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

The first study was established at the Sheyenne National Grassland (SNG) near Lisbon, ND in June 2001. Leafy spurge was in the true-flower growth stage when treatments were applied with a hand-held sprayer delivering 8.5 gpa at 35 psi. The experiment was in a randomized complete block design with three replicates and plots were 10 by 30 feet. Control was based on a visual estimate of percent stand reduction as compared to the untreated check.

Imazapic applied with picloram or picloram plus 2,4-D provided better leafy spurge control than picloram and picloram plus 2,4-D applied alone and control increased as the imazapic rate increased (Table 1). For instance, picloram plus 2,4-D applied alone provided an average of 78% leafy spurge control 12 MAT (months after treatment) but control averaged 95% when picloram or picloram plus 2,4-D was applied with imazapic at 1 oz/A. Leafy spurge control was similar whether or not 2,4-D or 28% N was included in the combination treatment. However, control declined or tended to decline when the imazapic rate was reduced from 1 to 0.25 oz/A. Leafy spurge control 15 MAT with imazapic at 1 oz/A with picloram or picloram plus 2,4-D averaged 43% compared to 8% with picloram plus 2,4-D and 13% with imazapic applied alone. Leafy spurge control 24 MAT averaged 31% with imazapic at 1 oz/A applied with picloram and picloram plus 2,4-D.

The second study was established at the Albert Ekre Research Center near Walcott and near Valley City, ND on June 20, 2002 to further evaluate leafy spurge control with reduced rates of imazapic plus picloram and 2,4-D. The experiment was established as previously described except there were four replicates at both locations.

As in the first experiment, leafy spurge control with the combination treatment of imazapic plus picloram plus 2,4-D provided better leafy spurge control than the herbicides applied alone (Table 2). For instance, leafy spurge control with picloram plus 2,4-D 12 and 15 MAT averaged 81 and 36%at Walcott, but when applied with imazapic control averaged 96 and 69%. In general, leafy spurge control was not influenced by a reduction in imazapic rates as seen in the first experiment. Control was similar whether or not 28% N or 2,4-D were included in the treatment. Leafy spurge control at Valley City was variable, not only between treatments but between observation dates, and may have been influenced by *Aphthona* spp. flea beetle biocontrol agents.

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

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

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

*Table 1.* Leafy spurge control from various combinations of imazapic plus picloram plus 2,4-D applied in June 2001 at Sheyenne National Grassland near Lisbon, ND.

| | | Control/MAT[1] | | | |
|---|---|---|---|---|---|
| Treatment | Rate | 3 | 12 | 15 | 24 |
| | —— oz/A —— | —— | —— % | —— | —— |
| Picloram + 2,4-D | 4 + 16 | 90 | 78 | 8 | 0 |
| Imazapic + MSO[2] + 28% N | 1 + 1 qt + 1 qt | 82 | 87 | 13 | 5 |
| Picloram + 2,4-D + imazapic + MSO[2] + 28% N | 4 + 16 + 1 + 1 qt + 1 qt | 98 | 94 | 33 | 33 |
| Picloram + 2,4-D + imazapic + MSO[2] + 28% N | 4 + 16 + 0.5 + 1 qt + 1 qt | 95 | 90 | 29 | 10 |
| Picloram + 2,4-D + imazapic + MSO[2] + 28% N | 4 + 16 + 0.25 + 1 qt + 1 qt | 95 | 87 | 13 | 0 |
| Picloram + 2,4-D + imazapic + MSO[2] | 4 + 16 + 1 + 1 qt | 96 | 94 | 49 | 26 |
| Picloram + 2,4-D + imazapic + MSO[2] | 4 + 16 + 0.5 + 1 qt | 99 | 89 | 23 | 14 |
| Picloram + 2,4-D + imazapic + MSO[2] | 4 + 16 + 0.25 + 1 qt | 99 | 84 | 18 | 7 |
| Picloram + imazapic + MSO[2] | 4 + 1 + 1 qt | 89 | 96 | 47 | 32 |
| Picloram + imazapic + MSO[2] | 4 + 0.5 + 1 qt | 88 | 91 | 30 | 24 |
| Picloram + imazapic + MSO[2] | 4 + 0.25 + 1 qt | 95 | 86 | 17 | 6 |
| LSD (0.05) | | 8 | 5 | 24 | 13.5[3] |

[1] Months after treatment.

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

[3] LSD (0.10).

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

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

[1] Months after treatment.

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

[3] LSD (0.10).

*Table 3.* Leafy spurge control 9 and 12 months after treatment with imazapic at various rates applied in September 2002 at Walcott, Jamestown, Valley City, and the Sheyenne National Grassland (SNG), ND

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

[1] Grass injury.

[2] Does not include the SNG data.

[3] MSO = Methylated seed oi, Scoil by AGSCO, Grand Forks, ND.

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

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

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

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

In general, dicamba plus diflufenzopyr spring-applied provided similar leafy spurge control when applied alone or with imazapic or imazapic plus 2,4-D at comparable rates regardless of evaluation date (Table 2). Also, quinclorac alone spring-applied generally provided similar leafy spurge control compared to quinclorac applied with dicamba plus diflufenzopyr. Imazapic alone fall-applied provided the best long-term leafy spurge control, which averaged 99% over both rates 12 months after treatment. However, grass injury 9 MAT averaged over both locations was 11 and 22% with imazapic at 2 and 3 oz/A, respectively. Grass injury only slightly declined by 12 MAT. Leafy spurge control averaged of 85 and 98% 18 MAT when imazapic was applied at 2 and 3 oz/A, respectively. Leafy spurge control with imazapic at 3 oz/A averaged 94% 24 MAT at the SNG, but only 62% at Walcott, while imazapic applied at 2 oz/A averaged 71 and 55%, respectively (data not shown). Grass injury was not observed with either treatment 24 MAT.

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

Leafy spurge control 12 MAT with imazapic was similar when applied at 1 oz/A alone or with diflufenzopyr or diflufenzopyr plus dicamba and averaged 92 and 73% at the SNG and Valley City, respectively(Table 3). Imazapic at 2 oz/A averaged 95% leafy spurge control 12 MAT regardless of location compared to 49% with picloram plus 2,4-D at 8 + 16 oz/A. Also, quinclorac applied with imazapic provided similar leafy spurge control to the herbicides applied alone (Table 4). Again, the addition of diflufenzopyr with imazapic or quinclorac provided similar leafy spurge control to the herbicides applied alone.

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

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

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

[a]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.

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

[a] Months after treatment; spring/fall.

[b] Grass injury.

[c] MSO = methylated seed oil at 1 qt/A , Scoil by AGSCO, Grand Forks, ND 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.* Leafy spurge control with imazapic applied alone or with diflufenzopyr and diflufenzopyr plus dicamba on the Sheyenne National Grassland (SNG) and near Valley City, North Dakota in September 2002.

| Treatment | Rate | Location / time after treatment: 9 MAT[a] SNG Control | 9 MAT SNG GI | 9 MAT Valley City Control | 9 MAT Valley City GI | 12 MAT SNG Control | 12 MAT Valley City Control |
|---|---|---|---|---|---|---|---|
| | —— oz/A —— | —— % —— | | | | | |
| Imazapic + MSO[b] | 1 + 1 qt | 99 | 1 | 100 | 8 | 93 | 67 |
| Imazapic + diflufenzopyr + MSO[b] | 1 + 0.2 + 1 qt | 99 | 1 | 99 | 9 | 94 | 72 |
| Imazapic + diflufenzopyr + MSO[b] | 1 + 0.1 + 1 qt | 94 | 2 | 100 | 6 | 92 | 76 |
| Imazapic + diflufenzopyr + MSO[b] | 1 + 0.5 + 1 qt | 96 | 1 | 99 | 5 | 93 | 81 |
| Imazapic + dicamba + diflufenzopyr[c] + MSO[b] | 1 + 0.6 + 0.2 + 1 qt | 92 | 3 | 99 | 5 | 87 | 77 |
| Imazapic + dicamba + diflufenzopyr[c] + MSO[b] | 1 + 0.3 + 0.1 + 1 qt | 98 | 1 | 100 | 17 | 88 | 82 |
| Imazapic + dicamba + diflufenzopyr[c] + MSO[b] | 1 + 0.5 + 0.15 + 1 qt | 98 | 5 | 100 | 8 | 94 | 56 |
| Dicamba + diflufenzopyr[c] + MSO[b] | 3 + 1.2 + 1 qt | 70 | 0 | 99 | 4 | 3 | 36 |
| Dicamba + diflufenzopyr[c] + MSO[b] | 0.3 + 0.1 + 1 qt | 85 | 0 | 88 | 4 | 0 | 15 |
| Imazapic + MSO[b] | 2 + 1 qt | 99 | 6 | 100 | 24 | 96 | 94 |
| Picloram + 2,4-D | 8 + 16 | 99 | 2 | 99 | 9 | 41 | 56 |
| LSD (0.05) | | 15 | 5 | 7 | 9 | 11 | 22 |

[a] Months after treatment.

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

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

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

| | | Location/Time after treatment | | | | | |
|---|---|---|---|---|---|---|---|
| | | 9 MAT[a] | | | | 12 MAT | |
| | | SNG | | Valley City | | SNG | Valley City |
| Treatment | Rate | Control | G I[b] | Control | G I[b] | Control | |
| | —— oz/A —— | —— % —— | | | | | |
| Imazapic + MSO[b] | 1 + 1 qt | 95 | 7 | 99 | 6 | 93 | 89 |
| Imazapic + diflufenzopyr + MSO[b] | 1 + 0.1 + 1 qt | 90 | 9 | 99 | 8 | 79 | 90 |
| Imazapic + quinclorac + MSO[b] | 1 + 2 + 1 qt | 96 | 3 | 100 | 9 | 94 | 91 |
| Imazapic + quinclorac + MSO[b] | 1 + 4 + 1 qt | 97 | 7 | 100 | 11 | 92 | 93 |
| Imazapic + quinclorac + diflufenzopyr + MSO[b] | 1 + 2 + 0.1 + 1 qt | 93 | 6 | 99 | 9 | 90 | 94 |
| Imazapic + quinclorac + diflufenzopyr + MSO[b] | 1 + 4 + 0.1 + 1 qt | 96 | 7 | 99 | 3 | 84 | 91 |
| Imazapic + dicamba + diflufenzopyr[c] + quinclorac + MSO[b] | 1 + 0.5 + 0.15 + 3 + 1 qt | 99 | 16 | 100 | 6 | 89 | 92 |
| Quinclorac + diflufenzopyr + MSO[b] | 2 + 0.1 + 1 qt | 71 | 0 | 99 | 1 | 68 | 72 |
| Quinclorac + diflufenzopyr + MSO[b] | 4 + 0.1 + 1 qt | 89 | 2 | 99 | 1 | 63 | 90 |
| Quinclorac + MSO[b] | 4 + 1 qt | 87 | 0 | 99 | 0 | 61 | 78 |
| Quinclorac + dicamba + diflufenzopyr[c] + MSO[b] | 8 + 6 + 3 + 1 qt | 98 | 2 | 99 | 1 | 64 | 97 |
| Picloram + 2,4-D | 8 + 16 | 99 | 4 | 99 | 2 | 72 | 74 |
| LSD (0.05) | | 7[e] | 6 | NS | 7 | 16 | 8 |

[a] Months after treatment.

[b] Grass injury.

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

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

[e] LSD (0.10).

Control of Canada thistle, perennial sowthistle, fringed sage and other troublesome weeds with herbicide mixtures that contain metsulfuron. Rodney G. Lym. (Plant Sciences Department, North Dakota State University, Fargo, ND 58105). Metsulfuron is a relatively low cost alternative to auxin-type herbicides for weed control in pasture, rangeland, and wild lands. However, metsulfuron generally has a narrow weed control spectrum and only moderate soil residual, which may be needed for long-term weed control. The purpose of this research was to evaluate metsulfuron applied alone and in combination with other herbicides for control of several noxious and troublesome weeds.

The first experiment was established on cropland that had been unused for 2 yr on the campus of North Dakota State University, Fargo. Metsulfuron applied alone or with several other herbicides was evaluated for control of Canada thistle (*Cirsium arvense* L.), plumeless thistle (*Carduus acanthoides* L.), prickly lettuce (*Lactuca serriola* L.), prostrate knotweed (*Polygonum aviculare* L.), and scentless chamomile (*Matricaria chamomilla* L.), also called false chamomile. The herbicides were applied on June 14, 2002 when the weeds were 3 inches or less in height and the thistles were in the rosette growth stage. The herbicides were applied using a hand-held boom sprayer delivering 17 gpa at 35 psi. The plots were 9 by 30 feet and replicated four times in a randomized complete block design. Control was based on a visual estimate of percent stand reduction as compared to the untreated check.

Metsulfuron at 0.06 oz/A alone provided 98 and 100% control of prickly lettuce and scentless chamomile 2 MAT (months after treatment) but did not provide satisfactory control of Canada thistle, plumeless thistle or prostrate knotweed (Table 1). Plumeless thistle and prostrate knotweed control improved to 90% or greater when metsulfuron was applied with 2,4-D plus dicamba or MCPA plus dicamba, but Canada thistle control still averaged less than 50% 2 MAT. Weed control for all species evaluated was similar whether metsulfuron was applied alone or with fluroxypyr or thifensulfuron plus tribenuron.

The second experiment was established on fallow cropland near Fargo to evaluate metsulfuron applied alone at various rates or with thifensulfuron plus tribenuron for perennial sowthistle (*Sonchus arvensis* L.) and Canada thistle control. Treatments were applied on June 20, 2002 as previously described, except the plots were 9 by 25 feet. Perennial sowthistle and Canada thistle were in the rosette growth stage with 4 to 10 leaves.

Metsulfuron provided nearly complete control of perennial sowthistle 15 MAT regardless of application rate (Table 2). Canada thistle control was similar regardless of metsulfuron rate or the addition of thifensulfuron plus tribenuron and averaged 74% control 15 MAT compared to only 43% control with clopyralid plus 2,4-D.

The third experiment was established to evaluate Canada thistle control by metsulfuron applied with dicamba plus 2,4-D in the fall. Herbicides were applied on Sept. 25, 2002 following a light frost when Canada thistle was in the rosette growth stage or had bolted and flowered and was 10 to 36 inches tall. The study was established as previously described near Fargo except the plots were 10 by 30 feet.

Metsulfuron plus dicamba plus 2,4-D provided short-term Canada thistle control and control 9 MAT increased from 86 to 96% as application rate increased (Table 3). However, control declined rapidly with all treatments that contained metsulfuron to less than 60% 12 MAT. Clopyralid plus triclopyr provided the best long-term control which averaged 90% 12 MAT.

The fourth and fifth experiments were established to evaluate metsulfuron applied with dicamba plus 2,4-D in the spring or fall for fringed sage control. The experiment was established on a pasture southwest of Jamestown, ND, with a dense stand of fringed sage. Herbicides were applied in separate experiments on June 25, 2002 when the fringed sage was in the vegetative growth stage or on Sept. 10, 2002 after the plants had flowered and were 10 to 12 inches tall. The plots were 10 by 30 feet, and treatments were replicated four times in a randomized complete block design.

Fringed sage control tended to increase as the metsulfuron plus dicamba plus 2,4-D rate increased (Table 4). Although not directly comparable, treatments applied in June tended to provide better control 12 MAT than the same treatment applied in September. For instance, metsulfuron plus dicamba plus 2,4-D at 0.15 + 2 + 5.8 oz/A applied in spring or fall provided 58 and 41% fringed sage control, respectively, 12 MAT. The mixture of metsulfuron with dicamba plus 2,4-D tended to provide better fringed sage control than clopyralid plus triclopyr when spring-applied but not fall-applied.

In summary, metsulfuron alone provided excellent control of perennial sowthistle and scentless chamomile but not the thistle species evaluated in these studies. Plumeless thistle control but not Canada thistle was improved when metsulfuron was applied with dicamba plus 2,4-D. The addition of thifensulfuron plus tribenuron to metsulfuron did not affect weed control regardless of the species evaluated in these studies. Fringed sage control with metsulfuron applied with dicamba plus 2,4-D was acceptable, especially when applied in June. Metsulfuron plus dicamba plus 2,4-D costs $6 to $14/A at the general use rates and, depending on the weed species present, is a cost-effective option for broadleaf weed control in pasture and rangeland.

*Table 1.* Control of prickly lettuce, Canada thistle, plumeless thistle, prostrate knotweed, and scentless chamomile by metsulfuron alone and with other herbicides applied in June 2002 at Fargo, ND.

| | | Time after treatment/weed species | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 MAT[1] | | | | 2 MAT | | | | 12 MAT | | |
| Treatment[2] | Rate | PRLE[1] | CT[1] | PLTH[1] | PRKW[1] | PRLE | CT | PLTH | Cham | PRLE | CT | PLTH |
| | oz/A | % | | | | | | | | | | |
| Metsulfuron | 0.06 | 92 | 51 | 56 | 78 | 98 | 23 | 63 | 100 | 96 | 10 | 67 |
| Metsulfuron + 2,4-D + dicamba | 0.3 + 16 + 8 | 100 | 70 | 90 | 96 | 100 | 43 | 100 | 100 | 100 | 8 | 99 |
| Metsulfuron + 2,4-D + dicamba | 0.6 + 16 + 8 | 99 | 81 | 93 | 99 | 100 | 48 | 100 | 100 | 99 | 5 | 96 |
| Metsulfuron + MCPA + dicamba | 0.3 + 8 + 8 | 100 | 84 | 86 | 100 | 100 | 62 | 100 | 100 | 100 | 5 | 96 |
| Metsulfuron + fluroxypyr | 0.3 + 1 | 93 | 50 | 70 | 56 | 100 | 30 | 89 | 100 | 100 | 0 | 84 |
| Metsulfuron + thifensulfuron + tribenuron[3] | 0.03 + 0.075 + 0.037 | 93 | 46 | 59 | 49 | 99 | 20 | 37 | 100 | 94 | 14 | 31 |
| Metsulfuron + thifensulfuron +tribenuron[3] | 0.06 + 0.15 + 0.074 | 87 | 40 | 46 | 95 | 99 | 31 | 73 | 100 | 99 | 8 | 61 |
| 2,4-D + dicamba | 16 + 8 | 96 | 68 | 90 | 96 | 100 | 35 | 98 | 92 | 83 | 9 | 57 |
| MCPA + dicamba | 8 + 8 + | 99 | 69 | 82 | 99 | 100 | 44 | 98 | 41 | 87 | 18 | 91 |
| Fluroxypyr | 1 | 21 | 0 | 31 | 33 | 6 | 0 | 25 | 53 | 91 | 0 | 23 |
| Clopyralid + triclopyr[4] | 13.5 + 4.5 | 100 | 87 | 94 | 78 | 100 | 73 | 100 | 90 | 91 | 45 | 73 |
| LSD (0.05) | | 7 | 25 | 19 | 38 | 6 | NS | 36 | 28 | NS | 22 | 27[5] |

[1] Abbreviations: MAT = months after treatment; PRLE = Prickly lettuce; CT = Canada thistle; PLTH = plumeless thistle; PRKW = prostrate knotweed, Cham = scentless chamomile.
[2] Surfactant X-77 at 0.25% v/v was applied with all treatments.
[3] Commercial formulation - Harmony Extra by DuPont, Wilmington, DE.
[4] Commercial formulation - Redeem by Dow AgroSciences, Indianapolis, IN.
[5] LSD = (0.10).

*Table 2.* Control of perennial sowthistle and Canada thistle by metsulfuron alone and with other herbicides applied in June 2002, at Fargo, ND.

| | Time after treatment/weed species | | |
|---|---|---|---|
| | 1 MAT[1] | 12 MAT | 15 MAT |

| Treatment[2] | Rate | PEST[1] | CT[1] | PEST | CT | PEST | CT |
|---|---|---|---|---|---|---|---|
| | —— oz/A —— | —— | —— | —— % | —— | —— | —— |
| Metsulfuron | 0.06 | 100 | 87 | 99 | 84 | 98 | 80 |
| Metsulfuron | 0.075 | 94 | 83 | 97 | 71 | 99 | 74 |
| Metsulfuron | 0.15 | 98 | 91 | 97 | 81 | 95 | 75 |
| Metsulfuron | 0.3 | 100 | 94 | 96 | 85 | 99 | 78 |
| Metsulfuron + thifensulfuron + tribenuron[3] | 0.03 + 0.075 + 0.037 | 97 | 85 | 96 | 80 | 92 | 70 |
| Metsulfuron + thifensulfuron + tribenuron[3] | 0.06 + 0.15 + 0.074 | 99 | 81 | 98 | 68 | 99 | 68 |
| Clopyralid + 2,4-D[d] | 1.52 + 8 | 96 | 76 | 94 | 73 | 65 | 43 |
| Glyphosate | 6 | 65 | 24 | 55 | 10 | 43 | 0 |
| LSD (0.05) | | 9 | 12 | 10 | 18 | 34 | 28 |

[1] Abbreviations: MAT = months after treatment; PEST = perennial sowthistle; CT = Canada thistle.

[2] Surfactant X-77 at 0.25% was applied with all treatments.

[3] Commercial formulation - Harmony Extra by DuPont, Wilmington, DE.

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

*Table 3.* Canada thistle control by metsulfuron with dicamba plus 2,4-D applied in September 2002, at Fargo, ND.

| Treatment | Rate | Control | |
|---|---|---|---|
| | | 9 MAT[1] | 12 MAT |
| | ——— oz/A ——— | ——— % | ——— |
| Metsulfuron + dicamba + 2,4-D[2] + MSO[3] | 0.15 + 2 +5.76 + 1 qt | 86 | 12 |
| Metsulfuron + dicamba + 2,4-D[2] + MSO[3] | 0.3 + 4 + 11.5 + 1 qt | 93 | 35 |
| Metsulfuron + dicamba + 2,4-D[2] + MSO[3] | 0.6 + 8 + 23 + 1 qt | 96 | 57 |
| Clopyralid + triclopyr[4] + X-77[5] | 4.5 + 13.5 + 0.25% | 97 | 90 |
| | | | |
| LSD (0.05) | | 6 | 21 |

[1] MAT = Months after treatment.
[2] Commercial formulation - Range Star by DuPont, Wilmington, DE.
[3] X-77 = nonionic surfactant from Loveland Industries, Greeley, CO.
[4] Commercial formulation - Redeem by Dow AgroSciences, Indianapolis, IN.
[5] MSO = methylated seed oil, Scoil by AGSCO, Grand Forks, ND.

*Table 4.* Control of fringed sage by metsulfuron with dicamba plus 2,4-D applied in June or September 2002 near Jamestown, ND.

| Treatment | Rate | Control | | |
|---|---|---|---|---|
| | | 2 MAT[1] | 12 MAT | 15 MAT |
| Spring applied | ——— oz/A ——— | ————— | % | ————— |
| Metsulfuron + dicamba + 2,4-D[2] + MSO[3] | 0.15 + 2 + 5.76 + 1 qt | 82 | 58 | 64 |
| Metsulfuron + dicamba + 2,4-D[2] + MSO[3] | 0.3 + 4 + 11.5 + 1 qt | 88 | 62 | 67 |
| Metsulfuron + dicamba + 2,4-D[2] + MSO[3] | 0.6 + 8 + 23 + 1 qt | 95 | 80 | 70 |
| Clopyralid + triclopyr[4] + X-77[5] | 4.5 + 13.5 + 0.25% | 85 | 48 | 46 |
| | | | | |
| LSD (0.05) | | 10 | 26[6] | 18 |
| | | | | |
| | | | 9 MAT | 12 MAT |
| Fall applied | | | ——— % | ——— |
| Metsulfuron + dicamba + 2,4-D[2] + MSO[3] | 0.15 + 2 + 5.76 + 1 qt | | 41 | 33 |
| Metsulfuron + dicamba + 2,4-D[2] + MSO[3] | 0.3 + 4 + 11.5 + 1 qt | | 60 | 51 |
| Metsulfuron + dicamba + 2,4-D[2] + MSO[3] | 0.6 + 8 + 23 + 1 qt | | 86 | 76 |
| Clopyralid + triclopyr[4] + X-77[5] | 4.5 + 13.5 + 0.25% | | 80 | 69 |
| | | | | |
| LSD (0.05) | | | 19[7] | 21 |

[1] MAT = Months after treatment.
[2] Commercial formulation - Range Star by DuPont, Wilmington, DE.
[3] MSO = methylated seed oil, Scoil by AGSCO, Grand Forks, ND.
[4] Commercial formulation - Redeem by Dow AgroSciences, Indianapolis, IN.
[5] X-77 = nonionic surfactant from Loveland Industries, Greeley, CO.
[6] LSD= (0.15) [7] LSD= (0.10)

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

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

Canada thistle control at Jamestown was better than at Valley City and data could not be combined over locations (Tables 1 and 2). Although not directly comparable, Canada thistle control 12 MAT (months after treatment) was much better when herbicides were applied in the fall (Table 2) compared to the same treatments applied in the spring (Table 1). Picloram applied at 6 oz/A in the spring tended to provide the best Canada thistle control at Jamestown compared to all other spring applied treatments and averaged 79% 12 MAT. The same treatment only averaged 10% control at Valley City (Table 1).

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

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

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

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

[a] Months after treatment.
[b] Commercial formulation - Curtail by Dow AgroSciences Indianapolis, IN.
[c] Commercial formulation - Redeem by Dow AgroSciences Indianapolis, IN.

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

| | | Location / time after treatment | | | |
|---|---|---|---|---|---|
| | | 9 MAT[a] | | 12 MAT | |
| Treatment | Rate | Valle y City | James town | Valley City | James town |
| | ——— oz/A ——— | —————— | —— % —— | —————— | |
| Clopyralid | 2.4 | 96 | 99 | 43 | 85 |
| Clopyralid | 4.8 | 98 | 99 | 88 | 91 |
| Clopyralid | 6.4 | 98 | 99 | 89 | 95 |
| Clopyralid + 2.4-D[b] | 4.8 + 25.5 | 96 | 99 | 48 | 80 |
| Clopyralid + 2,4-D[b] | 6.4 + 33.6 | 98 | 99 | 72 | 87 |
| Clopyralid + triclopyr[c] + X-77 | 4.5 + 13.5 + 0.25% | 97 | 99 | 80 | 94 |
| Clopyralid + triclopyr[c] + X-77 | 6 + 18 + 0.25% | 97 | 99 | 90 | 93 |
| Picloram | 6 | 98 | 99 | 97 | 99 |
| LSD (0.05) | | NS | NS | 25 | 10 |

[a] Months after treatment.
[b] Commercial formulation - Curtail by Dow AgroSciences, Indianapolis, IN.
[c] Commercial formulation - Redeem by Dow AgroSciences, Indianapolis, IN.

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

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

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

[1] Abbreviations: MAT = Months after treatment, RUKW = Russian knapweed, GI= grass injury.
[2] Commercial formulation - Redeem by Dow AgroSciences, Indianapolis, IN.
[3] MSO is methylated seed oil, Scoil by AGSCO, Grand Forks, ND.
[4] Commercial formulation - Range Star by DuPont, Wilmington, DE.
[5] Commercial formulation - Curtail by Dow AgroSciences, Indianapolis, IN.
[6] LSD (0.15).

Treatments that contained picloram or clopyralid provided greater than 90% Russian knapweed control 12 months after treatment (MAT) with little to no visible grass injury (Table). Imazapic at 3 oz/A provided 100% control up to 8 MAT but suppressed grass production, and Russian knapweed control declined to 79% by 12 MAT. Metsulfuron applied with dicamba and 2,4-D did not provide season-long Russian knapweed control and grass injury 8 MAT averaged 30%. Quinclorac only provided short-term Russian knapweed control. Very late-season treatments that contained picloram or clopyralid cost approximately $15 to $30/A at the rates used in this study and could be used to control Russian knapweed in a variety of environments.

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 rivers in two urban areas.

The first 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, stem 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. Initially, the number of stems increased 2 yr following the *Galerucella* spp. release from an average of 20 to 43/$m^2$ in 1998 to 2000, respectively. Thereafter, the number of stems declined regardless of the distance from the release point and averaged 2 stems/$m^2$ or less in 2003.

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.

The second study was established in a purple loosestrife infestation along a city storm drain in Fargo, ND. The experiment was designed as previously described except the distance measured from the release pole was increased to 100 feet in 25 foot increments. Approximately 10,000 *Galerucella* spp. were released in June 2002. As in the previous study the lythrum stem density increased initially following release (Table 3.) and *Galerucella* had established as egg masses and larvae were observed at and 25 feet from the release pole (Table 4).

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 | Stems 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | Stem height[b] 1999 | 2000 | 2001 | 2002 | 2003 | Spike length[bc] 1999 | 2000 | 2001 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | no./m² | | | | | | m | | | | | cm | | |
| 0 (release) | 10 | 15 | 58 | 30 | 2 | 2 | 1.4 | 0.4 | 0.8 | 0.2 | 0.2 | 0 | 0 | 0 |
| 25 feet | 14 | 19 | 22 | 10 | 22 | 1 | 1.2 | 0.5 | 0.5 | 0.3 | 0.1 | 10 | 0 | 0 |
| 50 feet | 35 | 14 | 50 | 31 | 8 | 0 | 0.9 | 0.8 | 0.7 | 0.2 | 0 | 6 | 10 | 0 |

[a] Estimates of purple loosestrife control were made in mid-July each year.
[b] Average of five tallest stems.
[c] No plants flowered after 2000 so data not shown.

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

| Distance from release[a] | 1998 Eggs | Larvae | Adults | 1999 Eggs | Larvae | Adults | 2000 Eggs | Larvae | Adults | 2001 Eggs | Larvae | Adults | 2002 Eggs | Larvae | Adults | 2003 Eggs | Larvae | Adults |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | no./m² | | | | | | | | | | | | | | | | | |
| 0 (release) | 0 | 2 | 1 | 0 | 0 | 0 | 40 | 0 | 4 | 23 | 94 | 0 | 119 | 54 | 4 | 5 | 4 | 0 |
| 25 feet | 2 | 1 | 0 | 2 | 0 | 2 | 11 | 0 | 1 | 0 | 34 | 4 | 169 | 82 | 5 | 1 | 0 | 0 |
| 50 feet | 0 | 1 | 0 | 6 | 0 | 2 | 30 | 0 | 2 | 13 | 10 | 8 | 52 | 21 | 2 | 0 | 0 | 0 |

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

*Table 3.* Purple loosestrife control with *Galerucella* spp. released in 2002 in Fargo, ND[a].

| Distance from release | Stems 2002 | 2003 | Stem height[b] 2002 | 2003 | Spike length[b] 2002 | 2003 |
|---|---|---|---|---|---|---|
| | no./m² | | m | | cm | |
| 0 (release) | 68 | 129 | 0.2 | 1.3 | 5 | 4.5 |
| 25 feet | 64 | 161 | 0.3 | 1.2 | 0.6 | 10 |
| 50 feet | 59 | 188 | 0.2 | 1.1 | 0 | 8.7 |
| 75 feet | • | 37 | • | 0.6 | • | 6.7 |
| 100 feet | • | 38 | • | 1.2 | • | 16.6 |

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

*Table 4.* Population change over time of *Galerucella* spp. on purple loosestrife at Fargo, ND[a]

| Distance from | 2003 | | |
|---|---|---|---|
| release | Eggs | Larvae | Adults |
| | no./m² | | |
| 0 (release) | 21 | 3 | 0 |
| 25 feet | 12 | 1 | 0 |
| 50 feet | 2 | 0 | 0 |
| 75 feet | 0 | 0 | 0 |
| 100 feet | 0 | 0 | 0 |

[a] Estimates of *Galerucella* spp. adults and egg masses were made in June of 2003.