Evaluation of diflufenzopyr with auxin herbicides for leafy spurge control. Rodney G. Lym. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Previous research at North Dakota State University has shown that both initial and long-term leafy spurge control was increased when diflufenzopyr was applied with various auxin herbicides including dicamba, quinclorac, picloram, and 2,4-D. In the initial trials diflufenzopyr was applied at a ratio of 2.5:1 herbicide:diflufenzopyr. The purpose of this research was to evaluate the effect of varying the ratio of herbicide to diflufenzopyr on both short- and long-term leafy spurge control with various herbicides.

The first experiment evaluated the optimum ratio of diflufenzopyr when applied with dicamba or quinclorac. The diflufenzopyr ratio varied from the standard ratio of 2.5:1 herbicide:diflufenzopyr to 5:1 and 10:1. Experiments were established near Jamestown and Valley City, ND, in early June 1998 when leafy spurge was in the true-flower growth stage. The herbicides were applied using a hand-held boom sprayer delivering 8.5 gpa at 35 psi. The plots were 10 by 30 feet, 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.

Both initial foliar injury 1 month after treatment (MAT) and topgrowth control 3 MAT usually were higher when diflufenzopyr was applied with dicamba and quinclorac compared to the herbicide applied alone (Table 1). However, injury and control were similar regardless of diflufenzopyr rate. For instance, leafy spurge control 3 MAT with dicamba applied alone averaged 84% but increased to an average of 97% when applied with diflufenzopyr. Control with quinclorac alone averaged 78% but increased to an average of 97% when applied with diflufenzopyr. Control 3 MAT averaged 78% when diflufenzopyr was applied with glyphosate plus 2,4-D compared to 44% when the herbicide combination was applied alone.

The addition of diflufenzopyr increased long-term leafy spurge control when applied with either dicamba or quinclorac compared to the herbicides applied alone. For instance, leafy spurge control 24 MAT averaged 63% with dicamba plus diflufenzopyr, versus 39% with dicamba alone (Table 1). The increase in control was similar regardless of the dicamba:diflufenzopyr ratio. Similarly, long-term leafy spurge control 24 MAT averaged 71% when diflufenzopyr was applied with quinclorac compared to only 49% when quinclorac was applied alone. Again, the increase in control was similar regardless of the quinclorac:diflufenzopyr ratio. The addition of diflufenzopyr to glyphosate plus 2,4-D did not result in a long-term increase in leafy spurge control.

The second and third experiments were established to evaluate the optimum ratio of diflufenzopyr when applied with picloram or picloram plus 2,4-D for leafy spurge control. Diflufenzopyr was applied from 1.6 to 6.4 oz/A with picloram at 8 oz/A or picloram plus 2,4-D at 4 + 16 oz/A. Leafy spurge was in the true-flower growth stage, the air temperature was 63 F with a dew point of 57 F on June 9, 1998 when the second experiment was established. When the third experiment was established on September 15, 1998, leafy spurge was in the fall regrowth stage with approximately 15% yellow foliage, and the air temperature was 78 F with a dew point of 60 F.

Consistent with the previous experiments long-term leafy spurge control increased when diflufenzopyr was applied with picloram or picloram plus 2,4-D compared to the herbicides alone, and the increase was similar regardless of the herbicide:diflufenzopyr ratio (Tables 2 and 3). Leafy spurge control 15 MAT averaged 88 and 83% when picloram or picloram plus 2,4-D were applied with diflufenzopyr compared to 62 or 38%, respectively, when the herbicides were applied (Table 3). Control averaged 84% with picloram at 8 oz/A plus diflufenzopyr 27 MAT compared to only 31% when picloram was applied alone.

In general, long-term leafy spurge control also was increased when diflufenzopyr plus picloram or picloram plus 2,4-D was fall-applied, but the increase was erratic (Table 3). For instance, leafy spurge control 12 MAT with picloram plus 2,4-D at 4 + 16 oz/A averaged only 1% compared to a range from 36 to 65% control when the same treatment was applied with diflufenzopyr. However, there was no clear trend between the amount of diflufenzopyr applied with picloram plus 2,4-D and leafy spurge control. Leafy spurge control with picloram at 8 oz/A averaged 37% 21 MAT compared to an average of 57% when applied with diflufenzopyr.

The fourth experiment was established to further evaluate the effect of the diflufenzopyr ratio on leafy spurge control with dicamba or quinclorac. Herbicides were applied at various rates with an herbicide:diflufenzopyr ratio of 2.5:1 or 10:1. The experiment was established at two locations, in early June 1999 near Valley City when leafy spurge was in the flowering growth stage and in mid-July near Fargo when leafy spurge was in late seed-set stage.

Leafy spurge control was similar when herbicides were applied at comparable rates regardless of the diflufenzopyr ratio (Table 4). Although not directly comparable, leafy spurge control tended to be higher when the herbicides were applied during the flowering growth stage compared to the seed-set stage. Control was independent of diflufenzopyr ratio (2.5:1 or 10:1). Biological control agents became established in the plots at Valley City in 2000 so only the Fargo location could be evaluated in 2001. Control declined regardless of treatment and remained independent of diflufenzopyr ratio.

In summary, diflufenzopyr increased long-term leafy spurge control by auxin-type herbicides and the increase was independent of the herbicide:diflufenzopyr ratio. No increase in non-target plant injury, such as grass injury, was observed at any location.

Table 1. Diflufenzopyr applied at various ratios with herbicides for leafy spurge control averaged over Jamestown and Valley City locations in North Dakota.

Treatment	Rate	Foliar injury	Control/MAT[a]			
		1 MAT[a]	3	12	15	24
	——— oz/A ———	———	———	%	———	———
Dicamba + X-77 + 28% N	32 + 0.25% + 1 qt	64	84	29	25	39
Dicamba + diflufenzopyr + X-77 + 28% N	32 + 3.2 + 0.25% + 1 qt	67	94	75	58	65
Dicamba + diflufenzopyr + X-77 + 28% N	32 + 6.4 + 0.25% + 1 qt	78	99	89	57	60
Dicamba + diflufenzopyr + X-77 + 28% N	32 + 12.8 + 0.25% + 1 qt	70	98	83	59	63
Quinclorac + MSO[b]	12 + 1 qt	47	78	85	54	49
Quinclorac + diflufenzopyr + MSO[b]	12 + 1.6 + 1 qt	61	96	96	83	72
Quinclorac + diflufenzopyr + MSO[b]	12 + 3.2 + 1 qt	60	97	98	82	70
Quinclorac + diflufenzopyr + MSO[b]	12 + 4.8 + 1 qt	66	98	96	75	71
Glyphosate + 2,4-D[c]	6 + 10	88	44	31	17	30
Glyphosate + 2,4-D[c] + diflufenzopyr	6 + 10 + 6.4	84	78	53	27	31
LSD (0.05)		8	8	14	13	15

[a] Months after treatment.

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

[c] Commercial formulation - Landmaster BW.

Table 2. Leafy spurge control with picloram or picloram plus 2,4-D combined with various ratios of diflufenzopyr applied in June 1998 near Valley City, North Dakota.

		Control/MAT[a]				
Treatment	Rate	3	12	15	24	27
	— oz/A —			%		
Picloram + diflufenzopyr	8 + 1.6	99	96	85	83	79
Picloram + diflufenzopyr	8 + 3.2	99	99	88	91	88
Picloram + diflufenzopyr	8 + 4.8	99	99	90	91	87
Picloram + diflufenzopyr	8 + 6.4	99	99	89	92	83
Picloram + 2,4-D + diflufenzopyr	4 + 16 +1.6	99	90	79	81	53
Picloram + 2,4-D + diflufenzopyr	4 + 16 + 3.2	98	93	82	79	65
Picloram + 2,4-D + diflufenzopyr	4 + 16 + 4.8	99	96	85	84	80
Picloram + 2,4-D + diflufenzopyr	4 + 16 + 6.4	99	98	85	81	76
Picloram	8	92	85	62	51	31
Picloram + 2,4-D	4 + 16	80	79	38	52	40
LSD (0.05)		5	11	13	16	22

[a] Months after treatment.

Table 3. Leafy spurge control with picloram or picloram plus 2,4-D combined with various ratios of diflufenzopyr applied in September 1998 near Valley City, North Dakota.

		Control/MAT[a]		
Treatment	Rate	9	12	21
	— oz/A —		%	
Picloram + diflufenzopyr	8 + 1.6	99	66	63
Picloram + diflufenzopyr	8 + 3.2	97	44	34
Picloram + diflufenzopyr	8 + 4.8	99	83	70
Picloram + diflufenzopyr	8 + 6.4	99	74	60
Picloram + 2,4-D + diflufenzopyr	4 + 16 +1.6	88	36	20
Picloram + 2,4-D + diflufenzopyr	4 + 16 + 3.2	93	65	43
Picloram + 2,4-D + diflufenzopyr	4 + 16 + 4.8	95	45	34
Picloram + 2,4-D + diflufenzopyr	4 + 16 + 6.4	95	40	31
Picloram	8	88	53	37
Picloram + 2,4-D	4 + 16	45	1	0
LSD (0.05)		12	26	22

[a] Months after treatment.

Table 4. Leafy spurge control with dicamba and quinclorac combined with various ratios of diflufenzopyr applied in June 1999 at Valley City, during the flowering growth stage or in July 1999 during seed-set at Fargo, North Dakota.

Treatment	Rate	1999 September Valley City	1999 September Fargo	2000 June Valley City	2000 June Fargo	2000 Aug Fargo	2001 June Fargo	2001 Aug Fargo
	lb/A	% control						
Dicamba + diflufenzopyr + X-77	2 + 0.2 + 0.25%	99	96	94	94	87	91	60
Dicamba + diflufenzopyr + X-77	2 + 0.8 + 0.25%	100	97	98	91	83	85	57
Dicamba + diflufenzopyr + X-77	1 + 0.1 + 0.25%	96	94	87	90	86	81	53
Dicamba + diflufenzopyr + X-77	1 + 0.4 + 0.25%	98	88	74	67	60	51	23
Dicamba + diflufenzopyr + X-77	0.5 + 0.05 + 0.25%	90	85	73	60	46	31	16
Dicamba + diflufenzopyr + X-77	0.5 + 0.2 + 0.25%	89	83	45	64	28	21	10
Quinclorac + diflufenzopyr + MSO[a]	0.75 + 0.075 + 1 qt	98	94	95	87	72	55	25
Quinclorac + diflufenzopyr + MSO[a]	0.75 + 0.3 + 1 qt	99	95	97	83	77	65	51
Quinclorac + diflufenzopyr + MSO[a]	0.5 + 0.05 + 1 qt	99	98	97	59	31	23	9
Quinclorac + diflufenzopyr + MSO[a]	0.5 + 0.20 + 1 qt	98	97	97	86	73	56	38
Quinclorac + diflufenzopyr + MSO[a]	0.25 + 0.025 + 1 qt	96	93	76	80	54	43	26
Quinclorac + diflufenzopyr + MSO[a]	0.25 + 0.10 + 1 qt	98	96	92	58	29	35	21
Diflufenzopyr + X-77	0.10 + 0.25%	0	0	0	14	0	0	0
Diflufenzopyr + X-77	0.20 + 0.25%	0	0	26	12	0	0	0
Diflufenzopyr + X-77	0.40 + 0.25%	0	0	0	8	0	0	0
Diflufenzopyr + X-77	0.80 + 0.25%	0	5	54	10	0	3	0
Picloram + 2,4-D	0.5 + 1	99	94	97	55	37	14	0
LSD (0.05)		4	8	32	21	29	34	25

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

Leafy spurge control with imazapic combined or alternated with picloram plus 2,4-D or quinclorac and dicamba. Rodney G. Lym. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Research at North Dakota State University has shown that imazapic provides good leafy spurge control when fall-applied but can injure grass, especially cool-season species. Thus, picloram plus 2,4-D may need to be applied in years alternating with imazapic to reduce grass injury from imazapic in a long-term management program. The purpose of this research was to evaluate imazapic applied alone, in rotation with picloram plus 2,4-D, or the three herbicides applied together for long-term leafy spurge control.

The first experiment was established at Jamestown and Valley City, North Dakota, in a dense stand of leafy spurge. Initial herbicide treatments were applied in early June 1998 during the true-flower growth stage or in mid-September when leafy spurge was in the fall regrowth stage. Initial treatments of imazapic were followed by picloram plus 2,4-D. Conversely, initial treatments of picloram plus 2,4-D were followed by imazapic. Imazapic was applied at 1 oz/A in the spring or 2 oz/A in the fall. Picloram plus 2,4-D was applied at the common use rate of 4 + 16 oz/A in the spring or 8 + 16 oz/A in the fall. The three-way mixture of picloram plus 2,4-D plus imazapic was applied once in the spring or fall with no follow-up treatment. Any treatment that included imazapic also contained methylated seed oil plus 28% N liquid fertilizer.

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 replications at both locations, and plots were 10 by 30 feet. Control was based on a visual estimate of percent stand reduction as compared to the untreated check.

The three-herbicide mixture of picloram plus 2,4-D plus imazapic applied once in the spring provided the best long-term leafy spurge control (Table 1). Control averaged across locations was 99% in June 2000, 24 MAT (months after treatment). This high level of control was unexpected and is better than the long-term average of picloram at 32 oz/A applied alone, which generally provides the best long-term control in the region. The same three-herbicide treatment applied in the fall only averaged 61 and 15% control 12 and 24 MAT, respectively.

During the summer of 2000, *Aphthona* spp. biological control agents were found in the research plots at both Valley City and Jamestown. The insect population rapidly increased at the Valley City location so that by June 2001, very few leafy spurge stems remained and the experiment could not be reevaluated. At Jamestown, the three-way mixture spring-applied provided 53% control in June 2001, (36 MAT) compared to 6 and 10% when picloram plus 2,4-D or imazapic were applied alone (Table 1).

The best split treatments for long-term leafy spurge control were picloram plus 2,4-D applied in the spring followed by imazapic in the fall and imazapic fall-applied followed by picloram plus 2,4-D in the spring. These treatments averaged 85 and 61% control in August 1999 and 2000, respectively. No grass injury was observed following any of the rotational treatments.

The high long-term control from the spring-applied three-way mixture exceeded that from any previous herbicide treatments evaluated by North Dakota State University. To maintain such long-term control usually requires two or three annual applications of either imazapic or picloram plus 2,4-D. To further evaluate leafy spurge control from herbicide mixtures experiments were established at Valley City and Jamestown in 2000 and on the Albert Ekre Experiment Station near Walcott and the Sheyenne National Grasslands (SNG) near Lisbon and at Fargo in 2001. The herbicides were applied in mid-June at each location. The herbicide mixtures were only applied in the spring since fall-applied treatments had given poor leafy spurge control in the first experiment. Herbicides were applied as previously described and there were four replications at all locations except Fargo, which had three replications.

The three-way mixture of picloram plus 2,4-D plus imazapic did not provide as much long-term leafy spurge control in the second study compared to the first study (Tables 1 and 2). However, the three-way mixture did provide better control 3 MAT than picloram plus 2,4-D alone in all evaluations except at Jamestown (Table 2). For instance, leafy spurge control 3 MAT averaged 74% with picloram plus 2,4-D and 92% with picloram plus 2,4-D plus imazapic. The addition of diflufenzopyr to the three-way mixture tended to increase control compared to the herbicides applied alone.

Leafy spurge control dramatically increased when quinclorac was applied with picloram plus 2,4-D compared to picloram plus 2,4-D applied alone (Table 2). For instance, control averaged 74% 3 MAT with picloram plus 2,4-D compared to 91% when quinclorac was included in the mixture. In general, the addition of diflufenzopyr to picloram plus 2,4-D plus quinclorac did not increase control compared to the herbicides applied alone. The combination treatment of quinclorac plus dicamba plus diflufenzopyr provided similar control to picloram plus 2,4-D plus imazapic 3 and 12 MAT. Control was not improved with the addition of imazapic to the quinclorac plus dicamba plus diflufenzopyr mixture. The *Aphthona* spp. biocontrol agent established in the research plots at the Jamestown location so the site could not be further evaluated.

All herbicide mixtures that contained imazapic or quinclorac provided better leafy spurge control 3 MAT in 2001 than picloram plus 2,4-D or imazapic applied alone (Table 3). The three-way mixture of picloram plus 2,4-D plus imazapic provided 98% control compared to only 75% with picloram plus 2,4-D alone, averaged over both locations. Leafy spurge control 3 MAT averaged 100% when diflufenzopyr was applied with picloram plus 2,4-D plus imazapic. As in the previous study, quinclorac plus dicamba plus diflufenzopyr provided similar control to picloram plus 2,4-D plus imazapic 3 MAT. Imazapic at 1 oz/A averaged 93% control 3 MAT at SNG which is much higher than normal with this herbicide applied in the spring.

Picloram plus 2,4-D plus imazapic was applied at normal field rates including adjuvants, in the first experiment, but full rates may not be needed. The purpose of the fourth experiment was to determine if 28% N was needed in the combination treatment for leafy spurge control and if the imazapic rate could be reduced. The experiment was established at Fargo and the SNG in June 2001. Leafy spurge control was similar when picloram plus 2,4-D were applied with imazapic rates reduced from 1 to 0.25 oz/A at both locations (Table 4). There was a tendency for leafy spurge control to be improved when 28% N was applied with the herbicides, compared to without, at SNG but not at Fargo. In general, leafy spurge control tended to be higher at SNG than at Fargo especially with imazapic at 1 oz/A applied alone.

In summary, the three-way mixture of picloram plus 2,4-D plus imazapic and most mixtures that contained quinclorac provided better long-term leafy spurge control than picloram plus 2,4-D applied alone. Imazapic at 1 oz/A plus MSO at 1qt/A would increase treatment cost by approximately $13/A over picloram plus 2,4-D alone to a total of $26/A, but the three-way mixture would be cost-effective if long-term control was improved one or more seasons. Treatments that included quinclorac plus dicamba would cost approximately $32/A.

Table 1. Leafy spurge control with imazapic combined or alternated with picloram and 2,4-D applied in the spring or fall at Jamestown (JMS) and Valley City (VC) beginning in June 1998.

				1998			1999						2000						2001
				August			June			August			June			August			June
Treatment	Rate	Treatment	Rate	JMS	VC	Mean	JMS	VC	Mean	JMS	VC	Mean	JMS	VC	Mean	JMS	VC	Mean	JMS
	— oz/A —		- oz/A -	% control															
Spring 1998		Fall 1998																	
Picloram+2,4-D	4+16	Imazapic+MSO[a]+28% N	2+1qt+1qt	85	88	86	99	99	99	70	95	82	64	82	73	42	75	58	6
Imazapic+MSO[a]+28% N	1+1qt+1qt	Picloram+2,4-D	8+16	28	58	43	99	99	99	53	82	67	43	76	59	18	69	43	10
Picloram+2,4-D+imazapic +MSO[a]+28% N	4+16+1+ 1qt+1qt	None		99	95	97	95	99	99	97	99	98	98	99	99	75	91	83	53
LSD (0.05)				11	16	7[b]													
Fall 1998		Spring 1999																	
Picloram+2,4-D	8+16	Imazapic+MSO[a]+28% N	1+1qt+1qt				98	94	96	82	91	87	98	95	96	47	82	64	20
Imazapic+MSO[a]+28% N	2+1qt+1qt	Picloram + 2,4-D	8+16				99	99	99	96	98	97	77	81	79	25	62	43	13
Picloram+2,4-D+ imazapic+MSO[a]+28% N	8+16+2+ 1qt+1qt	None					99	99	99	59	64	61	26	50	38	3	28	15	6
LSD (0.05)							NS	2	NS	11	16	9[c]	11	16	10[c]	29	14	15[c]	15

[a] Methylated seed oil was Scoil by AGSCO, Grand Forks, ND.
[b] Significant interaction between locations. Control with imazapic at Valley City was higher than at Jamestown.
[c] Control at Valley City was higher than at Jamestown.

Table 2. Leafy spurge control from various herbicide mixtures applied at two locations in North Dakota in June 2000.

		Control			
		3 MAT[a]			12 MAT[a]
Treatment	Rate	Valley City	Jamestown	Mean	Valley City
	oz/A	%			
Picloram + 2,4-D	4 + 16	68	79	74	31
Imazapic + MSO[b] + 28%N	1 + 1 qt + 1 qt	71	66	69	67
Picloram + 2,4-D + imazapic + MSO[b] + 28%N	4 + 16 + 1 + 1 qt + 1 qt	96	89	92	85
Picloram + 2,4-D + imazapic + diflufenzopyr + MSO[b] + 28%N	4 + 16 + 1+ 2 + 1 qt + 1 qt	99	100	99	94
Picloram + 2,4-D + quinclorac + MSO[b]	4 + 16 + 8 + 1 qt	91	92	91	59
Picloram + 2,4-D + quinclorac + diflufenzopyr + MSO[b]	4 + 16 + 6 + 2.5 + 1 qt	96	97	97	97
Quinclorac + diflufenzopyr + MSO[b]	6 + 1.2 + 1 qt	84	89	86	93
Quinclorac + dicamba + MSO[b]	6 + 3 + 1 qt	76	89	83	93
Quinclorac + dicamba + diflufenzopyr[c] + MSO[b]	6 + 3 + 1.2 + 1 qt	93	88	91	95
Quinclorac + dicamba + diflufenzopyr[c] + imazapic + MSO[b]	6 + 3 + 1.2 + 1 + 1 qt	87	84	86	96
LSD (0.05)		9	20	11	19[d]

[a]Months after treatment.
[b]Methylated seed oil was Scoil by AGSCO, Grand Forks, ND.
[c]Commercial formulation - Distinct.
[d]Only two replications were evaluated.

Table 3. Leafy spurge control 3 months after treatment from various herbicide mixtures applied in June 2001 at two locations in North Dakota.

Treatment	Rate	Control: Walcott	Control: Sheyenne National Grassland
	– oz/A –	%	%
Picloram + 2,4-D	4 + 16	68	82
Imazapic + MSO[a] + 28%N	1 + 1 qt + 1 qt	45	93
Picloram + 2,4-D + imazapic + MSO[a] + 28%N	4 + 16 + 1 + 1 qt + 1 qt	96	99
Picloram + 2,4-D + imazapic + diflufenzopyr + MSO[a] + 28%N	4 + 16 + 1 + 2 + 1 qt + 1 qt	100	100
Picloram + 2,4-D + quinclorac + MSO[a]	4 + 16 + 8 + 1 qt	96	99
Picloram + 2,4-D + quinclorac + diflufenzopyr + MSO[a]	4 + 16 + 6 + 2.5 + 1 qt	97	95
Quinclorac + diflufenzopyr + MSO[a]	6 + 1.2 + 1 qt	93	96
Quinclorac + dicamba + MSO[a]	6 + 3 + 1 qt	90	92
Quinclorac + dicamba + diflufenzopyr[b] + MSO[a]	6 + 3 + 1.2 + 1 qt	97	97
Quinclorac + dicamba + diflufenzopyr[b] + imazapic + MSO[a]	6 + 3 + 1.2 + 1 + 1 qt	97	96
LSD (0.05)		16	7

[a]MSO is methylated seed oil by AGSCO, Grand Forks, ND.
[b]Commercial formulation - Distinct.

Table 4. Leafy spurge control 3 months after treatment with various combinations of picloram plus 2,4-D plus imazapic applied in June 2001 at two locations in North Dakota.

Treatment	Rate	Control: Fargo	Control: Sheyenne National Grasland
	oz/A	%	%
Picloram + 2,4-D	4 + 16	65	90
Imazapic + MSO[a] + 28% N	1 + 1 qt + 1 qt	3	82
Picloram + 2,4-D + imazapic + MSO[a] + 28% N	4 + 16 + 1 + 1 qt + 1 qt	84	98
Picloram + 2,4-D + imazapic + MSO[a] + 28% N	4 + 16 + 0.5 + 1 qt + 1 qt	84	95
Picloram + 2,4-D + imazapic + MSO[a] + 28% N	4 + 16 + 0.25 + 1 qt + 1 qt	77	95
Picloram + 2,4-D + imazapic + MSO[a]	4 + 16 + 1 + 1 qt	88	96
Picloram + 2,4-D + imazapic + MSO[a]	4 + 16 + 0.5 + 1 qt	87	99
Picloram + 2,4-D + imazapic + MSO[a]	4 + 16 + 0.25 + 1 qt	79	99
Picloram + imazapic + MSO[a]	4 + 1 + 1 qt	84	89
Picloram + imazapic + MSO[a]	4 + 0.5 + 1 qt	86	88
Picloram + imazapic + MSO[a]	4 + 0.25 + 1 qt	73	95
LSD (0.05)		22	8

[a]MSO[b] is methylated seed oil by AGSCO, Grand Forks, ND.

Evaluation of imazapic and quinclorac applied under trees and other woody species. Rodney G. Lym and Katheryn M. Christianson. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Most herbicides used for leafy spurge control are broad spectrum and cannot be used near trees and other woody species such as in shelter belts and wind breaks. Control using biological agents such as *Aphthona* spp. flea beetles also has been poor because the insects tend to avoid shaded areas. The leafy spurge gall midge *Spurgia esula* will establish under trees, but only prevents leafy spurge seed-set and does not reduce the root system. Imazapic and quinclorac provide excellent leafy spurge control and may be useful under and near woody species because both herbicides have a narrow weed control spectrum. The purpose of this research was to evaluate the effect of imazapic and quinclorac on various woody species when applied at rates that will control leafy spruge.

The experiment was established at three locations in well established wind breaks. The first location was on the North Dakota State University campus and included mature arborvitae (*Thuja occidentalis*), aka Northern White cedar. The plots were 15 by 50 feet with three replicates. The second location was an experimental tree planting on the NDSU research station at Casselton, and included black walnut (*Juglans nigra*), Siberian elm (*Ulmus pumila*), and white oak (*Quercus alba*) planted in 1990. The plots were 10 by 38 feet with two replicates. The third site was a mature shelter belt near Valley City, North Dakota, which included two rows each of juniper (*Juniperus scopulorum*), Black Hills spruce (*Picea glauca* var. *densata*), Siberian elm, and one row of common lilac (*Syringa vulgaris*). The plots at Valley City were 20 by 55 feet with two replicates.

Herbicides were applied with a single nozzle back-pack sprayer delivering 60 gpa at 25 psi. Application was made to the surface area walking back and forth within the plot in each shelter belt. A dye was added to the treatment solution to ensure uniform application. No attempt was made to prevent occasional spray from hitting the lower branches of the trees and shrubs. Spring- and fall-applied treatments were made the third week of May or mid-September 2000, respectively. Injury was based on visual observation of plants in the treated plots compared to the untreated control.

There was no visible injury 1, 3, 9, or 12 months after treatment (MAT) to arborvitae, black walnut, Siberian elm or white oak regardless of treatment or application date (data not shown). However, injury was observed on juniper, Black Hills spruce, and lilac at the Valley City location (Table). Imazapic spring-applied at 2 or 3 oz/A injured the new growth (candles) of both juniper and Black Hills spruce 1 and 3 MAT. The candles were yellow and injury increased as imazapic rate increased. Injury generally was less when imazapic was applied with 2,4-D compared to imazapic applied alone. Quinclorac applied alone or with diflufenzopyr caused some yellowing on new growth in spruce when evaluated 1 MAT but not 3 MAT. Fall-applied imazapic or quinclorac did not injure either juniper or spruce. The yellowing of new growth observed in 2000 was absent in 2001 and plant growth was similar to the untreated control.

Lilac was severely injured by imazapic and slightly injured by quinclorac, regardless whether the herbicides were spring- or fall-applied (Table). Imazapic applied to lilac resulted in severely stunted or no leaf growth, while quinclorac caused twisted leaf growth typical of auxin herbicides. Injury from imazapic alone or applied with 2,4-D was much greater when fall-applied compared to spring-applied. For instance, imazapic at 2 oz/A spring-applied caused 20 and 10% lilac injury 1 and 3 MAT, respectively, and the plants recovered. The same treatment fall-applied resulted in 90% injury the following spring (9 MAT) and most injured branches were dead by September 2001 (12 MAT) (data not shown). Lilac injury from quinclorac did not exceed 10%, was short-lived and no plants were killed (Table). Grass injury averaged 10% with imazapic or imazapic plus 2,4-D applied in the fall, but not the spring.

Both quinclorac and imazapic can be used to control leafy spurge under certain tree and brush species. Neither herbicide injured elm, oak, walnut or cedar species. Both juniper and Black Hills spruce were injured by imazapic, which caused yellowing of the new growth (candles), but had no long-term effect on growth. However, imazapic at 2 or 3 oz/A fall-applied alone or with 2,4-D resulted in severe lilac injury or death, respectively. Lilac injury from quinclorac was minor and the plants soon recovered.

Table. Effect on several woody species from spring or fall application of imazapic or quinclorac.

Treatment	Rate	Injury 1 MAT[a]				Injury 3 MAT[a]				Injury 12/9/12 MAT[a]				
		Juniper	Spruce	Lilac	Elm	Juniper	Spruce	Lilac	Elm	Juniper	Spruce	Lilac	Elm	GI[b]
	oz/A	%												
Spring-applied treatments														
Imazapic + MSO[c]	2 + 1 qt	6	40	20	0	4	1	10	0	0	0	0	0	0
Imazapic + MSO[c]	3 + 1 qt	8	49	13	0	18	18	0	0	0	0	0	0	0
Imazapic + 2,4-D[d] + MSO[c]	2 + 4 + 1 qt	4	3	15	0	1	0	15	0	0	0	0	0	0
Imazapic + 2,4-D[d] + MSO[c]	3 + 6 + 1qt	3	31	55	0	2	0	35	0	0	0	10	0	0
Quinclorac + MSO[c]	12 + 1 qt	1	8	8	0	1	0	5	0	0	0	0	0	0
Quinclorac + diflufenzopyr + MSO[c]	12 + 1.2 + 1 qt	0	10	10	0	0	0	5	0	0	0	0	0	0
Untreated		0	0	0	0	0	0	0	0	0	0	0	0	0
LSD (0.05)		4	32[e]	30[e]	NS	6	11[e]	18[e]	NS					
Fall-applied treatments														
Imazapic + MSO[c]	2 + 1 qt									0	0	90/70[f]	0	18
Imazapic + MSO[c]	3 + 1 qt									0	0	100/90	0	9
Imazapic + 2,4-D[d] + MSO[c]	2 + 4 + 1 qt									0	0	65/70	0	5
Imazapic + 2,4-D[d] + MSO[c]	3 + 6 + 1qt									0	0	95/90	0	9
Quinclorac + MSO[c]	12 + 1 qt									0	0	0	0	0
Quinclorac + diflufenzopyr + MSO[c]	12 + 1.2 + 1 qt									0	0	5	0	0
LSD (0.05)												24/25		8

[a]Months after treatment, evaluated 12 MAT for spring-applied treatments and 9 MAT for fall-applied treatments. Evaluated for visible injury, i.e., yellow new growth (imazapic) or auxin injury (imazapic plus 2,4-D or quinclorac).
[b]Grass injury.
[c]Methylated seed oil was Scoil by AGSCO, Grand Forks, ND.
[d]Commercial formulation - Oasis.
[e]LSD = 0.10.
[f]9 MAT/12 MAT.

Evaluation of leafy spurge control with quinclorac granules. Rodney G. Lym. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Research has shown that quinclorac will control leafy spurge. Leafy spurge control 12 MAT (months after treatment) averaged 38 and 77% when quinclorac was applied at 0.5 and 1.5 lb/A, respectively, in North Dakota. Quinclorac has several advantages over the presently used herbicides for leafy spurge control. The application window for fall treatment is broad ranging from September 1 to October 15. No desirable forage grasses were injured at any quinclorac rate or location in a six-state regional study. Also, quinclorac did not injure many desirable broadleaf species including leadplant (*Amorpha canescens* Pursh), purple prairie clover (*Dalea purpurea* Vent.), prairie wild rose (*Rosa arkansana* Porter), willow (*Salix* spp.), and wild raspberry (*Rubus* spp.). The purpose of this research was to compare leafy spurge control with quinclorac applied as a liquid or granular formulation.

The experiment was established at Camp Grafton South (CGS) near McHenry and near Valley City, ND on September 7 and 8, 2000, respectively. Leafy spurge was in the fall regrowth stage at both locations, 12 to 18 inches tall at Valley City and 10 to 42 inches tall at CGS. Quinclorac liquid formulation was applied with a hand-held sprayer delivering 8.5 gpa at 35 psi, while the granular formulation was applied by hand walking through the plot three times for as uniform coverage as possible. The plots were 10 by 30 feet in a randomized complete block design with four replicates. Treatments were visually evaluated with control based on percent stand reduction compared to the untreated control.

		Control/MAT[a]	
Treatment	Rate	9	12
	— oz/A —	— % —	
Quinclorac	6	42	6
Quinclorac	12	66	19
Quinclorac + MSO	6 + 1 qt	78	27
Quinclorac + MSO	12 + 1 qt	89	29
Quinclorac 1.5% granule	6	26	0
Quinclorac 1.5% granule	12	86	32
Picloram + 2,4-D	8 + 16	65	26
Imazapic + MSO	2 + 1 qt	92[b]	16
LSD (0.05)		18	15

[a]Months after treatment.
[b]Grass injury averaged 16%.

Only data from the CGS location were analyzed as *Aphthona* spp. biocontrol agents had established at the Valley City location and control from the insects and herbicides could not be separated. Quinclorac granules applied at 12 but not 6 oz/A provided similar control to quinclorac liquid plus MSO 9 and 12 MAT and averaged 81 and 31%, respectively (Table). The lower control with quinclorac at 6 oz/A compared to quinclorac liquid applied with or without MSO is likely due to poor distribution of the granules when applied by hand at the low rate. Quinclorac at 12 oz/A, regardless of formulation, tended to provide better leafy spurge control than imazapic 12 MAT. In general, leafy spurge control was lower than commonly observed in the state with these herbicides regardless of treatment. The reason for the poorer control is not known, as weather conditions were ideal when the treatments were applied. Quinclorac granules could provide similar leafy spurge control to the liquid formulation if the application rate was high enough to ensure uniform coverage.

Evaluation of metsulfuron for perennial sowthistle control. Rodney G. Lym. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Metsulfuron is often used for general weed and brush control on industrial non-crop sites and for control of certain weeds in pasture and roadsides. Perennial sowthistle has increased rapidly in North Dakota since the mid 1990's following several years of above average precipitation and is often more difficult to control with herbicides than Canada thistle. Previous research at North Dakota State University has shown that metsulfuron will control perennial sowthistle but can also cause injury to desirable species. The purpose of this research was to establish an application rate of metsulfuron that would control perennial sowthistle with minimal damage to desirable grass species.

The experiment was established at Fargo in a dense perennial sowthistle stand with an under story of Kentucky bluegrass and weedy annual grasses and broadleaf species such as foxtail and ragweed. Herbicides were applied on July 11, 2000, when perennial sowthistle was in the bolted to flowering growth stage and 10 to 36 inches tall. The treatments were applied with a CO_2 backpack sprayer delivering 8.5 gpa at 35 psi. The plots were 10 by 30 feet, and the experiment was a randomized complete block design with four replicates. The air temperature was 72 F, the dew point 68 F, and the soil temperature was 72 F at the 1 inch depth. Perennial sowthistle (PEST) control and bare ground evaluations were based on percent reduction compared to the untreated control.

		Control/MAT[a]				
		2	11		14	
Treatment	Rate	PEST	PEST	BG[b]	PEST	BG[b]
	— oz/A —	—	—	%	—	—
Metsulfuron + X-77	0.3 + 0.25%	88	99	20	96	3
Metsulfuron + X-77	0.45 + 0.25%	96	96	53	100	21
Metsulfuron + X-77	0.6 + 0.25%	92	99	76	100	38
Metsulfuron + X-77	0.9 + 0.25%	100	99	58	100	49
Metsulfuron + X-77	1.2 + 0.25%	100	100	80	100	76
Metsulfuron + X-77	1.8 + 0.25%	100	100	76	100	67
Clopyralid + X-77	4 + 0.25%	63	85	1	57	1
Clopyralid + 2,4-D[c] + X-77	3 + 16 + 0.25%	84	90	5	89	0
Dicamba + diflufenzopyr[d] + X-77	3 + 1.2 + 0.25%	60	47	0	13	0
LSD (0.05)		14	6	24	21	25

[a]Months after treatment.
[b]Bare ground
[c]Commercial formulation - Curtail.
[d]Commercial formulation - Distinct.

Metsulfuron provided excellent perennial sowthistle control at all application rates evaluated. Control with metsulfuron at 0.6 oz/A or less tended to increase between the 2 and 11 month after treatment (MAT) evaluations. Metsulfuron at 1.2 to 1.8 oz/A provided 100% perennial sowthistle control but also averaged 78 and 72% bare ground 11 and 14 MAT, respectively. Clopyralid plus 2,4-D at 3 + 16 oz/A provided similar perennial sowthistle control as metsulfuron at 0.3 oz/A and better control than clopyralid at 4 oz/A alone. Dicamba plus diflufenzopyr did not provide satisfactory perennial sowthistle control. Metsulfuron at the lowest rate evaluated (0.3 oz/A) provided the most cost-effective perennial sowthistle control and the least injury to other species.

Canada thistle, bull thistle, Flodman thistle, and goldenrod control with herbicide mixtures. Rodney G. Lym. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Canada thistle has increased rapidly in North Dakota during the last decade and currently is estimated to infest over 1.7 million acres, compared to 822,000 acres in 1992. The increase has occurred in cropland, pasture and rangeland, as well as wild land. The increase is due in part to the much above average precipitation received in the state since 1993. Other thistle species, such as the biennial bull thistle and the perennial native Flodman thistle, have also increased in acreage. The purpose of this research was to compare various herbicide mixtures, especially those that contain clopyralid, for thistle control.

The first two experiments were established in dense Canada thistle patches located within the Theodore Roosevelt National Park near Medora, ND. Separate spring and fall studies were established on June 22 and September 11, 2000, respectively. The spring treatments were applied to Canada thistle in the rosette to early bolt growth stage, 8 to 16 inches tall. The experiment was a randomized complete block design with four replicates and plots were 9 by 25 feet. The fall treatments were applied to Canada thistle in the post-bloom growth stage with numerous fall rosettes beginning growth within the canopy. The plots were 8 by 30 feet with three replicates. Herbicides were applied with a hand-held sprayer delivering 8.5 gpa at 35 psi. Treatments were visually evaluated with control based on percent stand reduction compared to the untreated control.

Clopyralid alone generally provided better Canada thistle control at comparable rates than when applied with triclopyr or 2,4-D (Table 1). For instance, Canada thistle control was 90% 3 months after treatment (MAT) when clopyralid at 4 oz/A was applied alone, compared to 75 and 76% when clopyralid at 4.5 oz/A was applied with triclopyr or at 4 oz/A with 2,4-D, respectively. Long-term Canada thistle control (15 MAT) was also better with clopyralid alone and averaged 70% control compared to 34% when clopyralid at a similar rates was applied with triclopyr or 2,4-D. Canada thistle control with dicamba plus diflufenzopyr averaged 91% 3 MAT but declined to 56% by 15 MAT.

Clopyralid or picloram fall-applied alone at 8 oz/A provided excellent Canada thistle control which averaged 98% 12 MAT (Table 2). Although not directly comparable, clopyralid alone at 8 oz/A provided better Canada thistle control than clopyralid at 6 oz/A plus triclopyr. Unlike the spring treatment, dicamba plus diflufenzopyr fall-applied provided very poor control, and averaged only 9% 9 MAT.

The third experiment was established in a weedy pasture on the Albert Ekre Research Center near Walcott, ND, on May 31, 2000. Although many common perennial pasture weeds were present, only goldenrod, bull thistle, and Flodman thistle were uniformly distributed enough for evaluation of herbicide treatments. Treatments were applied as previously described, and the plots were 10 by 30 feet and replicated four times.

In general, goldenrod control averaged 80% or better 1 MAT with all treatments evaluated, except when clopyralid was applied alone at 4 oz/A or triclopyr at 9 oz/A (Table 3). All treatments provided near 100% goldenrod control 3 MAT (data not shown). All treatments evaluated provided excellent bull thistle and Flodman thistle control which averaged 98% 16 MAT.

Table 1. Canada thistle control with various formulations of clopyralid applied to Canada thistle in June 2000 in Theodore Roosevelt National Park near Medora, ND.

		Control/MAT[a]			
Treatment	Rate	3	11	12	15
	—— oz/A ——	——	—— %	——	——
Clopyralid + triclopyr[b] + X-77	2.25 + 6.75 + 0.25%	63	28	39	19
Clopyralid + triclopyr[b] + X-77	3 + 9 + 0.25%	76	40	49	29
Clopyralid + triclopyr[b] + X-77	3.75 + 11.25 + 0.25%	70	41	50	43
Clopyralid + triclopyr[b] + X-77	4.5 + 13.5 + 0.25%	75	50	36	36
Clopyralid + 2,4-D[c] + X-77	3 + 16 + 0.25%	74	51	40	37
Clopyralid + 2,4-D[c] + X-77	4 + 24 + 0.25%	76	56	63	47
Clopyralid + X-77	2 + 0.25%	95	93	90	72
Clopyralid + X-77	4 + 0.25%	90	81	87	68
2,4-D + X-77	32 + 0.25%	22	11	13	8
Dicamba + diflufenzopyr[d] + X-77	3 + 1.2 + 0.25%	91	68	54	56
LSD (0.05)		24[e]	34	36	34

[a]Months after treatment.
[b]Commercial formulation - Redeem.
[c]Commercial formulation - Curtail.
[d]Commercial formulation - Distinct.
[e]LSD (0.10).

Table 2. Canada thistle control with various formulations of clopyralid applied to Canada thistle in September 2000 in Theodore Roosevelt National Park near Medora, ND.

Treatment	Rate	Control/MAT[a] 8	9	12
	oz/A	%		
Clopyralid + triclopyr[b] + X-77	3.75 + 11.25 + 0.25%	98	83	38
Clopyralid + triclopyr[b] + X-77	4.5 + 13.5 + 0.25%	94	91	58
Clopyralid + triclopyr[b] + X-77	5.25 + 15.75 + 0.25%	93	73	38
Clopyralid + triclopyr[b] + X-77	6 + 18 + 0.25%	99	80	64
Clopyralid + X-77	8 + 0.25%	99	92	97
Picloram	8	99	73	100
Dicamba + diflufenzopyr[c] + X-77	3 + 1.2 + 0.25%	37	9	0
LSD (0.05)		31	15	47[d]

[a] Months after treatment.
[b] Commercial formulation - Redeem.
[c] Commercial formulation - Distinct.
[d] Only two of the three replicates could be evaluated.

Table 3. Goldenrod, bull thistle and Flodman thistle control with various formulations of clopyralid applied in June 2000.

		Control/MAT[a]				
		1		3	11	16
Treatment	Rate	Golden rod	Thistle[b]	Thistle[b]	Thistle[b]	Thistle[b]
	oz/A	%				
Clopyralid + triclopyr[c] + X-77	3 + 9 + 0.25%	81	91	100	98	98
Clopyralid + triclopyr[c] + X-77	4.5 + 13.5 + 0.25%	85	96	100	98	99
Clopyralid + triclopyr[c] + X-77	6 + 18 + 0.25%	95	97	100	98	100
Clopyralid + 2,4-D[d] + X-77	3 + 16 +0.25%	83	96	100	98	99
Clopyralid + 2,4-D[d] + X-77	4 + 24 + 0.25%	86	96	100	99	99
Clopyralid + X-77	4 + 0.25%	63	98	100	97	99
Dicamba + diflufenzopyr[e] + quinclorac + MSO[f]	3 + 1.2 + 6 + 0.25%	79	86	100	97	99
Dicamba + diflufenzopyr[e] + X-77	3 + 1.2 + 0.25%	89	94	100	98	99
Triclopyr + X-77	9 + 0.25%	59	76	94	93	92
Triclopyr + X-77	18 + 0.25%	90	85	100	84	91
LSD (0.05)		18	9	3	9	5

[a]Months after treatment.
[b]Mixture of bull thistle and Flodman thistle.
[c]Commercial formulation - Redeem.
[d]Commercial formulation - Curtail.
[e]Commercial formulation - Distinct.

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

Evaluation of Roundup Ultra and Roundup Custom applied with various adjuvants for quackgrass control. Katheryn M. Christianson and Rodney G. Lym. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Previous research at North Dakota State University has shown that a fall application of glyphosate provides good quackgrass control the following growing season. However, glyphosate (original Roundup ®) was applied at 24 or 36 oz/A plus X-77 in those trials. Presently, many glyphosate formulations contain adjuvants and can often be applied at lower use rates than in the previous studies. For example, the recommended glyphosate application rate for quackgrass control is 12 oz/A or less when applied as Roundup Ultra® or similar glyphosate products that contain non-ionic surfactants (NIS). The purpose of this research was to evaluate long-term quackgrass control with glyphosate applied alone or with various adjuvants either contained in the commercial formulation or tank-mixed with the herbicide.

The experiment was established in a solid quackgrass stand at Fargo, ND on October 4, 2000. The quackgrass had been mowed in July and was 8 to 10 inches tall with some senescence from a frost in September. The glyphosate formulations evaluated either contained a complete compliment of NIS (Roundup Ultra ®) or did not contain any NIS (Roundup Custom ®). Ammonium sulfate (AMS) or CL9804, proprietary adjuvant by Agriliance, were included in the evaluations. The treatments were applied with a CO_2 backpack sprayer delivering 8.5 gpa at 35 psi. The plots were 10 by 30 feet, and the experiment was a randomized complete block design with four replicates. The air temperature was 69 F with a dew point of 55 F and the soil temperature at the 4 inch depth was 63 F. Quackgrass control was visually evaluated compared to the untreated control.

Treatment	Rate	Control		
		2 WAT[a]	6 MAT[b]	9 MAT[b]
	oz/A		%	
Glyphosate RU	6	27	25	26
Glyphosate RU + AMS	6 + 1%	45	54	31
Glyphosate RU + CL9804	6 + 2.5%	39	54	38
Glyphosate CU + CL9804	6 + 5%	51	36	21
Glyphosate RU	9	63	50	35
Glyphosate RU + AMS	9 + 1%	51	69	64
Glyphosate RU + CL9804	9 + 2.5%	59	68	56
Glyphosate CU + CL9804	9 + 5%	39	46	37
Glyphosate RU	12	70	71	63
Glyphosate RU + AMS	12 + 1%	76	79	71
Glyphosate RU + CL9804	12 + 2.5%	53	64	62
Glyphosate CU + CL9804	12 + 5%	63	72	66
LSD (0.05)		22	23	20

[a]Intial injury 2 weeks after treatment. [b]Months after treatment.

Initial quackgrass injury increased as glyphosate application rate increased independent of adjuvant. The addition of AMS and CL9804 increased or tended to increase quackgrass control with glyphosate RU at the 6 and 9 oz/A rate compared to glyphosate RU alone 6 months after treatment (MAT) and at the 9 oz/A rate 9 MAT (Table). Glyphosate RU at 12 oz/A provided the best long-term quackgrass control and averaged 66% 9 MAT regardless if applied alone or with AMS or CL9804. Glyphosate RU at 9 oz/A applied with AMS or CL9804 provided long-term quackgrass control similar to glyphosate RU at 12 oz/A and could be used to reduce the glyphosate application rate. Glyphosate CU plus CL9804 provided quackgrass control similar to glyphosate RU alone at the same application rate.

<u>Evaluation of herbicides for purple loosestrife control</u>. Rodney G. Lym and Katheryn M. Christianson. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Purple loosestrife is not widely established in North Dakota but isolated patches continue to be found especially in urban areas. Biological control agents have become established in the larger infestations, but mosquito control programs often reduce the biocontrol agent population and thus purple loosestrife control. The purpose of this research was to evaluate 2,4-D, triclopyr, and glyphosate, for purple loosestrife control.

The experiment was established in Chautauqua Park along the Sheyenne River in Valley City, ND on August 1, 2000. Purple loosestrife was beginning to flower and ranged from 0.5 to 6 feet in height. Cattails were present and were approximately 6 feet tall. Herbicides were applied with a single-nozzle backpack sprayer with a hollow cone nozzle delivering approximately 60 gpa at 35 psi. The air temperature was 82 F with a dew point of 67 F. The plots were 8 by 30 feet with two replicates and followed the shoreline of the river. Evaluations were based on percent stand reduction compared to the untreated control.

Treatment	Rate	Control/MAT[a] 1	11	13
	— lb/A —	%		
NB20652[b]	0.94	100	31	26
NB30380[c]	2.5	100	98	81
Glyphosate	3.6	100	100	92
Triclopyr	2.7	100	98	92
LSD (0.05)		NS	17	25

[a]Months after treatment.
[b]2,4-D formulation at 1.88 lb/gal 2,4-D acid from PBI-Gordon.
[c]2,4-D formulation at 5 lb/gal 2,4-D acid from PBI-Gordon.

The 2,4-D formulation NB30380 provided much better purple loosestrife control than NB20652 and averaged 81 compared to 26% control 13 MAT, respectively (Table). Purple loosestrife control from glyphosate and triclopyr averaged 92% 13 MAT and was similar to previous experiments conducted at North Dakota State University. Glyphosate also provided near complete control of cattails (data not shown). The high purple loosestrife control from 2,4-D formulated as NB30380 was unexpected and will be further evaluated.

Biological control of purple loosestrife in North Dakota. Rodney G. Lym and Katheryn M. Christianson. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Purple loosestrife is found in 11 North Dakota counties with the largest infestations in urban areas. Biological control of purple loosestrife fits well in urban areas considering public apprehension about herbicides sprayed in close proximity to residential areas. Three species of purple loosestrife biological control agents were introduced in North Dakota in 1997 and 1998. The biological control agents included two leaf beetles, *Galerucella calmariensis* and *G. pusilla*, released in Grand Forks and Valley City, ND, and *Hylobius transversevittatus*, a root feeding weevil, in Grand Forks. The objective of this research was to evaluate purple loosestrife control with *Galerucella* spp. along a river in an urban area.

The experiment was established in Chautauqua Park along the Sheyenne River in Valley City, North Dakota. A mixed population of about 4000 *Galerucella calmariensis* and 10,000 *G. pusilla* were released at a single point in June 1998 and 1999, respectively. The number of *Galerucella* spp. adults and egg masses, as well as purple loosestrife stems, plant height, and spike length were recorded at the release point and at 25 foot increments both up and down stream from the release point. In a 1-m^2 area, measurements included the number of eggs, larvae, and adults estimated by counting for 60 seconds, height of the five tallest stems, length of the five longest flower spikes, and the total number of stems.

Galerucella spp. established the first year after release because both adults and egg masses were found in 1999 and the population increased through 2001 (Tables 1 and 2). *Gallerucella* spp. began to decrease the loosestrife stem height and flower spike length 2 yr after release (2000). For instance, stem height was reduced at the release pole from 1.4 m in 1999 to 0.4 m in 2000. Stem height in 2001 was similar to that measured in 2000. The average flower spike length was reduced to zero at the release pole and 25 feet from the pole in 2000, 2 yr after release, and at 50 feet in 2001. The number of stems increased 2 yr following the *Galerucella* spp. release even though the number of flowering plants and stem length decreased. In general, the plants were short and remained in the vegetative growth stage 2 and 3 yr after the first biological control agent was released.

The number of eggs observed increased from an average of 1/m^2 in 1998 to 27/m^2 in 2000, while larvae began to increase in 2001 and averaged 46/m^2 in 2001 (Table 2). The largest number of eggs, larvae, and adults were usually found near the original release pole and decreased as the distance from the release pole increased even 3 yr after release. However, adults and evidence of larvae feeding were observed well away from the experiment which indicated the *Galerucella* spp. were moving out of the research location as the insect population increased.

In this study, *Galerucella* spp. established and began to reduce the purple loosestrife infestation 2 yr following release. Biological control of purple loosestrife can be an alternative to chemical control in urban areas as long as insecticides sprayed for mosquito control are restricted from the release area.

Table 1. Purple loosestrife control with *Galerucella* spp. released in 1998 in Valley City, ND[a].

Distance from	Flowering stems			Stems				Stem height			Spike length		
release	1998	2000	2001	1998	1999	2000	2001	1999	2000	2001	1999	2000	2001
	no./m^2			no./m^2				m			cm		
0 (release)	0	0	0	10	15	58	30	1.4	0.4	0.8	0	0	0
25 feet	6	0	0	14	19	22	10	1.2	0.5	0.5	10	0	0
50 feet	2	0	0	35	14	50	31	0.9	0.8	0.7	6	10	0

[a] Estimates of purple loosestrife control were made in mid-July each year.

Table 2. Population change over time of *Galerucella* spp. on purple loosestrife at Valley City, ND[a].

Distance from	1998			1999			2000			2001		
release[a]	Eggs	Larvae	Adults	Eggs	Larvae	Adults	Eggs	Larvae	Adults	Eggs	Larvae	Adults
	no./m^2											
0 (release)	0	2	1	0	0	0	40	0	4	23	94	0
25 feet	2	1	0	2	0	2	11	0	1	0	34	4
50 feet	0	1	0	6	0	2	30	0	2	13	10	8

[a] Estimates of *Galerucella* spp. adults and egg masses were made in June of each year.

Spotted knapweed, diffuse knapweed, and Russian knapweed control with herbicide mixtures. Rodney G. Lym and Katheryn M. Christianson. (Department of Plant Sciences, North Dakota State University, Fargo, ND 58105). Members of the knapweed genus are increasing in acreage in North Dakota and the region. Chemical control of the annual species such as spotted and diffuse knapweed has been effective and is relatively inexpensive. However, control of the perennial Russian knapweed has been difficult and can be costly because of the high herbicide rates required. Previous research at North Dakota State University has found that mixtures of herbicides can provide more cost-effective weed control than a single chemical used alone. The purpose of this research was to evaluate control of various knapweed species using herbicide mixtures.

The first experiment was established on July 8, 1999, near Hawley, MN when spotted knapweed was in the rosette growth stage and beginning to bolt. Herbicides were applied during warm humid conditions with an air temperature of 70 F and a dew point of 67 F. The soil was sandy gravel with an organic matter of 2.2% and a pH of 8.5. The experiment was a randomized complete block design with four replicates. Treatments were applied with a hand-held sprayer delivering 8.5 gpa at 35 psi. The plots were 7 by 30 feet. Treatments were visually evaluated in late-May and late August 2000 and 2001 with control based on percent stand reduction as compared to the control.

Spotted knapweed control 2 months after treatment (MAT) was similar regardless of herbicide mixture, but long-term control was better with 2,4-D plus sulfentrazone (except the NB30027 formulation), carfentrazone, or triclopyr than with 2,4-D alone or with imazapic (Table 1). For instance, spotted knapweed control with 2,4-D plus sulfentrazone formulated as NB30021 or NB30408 averaged 78 and 86% control 25 MAT compared to 48% with 2,4-D alone. Control 25 MAT only averaged 55% with 2,4-D plus sulfentrazone in the NB30027 mixture. When imazapic was included in the mixture (NB30409 or NB30410), control only averaged 15% or less 25 MAT. 2,4-D plus triclopyr provided 83% control 2 MAT, which slowly declined to 67% by 25 MAT.

The second experiment evaluated control of diffuse knapweed which had established in a rocky pasture previously used as a gravel pit near Pingree, ND. Herbicides were applied on June 23, 2000, when the diffuse knapweed was in the rosette to bolting growth stage, up to 18 inches tall and beginning to form flower buds. The air temperature was 62 F with a dew point of 61 F with light dew on the plants and an overcast sky. Plots were 9 by 30 feet with four replications in a randomized complete block design and herbicides were applied as previously described.

All herbicide treatments evaluated provided excellent diffuse knapweed control by 11 MAT except fluroxypyr applied either alone or with metsulfuron (Table 2). Control 15 MAT averaged 97% or better with mixtures of metsulfuron plus dicamba plus either 2,4-D or MCPA, picloram plus 2,4-D, dicamba plus diflufenzopyr, quinclorac plus diflufenzopyr, and clopyralid plus 2,4-D. Control 15 MAT with fluroxypyr applied alone or with metsulfuron only averaged 41 and 20%, respectively.

The third experiment evaluated Russian knapweed control with various herbicide mixtures. The experiment was established in the Theodore Roosevelt National Park near Medora, ND, on September 12, 2000, when the Russian knapweed was in the bolt to flowering growth stage and 18 to 36 inches tall. The infestation had been sprayed the previous year with picloram by park personnel to prevent spread of the infestation in the park. The temperature was 65 F with a dew point of 53 F and the soil temperature of 55 F at the 2 inch depth. The plots were 8 by 40 feet with three replications, and herbicides were applied as previously described.

Russian knapweed control was quite variable regardless of treatment (Table 3). The variability in control from plot to plot could be due to picloram applied the previous year. Treatments that tended to look better visually, but did not separate out statistically included quinclorac plus diflufenzopyr and imazapic applied with MSO and 28% N. However, no treatment consistently provided satisfactory Russian knapweed control.

In general, herbicide mixtures provided better knapweed control than single herbicides. Both diffuse and spotted knapweed were relatively easy to control, but no treatment evaluated provided satisfactory Russian knapweed control.

Table 1. Spotted knapweed control with 2,4-D applied with various plant growth regulators.

Treatment[b]	Rate	Control/MAT[a]				
		2	11	13	22	25
	lb/A	%				
2,4-D + sulfentrazone (NB30021)	1.97 + 0.03	84	97	89	80	78
2,4-D + sulfentrazone (NB30027)	1.97 + 0.03	86	92	86	68	55
2,4-D + sulfentrazone + 5-ALA (NB30408)	1.96 + 0.03 + 0.01	85	97	91	87	86
2,4-D + sulfentrazone+imazapic (NB30409)	0.86 + 0.03 + 0.11	88	63	47	31	15
2,4-D+imazapic+sulfentrazone+mefluidide (NB30410)	0.7+0.088+0.025+0.19	83	46	52	26	9
2,4-D + carfentrazone (NB30411)	1.98 + 0.02	83	96	88	73	61
2,4-D + carfentrazone + 5-ALA (NB30412)	1.98 + 0.02 + 0.01	86	96	90	88	69
2,4-D mixed amine[c]	1.92	86	87	82	66	48
2,4-D + triclopyr[d]	1 + 0.5	83	91	80	70	67
LSD (0.05)		NS	8	10	18	25

[a]Months after treatment.
[b]All treatments were applied with X-77 at 0.25%.
[c]Commercial formulation - Hi-Dep.
[d]Commercial formulation - Crossbow.

Table 2. Diffuse knapweed control with various herbicide mixtures.

Treatment	Rate	Control/MAT[a] 2	11	15
	oz/A	%		
Metsulfuron + 2,4-D + dicamba + X-77	0.3 + 16 + 8 + 0.25%	90	98	99
Metsulfuron + MCPA + dicamba + X-77	0.3 + 8 + 8 + 0.25%	97	99	97
2,4-D + dicamba + X-77	16 + 8 + 0.25%	93	97	99
MCPA + dicamba + X-77	8 + 8 + 0.25%	93	98	99
Metsulfuron + 2,4-D + dicamba + X-77	0.6 + 16 + 8 + 0.25%	100	99	100
Metsulfuron + fluroxypyr + X-77	0.3 + 1 + 0.25%	28	52	20
Fluroxypyr + X-77	1 + 0.25%	11	50	41
Picloram + 2,4-D	4 + 1 6	100	98	99
Dicamba + diflufenzopyr[b] + X-77	11.2 + 0.25%	96	99	99
Quinclorac + MSO[c]	12 + 0.25%	56	88	97
Quinclorac + diflufenzopyr + MSO[c]	12 + 1.2 + 0.25%	70	97	98
Clopyralid + triclopyr[d] + X-77	3 + 9 + 0.25%	97	97	99
LSD (0.05)		18	19	21

[a]Months after treatment.
[b]Commercial formulation - Distinct.
[c]Methylated seed oil was Scoil by AGSCO, Grand Forks, ND.
[d]Commercial formulation - Redeem.

Table 3. Russian knapweed control with various herbicide mixtures applied in September.

Treatment	Rate	Control/MAT[a] 10	12
	oz/A	%	
Metsulfuron + 2,4-D + dicamba[b] + X-77	0.3 + 16 + 8 + 0.25%	45	40
Metsulfuron + MCPA + dicamba[b] + X-77	0.3 + 8 + 8 + 0.25%	37	35
Metsulfuron + fluroxypyr + X-77	0.3 + 1 + 0.25%	22	47
Picloram + 2,4-D	8 + 16	33	43
Quinclorac + diflufenzopyr + MSO[c]	12 + 1.2 + 0.25%	33	70
Clopyralid + triclopyr[d] + X-77	6 + 18 + 0.25%	37	52
Imazapic + 2,4-D[e] + MSO[b]	3 + 6 + 1 qt	47	44
Imazapic + MSO[c] + 28%N	3 + 1 qt + 1 qt	67	58
LSD (0.05)		NS	NS

[a]Months after treatment.
[b]Commercial formulation - Clarity.
[c]Methylated seed oil was Sunit by AGSCO, Grand Forks, ND.
[d]Commercial formulation - Redeem.
[e]Commercial formulation - Oasis.

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Leafy spurge demonstration plots, Ekre station.

Annual application date and treatment	Cost[a]	Rate	Control 1994 June	1994 Sept	1995 June	1995 Sept	1997 June	1997 Sept	1998 June	1998 Sept	1999 June	1999 Sept	2000 June	2000 Sept	2001 June	2001 Sept
	$/A	lb/A	%													
September (begun in 1993)																
Picloram + 2,4-D amine	28	0.5+1	90	80	98	95	100	99	100	88	100	92	100	99	98	99
Picloram	25	0.5	95	70	100	98	100	97	100	92	100	95	100	100	99	99
Picloram + 2,4-D amine	14	0.25+1	98	48	100	65	100	95	100	85	100	90	100	98	95	95
2,4-D amine	6	2	10	5	75	40	90	55	80	45	78	60	78	60	55	48
Dicamba	36	2	85	20	90	50	97	73	95	75	85	95	99	98	89	96
Glyphosate + 2,4-D[b]	8	0.4+0.6	80[c]	25[c]	35[e]	45	60[f]	0	..	..	..	40	40	60	0	0
Imazapic + Scoil + 28% N[g]	20	0.125+1 qt+1 qt					99	95	100	95	99	75	100	96	100	98
June (begun in 1994)																
Picloram	13	0.25		20[d]	30	68	80	78	88	83	87	90	94	95	98	70
Fosamine	80	8		78[d]	77	87	7	98	85	60	90	90	70[d]	79	78	80
Picloram + 2,4-D amine	28	0.5+1		63[d]	65	98	100	100	95	98	100	95	99	100	99	99
Picloram	25	0.5		33[d]	45	97	97	98	97	98	100	96	99	100	100	95
Picloram + 2,4-D amine	14	0.25+1		0[d]	•	25	68	90	90	98	83	96	85	100	82	85
2,4-D amine	6	2		0[d]	•	0	12	87	20	90	7	15	10	60	25	35
Dicamba	36	2		0[d]	•	23	50	100	50	90	18	55	53	99	47	50
Glyphosate + 2,4-D[b]	8	0.4+0.6		0[d]	•	25	35	0	70	98	20	10	33	70	53	35
June (begun 2000)																
Picloram+2,4-D +imazapic+MSO+28% N	25	0.25+1+0.06 +1 qt + 1 qt												100	99	100
Quinclorac + dicamba + diflufenzopyr[h] + MSO	32	0.375 + 0.18 + 0.075 + 1 qt												100	99	93
Quinclorac granules	NA	0.5												20	90	30

[a] Annual treatment cost, but does not include application cost.
[b] Commercial formulation - Landmaster BW. Distontinued in 2000.
[c] Grass injury was 60% in June 94 and 10% in Sept, treatment was discontinued after 1995 application because grass injury averaged 87%.
[d] Rain fell within 2 hours of treatment, resulting in much below average control.
[e] Grass injury was 60%.
[f] Grass injury was 30% and retreatments were stopped.
[g] Imazapic was first applied in Sept. 1996.
[h] Commercial formulation - Distinct.

Demonstration of leafy spurge control with various herbicides at Camp Grafton South.

Annual treatment	Rate	1998 May Control	1998 May Grs inj.	1998 August Control[b]	1999 May Control	1999 Aug Control	2000 June Control	2000 September Control	2000 September Grs inj.	2001 June Control	2001 August Control
	— oz/A—	—	—	—	—	—	%	—	—	—	—
Applied beginning in June 1998											
Picloram	4	..	..	20	12	50	38	94	0	72	95
Picloram + 2,4-D	4 + 16	..	..	50	7	80	70	90	0	85	85
Picloram + 2,4-D	8 + 16	..	..	55	83	90	90	99	0	96	89
Picloram	8	..	..	30	75	95	85	99	0	97	90
Fosamine	128	..	..	12	63	95	89	90	35	75	87
2,4-D	32	..	..	12	8	5	5	10	0	10	82
Dicamba	32	..	..	12	0	25	25	10	0	18	65
Glyphosate + 2,4-D[a]	16	..	..	73	8	50[c]	25	20	65	10	70
Applied beginning in June 2000											
Picloram+2,4-D + imazapic+MSO+28% N	4+16+1+1qt+ 1 qt							100	30[d]	60	50
Quinclorac+dicamba+diflufenzopyr[e]+MSO	6+3+1.2+1 qt							98	0	17	80
Quinclorac granule	8							10	0	80	40
Fall											
Picloram	8	85	15	45	92	40	95	65	0	95	87
Picloram + 2,4-D	8 + 16	88	25	33	92	25	92	72	0	96	81
Picloram + 2,4-D	4 + 16	78	10	10	86	30	68	40	0	85	53
2,4-D	32	20	0	0	50	0	45	0	0	20	0
Dicamba	32	65	5	40	75	20	70	70	0	87	52
Glyphosate + 2,4-D[a]	16	70	10	15	85[c]	10[c]	75	0[d]	80[f]	15	0
Imazapic+MSO+28% N	2 + 1 qt + 1qt	98	10	60	95	55	98	75	0	98	83
Quinclorac+dicamba+diflufenzopyr[e]+MSO	6+3+1.2+1 qt									95	60

[a] Commercial formulation - LandmasterBW.
[b] No grass injury was observed
[c] Approximately 20% grass injury observed.
[d] Brown tips on brome species only.
[e] Commercial formulation - Distinct.
[f] Treatment was not reapplied in 2000 due to high grass injury.

TEAM leafy spurge herbicide demonstration trial, Roger Meyers Ranch, Medora, ND.

Spring treatment	Year applied	Rate	Control 2001 May	Control 2001 Sept	Total cost [a] after 3 years	Comments
		oz/A	—— % ——		– $/A –	
2,4-D	1998, 1999, 2000	16	15	0	10	Top growth kill only, annual treatment
Picloram	1998, 1999, 2000	4	100	70	32	Short-term control only
Picloram + 2,4-D	1998, 1999, 2000	4 + 16	100	80	42	Better than either alone, annual treatment
Picloram + 2,4-D Picloram + 2,4-D	1998, 1999, 2000	8 + 16 4 + 16	100	92	52	Faster initial control than pint rate
Picloram	1998,1999	16	99	65	43	Spot treatment
Fosamine	1998, 1999	128	99	75	224	Use near edge of water
Dicamba	1998, 1999, 2000	32	100	60	123	Works best in western ND
Glyphosate + 2,4-D[b]	1998, 1999, 2000	6 +10	98	40	26	Occasional grass injury, less costly
Glyphosate + 2,4-D[b] Picloram + 2,4-D	1998, 2000 1999,	6 +10 4 +16	100	68	31	Rotational treatment reduces grass injury
Quinclorac + MSO Quinclorac+dicamba+diflufenzopyr+MSO[c]	1999, 2000	8 +1 qt 6+3+1+1 qt	100	97	80	Narrow spectrum, also good on field bindweed
Picloram+2,4-D+imazapic +MSO+28%N	2000	4+16+1+1 qt+1 qt	99	20	23	Three-way is better than picloram + 2,4-D alone.
Quinclorac granules	2000	8	75	10		Short-term control only. Not available.
Fall treatment						
Picloram	1998, 1999	8	100	45	65	Need the higher rate (quart) in the fall
2,4-D	1998, 1999, 2000	16	25	0	10	Top growth kill only
Picloram + 2,4-D	1998, 1999	8 + 16	100	70	49	Common fall treatment
Dicamba	1998, 1999, 2000	32	100	40	123	Best in western ND
Imazapic + MSO + 28% N	1998, 1999	2 + 1 qt + 1 qt	100	95	36	New fall treatment, has been effective
Imazapic + MSO + 28% N Picloram + 2,4-D	1998, 1999	2 + 1 qt + 1 qt 0.5 + 1	100	95	43	Rotational treatment to reduce grass injury
Quinclorac + MSO Quinclorac+dicamba+diflufenzopyr+MSO[c]	1999, 2000	8 + 1 qt 6+3+1+1 qt	100	95	80	

[a] Does not include application cost. [b] Commercial formulation, Landmaster BW. [c] Methylated seed oil.