates and plots were 10 by 25 feet. Control was based on a visual estimate of percent kochia reduction as compared to the untreated check.

		Evaluations/date				
Treatment	Rate	7 DAT[1]	14 DAT	30 DAT	60 DAT	90 DAT
Pre-emergence 1 May 2004	—— oz/A ——			% control		
Sulfentrazone	6	80	80	100	100	99
Sulfometuron	2.25	40	40	34	18	18
Diuron	104	78	83	100	97	97
Sulfentrazone + sulfometuron	6 + 2.25	70	80	100	100	99
Diuron + sulfometuron	104 + 2.25	90	90	100	100	99
Flumioxazin	5.1	70	70	82	100	99
LSD (0.05)		NS	NS	27	22	22
Post-emergence 1 July 2004						
Carfentrazone + MSO[2]	0.5 + 1 qt/A	39	62	98	99	
Glyphosate[3] + MSO	16 + 1 qt/A	10	65	100	99	
Glyphosate[3] + carfentrazone + MSO	16 + 0.5 + 1 qt/A	56	76	76	74	
ET-751 + MSO	0.052 + 1 qt/A	40	70	72	83	
Glyphosate[3] + ET-751 + MSO	16 + 0.026 + 1 qt/A	60	68	38	28	
Fluroxypyr + MSO	2.25 + 1 qt/A	77	92	97	97	
Bromoxynil + MSO	16 + 1 qt/A	63	95	100	100	
Oxyfluorfen	24	57	82	82	57	
LSD (0.05)		22	NS	NS	NS	

[1]Abreviation: Days after treatment.

[2]Methylated seed oil was Scoil by AGSCO, Grand Forks, ND.

[3] Commercial formulation Roundup UltraMax II by Monsanto Corp. St. Louis, MO.

All pre-emergent herbicides except sulfometuron provided season-long kochia control (Table). Sulfometuron applied with sulfentrazone or diuron provided similar kochia control to sulfentrazone and diuron applied alone. Carfentrazone, glyphosate, fluroxypyr, and bromoxynil provided excellent kochia control when applied alone to emerged kochia. However, control declined from 99 and 83% 60 DAT (days after treatment) to 74 and 28% when carfentrazone or ET-751, respectively, was applied with glyphosate. The potassium salt glyphosate formulation was used in these studies and likely caused antagonism with carfentrazone and ET-751. These two herbicides have often been applied with the ipa salt formulation of glyphosate without a loss in weed control. Several herbicides currently used in cropland in the region such as sulfentrazone or carfentrazone seem likely candidates for kochia control on non-cropland as well.