Evaluation of herbicide mixtures for increased leafy spurge control. 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. For instance, picloram applied with 2,4-D has provided more cost-effective leafy spurge control compared to picloram applied alone at the same or higher application rates. Also, glyphosate applied with 2,4-D provided approximately 70% leafy spurge control 1 yr after treatment with minimal grass injury compared to glyphosate alone which provided less than 10% control with 70% or greater grass injury. The purpose of this research was to evaluate various herbicide mixtures for leafy spurge control compared to the same herbicides applied alone.

The first experiment compared various mixtures of picloram, 2,4-D, imazapic, and quinclorac applied with diflufenzopyr, an auxin transport inhibitor. The experiment was established on the Sheyenne National Grassland (SNG) and near Walcott, ND, on June 8 and 22, 2001, respectively, when the leafy spurge was in the true-flower growth stage and 14 to 28 inches tall. The herbicides were applied 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 averaged over both locations was 78% with picloram plus 2,4-D 12 months after treatment (MAT) 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 was similar when quinclorac was applied alone or with diflufenzopyr, dicamba, or dicamba plus diflufenzopyr and averaged 88% 12 MAT over both locations. The combination of quinclorac plus dicamba plus diflufenzopyr plus imazapic tended to provided the best long-term leafy spurge control, which averaged 88% 15 MAT on the SNG and 51% at Walcott. However, this treatment would cost over $50/A and would likely not be cost-effective.

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. Herbicides were applied as previously described, and plots at both locations were 10 by 30 feet with three replications.

In general, dicamba plus diflufenzopyr provided similar leafy spurge control when applied alone or with imazapic or imazapic plus 2,4-D at comparable application rates regardless of evaluation date (Table 2). Also, quinclorac applied alone generally provided similar leafy spurge control compared to quinclorac applied with dicamba plus diflufenzopyr. Imazapic applied alone provided the best long-term leafy spurge control, which averaged 99% over both application rates 12 months after a fall treatment. However, grass injury 9 MAT averaged over both locations was 11 and 22% when imazapic was applied at 2 and 3 oz/A, respectively. Grass injury only slightly declined by 12 MAT.

The third experiment compared picloram plus 2,4-D plus imazapic applied with both an MSO and 28%N to the same treatments without 28%N, without 2,4-D and 28%N, and a reduced imazapic rate. The experiment was established as previously described on the SNG in mid-June 2001.

The combination of picloram plus 2,4-D plus imazapic provided better leafy spurge control than the standard treatment of picloram plus 2,4-D 12 and 15 MAT (Table 3). Control was similar whether or not 28%N and 28%N plus 2,4-D were included in the combination treatment at comparable application rates. However, leafy spurge control tended to decline when the imazapic rate was reduced from 1 to 0.5 or 0.25 oz/A, especially when evaluated 15 MAT.

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. Leafy spurge control was similar when picloram plus imazapic were applied alone or with 28%N or 2,4-D plus 28%N. In general, the addition of diflufenzopyr to various treatments that included picloram, 2,4-D, or imazapic did not improve leafy spurge control compared to herbicide treatments applied alone. Herbicide mixtures that included quinclorac generally provided similar control to quinclorac applied alone. Dicamba plus diflufenzopyr did not provide long-term leafy spurge control when applied alone or with other herbicides.

Table 1. Leafy spurge control from various herbicide mixtures applied in June 2001 near Walcott and on the Sheyenne National Grassland (SNG) in North Dakota.

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

[a]Months after treatment.

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

[c]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.

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

[a] Months after treatment; spring/fall.

[b] Grass injury.

[c] Methylated seed oil was Scoil by AGSCO, Grand Forks, ND at 1 qt/A for all treatments.

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

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

Table 3. Evaluation of various mixtures of picloram plus 2,4-D plus imazapic for leafy spurge control on the Sheyenne National Grassland in June 2001.

		Control/MAT[a]		
Treatment	Rate	3	12	15
	—— oz/A ——	——	%	——
Picloram + 2,4-D	4 + 16	90	78	8
Imazapic + MSO[b] + 28% N	1 + 1 qt + 1 qt	82	87	13
Picloram + 2,4-D + imazapic + MSO + 28% N	4 + 16 + 1 + 1 qt + 1 qt	98	94	33
Picloram + 2,4-D + imazapic + MSO + 28% N	4 + 16 + 0.5 + 1 qt + 1 qt	95	90	29
Picloram + 2,4-D + imazapic + MSO + 28% N	4 + 16 + 0.25 + 1 qt + 1 qt	95	87	13
Picloram + 2,4-D + imazapic + MSO	4 + 16 + 1 + 1 qt	96	94	49
Picloram + 2,4-D + imazapic + MSO	4 + 16 + 0.5 + 1 qt	99	89	23
Picloram + 2,4-D + imazapic + MSO	4 + 16 + 0.25 + 1 qt	99	84	18
Picloram + imazapic + MSO	4 + 1 + 1 qt	89	96	47
Picloram + imazapic + MSO	4 + 0.5 + 1 qt	88	91	30
Picloram + imazapic + MSO	4 + 0.25 + 1 qt	95	86	17
LSD (0.05)		8	5	24

[a] Months after treatment.

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

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 weeds that favor moist growing conditions, such as perennial sowthistle, Canada thistle, and dock, have increased rapidly in North Dakota since the mid 1990s following several years of above average precipitation. The purpose of this research was to evaluate metsulfuron for control of perennial sowthistle, Canada thistle, and other weeds commonly found during moist growing conditions.

The first 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 foxtails 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-pressurized 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 control and bare ground evaluations were based on a visual assessment of stand reduction compared to the untreated control.

Metsulfuron provided excellent perennial sowthistle control at all application rates evaluated (Table 1). 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 and 78 and 72% for all plants present (bare ground) 11 and 14 MAT, respectively. Perennial sowthistle control averaged from 91 to 100% 26 MAT as the metsulfuron application rate increased from 0.3 to 1.8 oz/A, respectively. Clopyralid plus 2,4-D at 3 + 16 oz/A provided similar perennial sowthistle control as metsulfuron at 0.3 oz/A for 23 MAT but control declined to 79% by 26 MAT. Clopyralid alone and dicamba plus diflufenzopyr generally did not provide satisfactory perennial sowthistle control. Metsulfuron at 0.3 oz/A, the lowest rate evaluated, provided the most cost-effective perennial sowthistle control and the least injury to other species.

The second experiment was established on May 30, 2001, near Fargo to evaluate control of perennial sowthistle, Canada thistle, swamp smartweed, and dandelion with metsulfuron compared to auxin herbicides. Perennial sowthistle and Canada thistle were in the rosette growth stage with 4 to 6 leaves; swamp smartweed was approximately 8 inches tall; and dandelion was flowering. The experimental design was the same as the first experiment, and treatments were applied as previously described. The air temperature was 72 F with moist soil and good growing conditions.

As in the first study, metsulfuron provided excellent perennial sowthistle control at all application rates evaluated (Table 2). However, control declined much faster in the second compared to the first experiment (Table 1). For instance, metsulfuron at 0.3 oz/A provided 90% perennial sowthistle control 12 MAT, but control declined to 60% 15 MAT. The same treatment provided over 90% control for 2 yr in the first study. Treatments that contained clopyralid provided less long-term perennial sowthistle control than those that contained metsulfuron. For instance, perennial sowthistle control averaged across metsulfuron at all rates was 94% compared to 86% with all treatments that contained clopyralid. Dicamba plus diflufenzopyr did not provide acceptable perennial sowthistle control.

In general, swamp smartweed and dandelion were easily controlled by the herbicides evaluated in this study (Table 2). Metsulfuron at 0.3 oz/A and clopyralid at 4 oz/A only provided 77 and 68% swamp smartweed control 1 MAT, and clopyralid alone and dicamba plus diflufenzopyr provided less than 50% initial dandelion control. However, all treatments provided 100% control of these weeds by 3 MAT, so these species were not further evaluated (data not shown). Treatments that contained clopyralid provided better Canada thistle control than dicamba plus diflufenzopyr and metsulfuron at all application rates evaluated except 0.9 oz/A (Table 2). Canada thistle control 12 MAT was 95% averaged over all treatments with clopyralid and metsulfuron at 0.9 oz/A compared to 78% or less with all other treatments. Canada thistle control rapidly declined by 15 MAT with all treatments except clopyralid at 4 oz/A, which averaged 85%.

The third experiment was also established on May 30, 2001, to further evaluate swamp smartweed control with metsulfuron. There was a dense stand of swamp smartweed, which ranged from 8 to 18 inches tall with 3 to 15 leaves. There also was a moderate density of perennial sowthistle and Canada thistle, which were in the rosette growth stage. The treatments were applied as previously described.

As in the previous studies, metsulfuron at all rates applied provided near complete control of swamp smartweed and perennial sowthistle (Table 3). However, in this study metsulfuron provided better Canada thistle control than clopyralid or with 2,4-D or triclopyr. For instance, Canada thistle control was 80% 15 MAT averaged over all metsulfuron treatments compared to 52% or less with treatments that contained clopyralid.

In summary, metsulfuron provided excellent long-term control of swamp smartweed and perennial sowthistle. Clopyralid provided better Canada thistle control than metsulfuron in two of the three studies. Further research is needed to determine if swamp smartweed and perennial sowthistle can be controlled with metsulfuron at rates less than 0.3 oz/A.

Table 1. Perennial sowthistle (PEST) control and bareground (BG) with metsulfuron applied in July 2000 at Fargo, ND.

		Control/MAT[a]								
		2	11		14		23		26	
Treatment	Rate	PEST	PEST	BG[b]	PEST	BG[b]	PEST	BG[b]	PEST	BG[b]
	oz/A	%								
Metsulfuron + X-77	0.3 + 0.25%	88	99	20	96	3	98	17	91	0
Metsulfuron + X-77	0.45 + 0.25%	96	96	53	100	21	97	1	96	0
Metsulfuron + X-77	0.6 + 0.25%	92	99	76	100	38	97	13	96	0
Metsulfuron + X-77	0.9 + 0.25%	100	99	58	100	49	99	20	100	0
Metsulfuron + X-77	1.2 + 0.25%	100	100	80	100	76	100	17	99	0
Metsulfuron + X-77	1.8 + 0.25%	100	100	76	100	67	99	16	100	0
Clopyralid + X-77	4 + 0.25%	63	85	1	57	1	63	14	49	0
Clopyralid + 2,4-D[b] + X-77	3 + 16 + 0.25%	84	90	5	89	0	80	10	79	0
Dicamba + diflufenzopyr[c] + X-77	3 + 1.2 + 0.25%	60	47	0	13	0	43	16	45	0
LSD (0.05)		14	6	24	21	25	20	NS	29	NS

[a]Months after treatment.

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

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

Table 2. Evaluation of metsulfuron and auxin herbicides for perennial sowthistle (PEST), swamp smartweed, Canada thistle (CT), and dandelion control applied in May 2001 near Fargo, ND.

		Control/MAT[a]									
		1				3		12		15	
Treatment	Rate	PEST	Swamp smartweed	CT	Dandelion	PEST	CT	PEST	CT	PEST	CT
	— oz/A —	— % —									
Metsulfuron + X-77	0.3 + 0.25%	70	77	64	92	97	45	90	69	60	3
Metsulfuron + X-77	0.45 + 0.25%	91	93	78	92	93	78	91	78	65	23
Metsulfuron + X-77	0.6 + 0.25%	96	80	58	93	100	78	97	74	67	13
Metsulfuron + X-77	0.9 + 0.25%	99	98	65	98	100	99	99	95	55	5
Clopyralid	4	86	68	87	35	95	99	88	95	57	85
Clopyralid + 2,4-D[b]	4 + 16	98	97	92	75	85	88	80	95	33	56
Clopyralid + triclopyr[c]	4 + 11	99	95	91	88	94	89	89	95	52	63
Dicamba + diflufenzopyrd[d] + X-77	3 + 1.2	46	90	51	45	54	49	72	74	38	23
LSD (0.05)		19	27	20	23	18	27	11	NS	NS	53

[a] Months after treatment. Control of swamp smartweed and dandelion was 100% 3 MAT regardless of treatment and were not further evaluated.

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

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

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

Table 3. Metsulfuron and auxin herbicides for swamp smartweed (SWSW), perennial sowthistle (PEST), and Canada thistle (CT) control near Fargo, ND .

		Control/Months after treatment										
		1		3			12			15		
Treatment	Rate	SWSW	PEST	SWSW	PEST	CT	SWSW	PEST	CT	SWSW	PEST	CT
	— oz/A —	— % control —										
Metsulfuron + X-77	0.3 + 0.25%	77	74	99	99	99	87	92	83	99	96	83
Metsulfuron + X-77	0.45 + 0.25%	89	97	100	100	97	88	97	76	100	99	78
Metsulfuron + X-77	0.6 + 0.25%	92	86	98	100	100	86	97	73	100	98	78
Metsulfuron + X-77	0.9 + 0.25%	93	99	98	100	99	95	95	32	100	100	80
Clopyralid	4	52	84	99	100	98	24	24	39	99	60	42
Clopyralid + 2,4-D[a]	4 + 16	99	98	100	100	97	97	53	48	100	21	34
Clopyralid + triclopyr[b]	4 + 11	92	96	100	100	97	93	32	51	95	34	52
Dicamba + diflufenzopyr[c] + X-77	3 + 1.2 + 0.25%	95	85	98	65	50	87	0	18	100	0	0
LSD (0.05)		24	NS	NS	9	19	26	31	40	4	31	34

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

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

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

Evaluation of various herbicide mixtures applied in May or September for Canada thistle control. 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 1.4 million acres, compared to 822,000 acres in 1992. The increase has occurred in cropland, pasture and rangeland, and wildland. The increase is due in part to the much above average precipitation received in the state since 1993. Although many people apply herbicides to control Canada thistle in July and August during flowering and seed-set, research at North Dakota State University has shown that the optimum timing for herbicide application is during the rosette growth stage in late-spring or fall. The purpose of this research was to compare various herbicide mixtures, especially those that contain clopyralid, for Canada thistle control when applied in the spring or fall.

The experiments were established in dense Canada thistle patches located near Fargo or Valley City, ND. Separate spring and fall studies were established on May 30 and 31, 2001, or September 18 and 13, 2001, at Fargo and Valley City, respectively. The Fargo location was former cropland that had been allowed to become weedy, while the Valley City location was wildland that was neither hayed nor grazed. The spring treatments were applied to Canada thistle in the rosette growth stage with an average of six leaves. The fall treatments were applied to Canada thistle in the post-bloom growth stage with numerous fall rosettes beginning growth within the canopy. The Canada thistle was 18 to 36 inches tall at Valley City but only 6 inches tall at Fargo because the area had been mowed in July. The experiments were in a randomized complete block design with three replicates at Valley City and four replicates at Fargo. Plots were 10 by 25 or 10 by 30 feet at Fargo and Valley City, respectively. 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.

All spring-applied herbicide treatments provided good Canada thistle control 3 months after treatment (MAT) except 2,4-D applied alone and metsulfuron (Table 1). Treatments that contained clopyralid or picloram provided the best control 12 MAT, especially at Fargo. For instance, Canada thistle control averaged over both locations was 85% when clopyralid was applied with triclopyr or 2,4-D, 87% when picloram was applied alone or with 2,4-D, but only 62% with dicamba applied alone or with 2,4-D. Control was similar when clopyralid was applied with triclopyr or 2,4-D at comparable clopyralid rates of 4 or 6.4 oz/A. 2,4-D plus triclopyr did not provide satisfactory Canada thistle control.

Canada thistle control 9 MAT generally was greater than 90% with all fall applied treatments except 2,4-D and dicamba plus 2,4-D at Fargo (Table 2). Control declined rapidly at both locations 12 MAT, and as in the first study, treatments that contained clopyralid or picloram provided the best control. Also, clopyralid plus 2,4-D provided similar control to clopyralid plus triclopyr and control 12 MAT increased as the clopyralid rate increased. Picloram at 6 oz/A applied alone generally provided better long-term Canada thistle control than picloram at 2 or 4 oz/A applied with 2,4-D.

In summary, clopyralid applied at greater than 5 oz/A with triclopyr or 2,4-D and picloram at 6 oz/A provided the best long-term Canada thistle control. Dicamba or picloram applied alone provided better control than the same herbicides applied at reduced rates with 2,4-D. Although not directly comparable, similar treatments applied in the spring provided better Canada thistle control 12 MAT compared to fall application.

Table 1. Canada thistle control by various herbicide mixtures applied in May 2001.

		Control/MAT[a]					
		3		12		15	
Treatment	Rate	Fargo	Valley City	Fargo	Valley City	Fargo	Valley City
	oz/A	%					
Clopyralid + triclopyr[b] + X-77	4 + 11+ 0.25%	81	84	62	93	45	50
Clopyralid + triclopyr[b] + X-77	4.8 + 13.2 + 0.25%	91	98	70	93	39	76
Clopyralid + triclopyr[b] + X-77	5.6 + 15.4 + 0.25%	94	96	83	96	62	80
Clopyralid + triclopyr[b] + X-77	6.4 + 17.6 + 0.25%	97	96	83	96	79	60
Clopyralid + 2,4-D[c]	4 + 24	91	96	85	83	56	59
Clopyralid + 2,4-D[c]	6.4 + 36	89	98	78	98	35	86
2,4-D + triclopyr[d] + X-77	16 + 8	76	74	62	83	35	23
2,4-D + X-77	32 + 0.25%	53	64	55	58	0	7
Dicamba + X-77	24 + 0.25%	70	78	28	92	23	13
Dicamba + 2,4-D[e]	12 + 36	75	89	57	71	28	12
Picloram + X-77	6 + 0.25%	98	96	89	93	80	77
Picloram + 2,4-D	2 + 8	79	84	80	92	50	48
Picloram + 2,4-D	4 + 16	89	94	74	94	33	72
Metsulfuron + X-77	0.18 + 0.25%	15	69	7	93	8	35
LSD (0.05)		17	17	17	15	36	20

[a] Months after treatment.
[b] Commercial formulation - Redeem by Dow AgroSciences, Indianapolis, IN.
[c] Commercial formulation - Curtail by Dow AgroSciences, Indianapolis, IN.
[d] Commercial formulation - Crossbow by Dow AgroSciences, Indianapolis, IN.
[e] Commercial formulation - Weedmaster by BASF, Research Triangle Park, NC.

Table 2. Canada thistle control by various herbicide mixtures applied in September 2001.

Treatment	Rate	Control/MAT[a]			
		9		12	
		Fargo	Valley City	Fargo	Valley City
	oz/A	%			
Clopyralid + triclopyr[b] + X-77	4 + 11+ 0.25%	92	99	60	73
Clopyralid + triclopyr[b] + X-77	4.8 + 13.2 + 0.25%	93	99	61	73
Clopyralid + triclopyr[b] + X-77	5.6 + 15.4 + 0.25%	97	99	68	82
Clopyralid + triclopyr[b] + X-77	6.4 + 17.6 + 0.25%	99	99	88	85
Clopyralid + 2,4-D[c]	4 + 24	88	98	49	70
Clopyralid + 2,4-D[c]	6.4 + 36	99	99	79	79
2,4-D + X-77	32 + 0.25%	23	85	12	2
Dicamba + X-77	24 + 0.25%	97	99	84	52
Dicamba + 2,4-D[d]	12 + 36	46	94	21	40
Picloram + X-77	6 + 0.25%	99	100	97	83
Picloram + 2,4-D	2 + 8	85	99	55	61
Picloram + 2,4-D	4 + 16	90	99	67	70
LSD (0.05)		10	3	20	20

[a] Months after treatment.

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

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

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

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 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. The experiment was a randomized complete block design and plots were 10 by 30 feet with four 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.

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). 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 and 27 MAT. All herbicide treatments evaluated in this study would provide good general broadleaf weed control in pastures, especially those with various thistle species.

Table. Goldenrod, bull thistle and Flodman thistle control with clopyralid applied alone or with other herbicides and dicamba plus diflufenzopyr in June 2000.

		Control/MAT[a]					
		1		3	11	16	27
Treatment	Rate	Golden rod	Thistle[b]	Thistle[b]	Thistle[b]	Thistle[b]	Thistle[b]
	oz/A	%					
Clopyralid + triclopyr[c] + X-77	3 + 9 + 0.25%	81	91	100	98	98	99
Clopyralid + triclopyr[c] + X-77	4.5 + 13.5 + 0.25%	85	96	100	98	99	99
Clopyralid + triclopyr[c] + X-77	6 + 18 + 0.25%	95	97	100	98	100	99
Clopyralid + 2,4-D[d] + X-77	3 + 16 +0.25%	83	96	100	98	99	100
Clopyralid + 2,4-D[d] + X-77	4 + 24 + 0.25%	86	96	100	99	99	100
Clopyralid + X-77	4 + 0.25%	63	98	100	97	99	100
Dicamba + diflufenzopyr[e] + quinclorac + MSO[f]	3 + 1.2 + 6 + 0.25%	79	86	100	97	99	100
Dicamba + diflufenzopyr[e] + + X-77	3 + 1.2 + 0.25%	89	94	100	98	99	98
Triclopyr + X-77	9 + 0.25%	59	76	94	93	92	96
Triclopyr + X-77	18 + 0.25%	90	85	100	84	91	98
LSD (0.05)		18	9	3	9	5	3

[a] Months after treatment.
[b] Mixture of bull thistle and Flodman thistle.
[c] Commercial formulation - Redeem, by DowAgro Sciences, Indianapolis, IN.
[d] Commercial formulation - Curtail.
[e] Commercial formulation - Distinct, by DowAgro Sciences, Indianapolis, IN.
[f] Methylated seed oil was Scoil by AGSCO, Grand Forks, ND.

Evaluation of herbicides for purple loosestrife control. Rodney G. Lym. (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 at two locations in North Dakota.

The first 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 tall. 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.

2,4-D acid as the NB30380 formulation provided much better purple loosestrife control 13 months after treatment (MAT) than as the NB20652 formulation and averaged 81 compared to 26% control, respectively (Table 1). Purple loosestrife control from glyphosate and triclopyr averaged 92% 13 MAT which was similar to control reported in previous experiments conducted at North Dakota State University. Glyphosate also provided near complete control of cattails (data not shown). The high level of purple loosestrife control continued through the second growing season (23 MAT), and averaged 83% with all treatments except NB20652.

A second experiment to evaluate the NB30380 formulation of 2,4-D acid compared to triclopyr and glyphosate for purple loosestrife control was established along a city drain in an open green space within the Fargo, ND, city limits. Purple loosestrife had been established for at least 5 yr, was flowering, and was approximately 18 inches tall when herbicides were applied on July 20, 2001. In this experiment, herbicides were applied with a hand-held 4-nozzle boom sprayer delivering 8.5 gpa at 35 psi. There were three replicates which paralleled the drain.

As in the first experiment, the NB30380 formulation of 2,4-D acid provided good initial purple loosestrife control, which averaged 84% 1 MAT. Control from NB30380 was much better than from the NB20652 and mixed amine 2,4-D formulations which averaged 32 and 45%, respectively. EH1389 is an experimental glyphosate formulation, which provided similar control to the commercial formulation, and averaged 85% 1 MAT. No treatment provided satisfactory purple loosestrife control the following growing season and control declined to 33% or less for all treatments 13 MAT.

Purple loosestrife control with triclopyr, glyphosate, and NB30380 varied by location which was likely due to more uniform coverage at the Valley City compared to the Fargo location. In the first study, herbicides were applied with a back-pack single-nozzle sprayer at approximately 60 gpa compared to a boom sprayer that delivered 8.5 gpa in the second experiment. Glyphosate and 2,4-D acid as the NB30380 formulation but not triclopyr, provided the most consistent purple loosestrife control regardless of application method.

Table1. Purple loosestrife control with various formulations of 2,4-D compared to glyphosate and triclopyr applied with a single nozzle sprayer at 60 gpa in Valley City, ND.

		Control/MAT[a]			
Treatment	Rate	1	11	13	23
	— lb/A —			%	
2,4-D acid (NB20652)[b]	0.94	100	31	26	35
2,4-D acid (NB30380)[c]	2.5	100	98	81	83
Glyphosate	3.6	100	100	92	88
Triclopyr	2.7	100	98	92	78
LSD (0.05)		NS	17	25	41

[a]Months after treatment.

[b]2,4-D acid formulation at 1.88 lb/gal from PBI-Gordon, Kansas City, MO.

[c]2,4-D acid formulation at 5 lb/gal from PBI-Gordon, Kansas City, MO.

Table 2. Purple loosestrife control with various formulations of 2,4-D compared to glyphosate and triclopyr applied with a boom sprayer at 8.5 gpa in Fargo, ND.

		Control/MAT[a]		
Treatment	Rate	1	11	13
	— lb/A —		%	
2,4-D acid (NB20652)[b] + NIS[c]	0.95 + 0.25%	32	20	0
2,4-D acid (NB22267)[d] + NIS[c]	0.95 + 0.25%	81	46	33
2,4-D amine[d] + NIS[c]	0.95 + 0.25%	45	46	33
Glyphosate (EH1389)[e]	3.6	83	50	25
Glyphosate + NIS[c]	3.6 + 0.25%	88	72	10
2,4-D acid (NB20652)[b] + glyphosate (EH1389)[e]	0.71 + 1.875	73	30	3
Triclopyr	1	53	28	10
2,4-D acid (NB30380)[f] + NIS[c]	2.5 + 0.25%	84	48	32
LSD (0.05)		26	NS	NS

[a] Months after treatment.

[b] 2,4-D acid formulation at 1.88 lb/gal from PBI-Gordon, Kansas City, MO.

[c] NIS was a nonionic surfactant, Aqua Zorb from PBI-Gordon, Kansas City, MO.

[d] 2,4-D DMA formulation at 1.88 lb/gal (HiDep) from PBI-Gordon, Kansas City, MO.

[e] Experimental formulation of glyphosate from PBI-Gordon, Kansas City, MO.

[f] 2,4-D acid formulation at 5 lb/gal from PBI-Gordon, Kansas City, MO.

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 as both adults and egg masses were found in 1999 and the population steadily increased through 2002 (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 by 2000, 2 yr after release, and at 50 feet by 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 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. By 2001 and 2002 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 and the lythrum population decreased.

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 release	Flowering stems				Stems					Stem height				Spike length	
	1998	2000	2001	2002	1998	1999	2000	2001	2002	1999	2000	2001	2002	1999	2000
	no./m^2				no./m^2					m				cm	
0 (release)	0	0	0	0	10	15	58	30	2	1.4	0.4	0.8	0.2	0	0
25 feet	6	0	0	0	14	19	22	10	22	1.2	0.5	0.5	0.3	10	0
50 feet	2	0	0	0	35	14	50	31	8	0.9	0.8	0.7	0.2	6	10

[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 release[a]	1998			1999			2000			2001			2002		
	Eggs	Larvae	Adults	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	119	54	4
25 feet	2	1	0	2	0	2	11	0	1	0	34	4	169	82	5
50 feet	0	1	0	6	0	2	30	0	2	13	10	8	52	21	2

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