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A summary of leafy spurge control with herbicides in North Dakota since 1963

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Leafy spurge (*Euphorbia esula* L.) is an introduced perennial weed that currently infests over 860,000 acres in North Dakota and is estimated to cause an economic loss of nearly \$13,000,000 annually (6). It is a long-lived perennial that was first reported in North Dakota in 1909 growing along a street in Fargo (3) and is now found in pasture, rangeland, and roadsides in every county of the state. Unlike many perennial weeds, leafy spurge will infest pasture and rangeland that is in otherwise excellent condition and can reduce the carrying capacity to nearly zero (4).

An integrated leafy spurge control program was begun at North Dakota State University in 1983 with the long range objective of stopping the spread of leafy spurge and gradually reducing the amount of infested acreage. The program combined researchers in the fields of agronomy, botany, entomology and plant pathology in a coordinated effort to find the most cost-effective method of leafy spurge control. Biological control of leafy spurge is the primary long-term goal, but herbicides are the only reliable control method presently available.

Several herbicides can provide effective leafy spurge control. However, perennial weed control by herbicides can vary from year to year depending on environmental conditions and experimental sites. Perennial weed infestations also vary in density at various sites. Data obtained by averaging leafy spurge control from several areas and years should provide the best assessment of a herbicides effectiveness for weed control. Data from experimental and demonstrational plots established by North Dakota State University were summarized for 2,4-D, dicamba (Banvel), picloram (Tordon) and glyphosate (Roundup), which are the primary herbicides currently used for leafy spurge control.

Materials and methods

Leafy spurge control by 2,4-D, dicamba, picloram and glyphosate at commonly applied rates in North Dakota was summarized for 20 years from many sites established between 1963 and 1982. Data were taken from 70 North Dakota Agricultural Experiment Station sites and 68 demonstration sites established by the North Dakota Cooperative Ex-

tension Service and summarized across years by herbicide. The 2,4-D amine and ester formulations have given similar leafy spurge control (5) and data were combined for this summary. Only the liquid formulations of dicamba and picloram were evaluated for this report. The herbicides were applied in water at 8 to 18 gallons per acre, except a few demonstration sites were treated in higher volumes.

Data for each treatment are a mean of percent control based on visual or stand count observations. Each plot evaluated was considered an observation; an experiment with four replications had four observations per treatment, while a demonstration with two replications at 12 sites had 24 observations. The number of observations per mean is presented in parentheses as a guide to the probable reliability of each mean. The data were analyzed using the General Linear Models procedure (8). Experiments containing biannual treatments had herbicides applied twice per year in both the spring and fall.

Results and discussion

Control with 2,4-D

Leafy spurge control varied widely when 2,4-D was applied at 1 or 2 pounds per acre and neither treatment provided long term control (Table 1). Leafy spurge control averaged 47 and 57 percent after three months for 2,4-D applied at 1 and 2 pounds per acre, respectively, but varied to a maximum of 98 percent and a minimum of 5 and 24 percent, respectively. Leafy spurge control decreased similarly for 2,4-D at 1 and 2 pounds per acre 12 months after application and averaged only 7 and 19 percent control, respectively. In North Dakota, 2,4-D can be expected to provide 50 to 70 percent leafy spurge control for one to two months. However, as with all herbicides, control can vary widely depending on environmental conditions, plant density, and how long the infestation has been present. There is a trend for 2,4-D to provide better control at 2 pounds per acre compared to 1 pound per acre. However, annual retreatment will be required in any case, so there may not be an economic advantage from applying the high rate of 2,4-D.

Biannual (both spring and fall) 2,4-D applications generally did not provide greater leafy spurge control than the initial treatment (Table 2). Leafy spurge control averaged for 2,4-D at 1 through 2 pounds per acre was 49 percent after one treatment (three months) and 59 percent after four treatments (24 months). Generally leafy spurge control was not enhanced by increasing the 2,4-D rate from 1 to 1.5 or 2 pounds per acre in a biannual treatment program. Leafy spurge control at 12 months declined substantially following a single 2,4-D application (Table 1), while biannual 2,4-D treatments maintained the initial level of weed control. However, Bybee and Messersmith (2) reported that leafy spurge reestablished to the original density within one year after discontinuation of treatments that had been applied biannually for 4.5 years. Both annual and biannual 2,4-D applications should eliminate seed production and greatly reduce or prevent a leafy spurge stand from expanding. Annual 2,4-D applications for leafy spurge control provide nearly a 40 percent increase in forage production over untreated areas (4), and presumably biannual 2,4-D applications would provide a similar increase in forage production.

Table 1. Average leafy spurge control with 2,4-D, dicamba or picloram spring or fall applied for leafy spurge control in North Dakota.

Herbicide	Rate (lb/A)	Months after treatment	Control	
			Mean ¹	Range
			----- (%) -----	
2,4-D	1	3	47(197)	5 to 98
	2	3	57(190)	24 to 98
	1	9	19(32)	2 to 52
	2	9	20(22)	8 to 33
	1	12	7(40)	0 to 25
	2	12	19(91)	0 to 48
Dicamba	4	12	48(64)	19 to 81
	6	12	49(25)	5 to 82
	8	12	72(57)	34 to 93
	4	24	12(9)	9 to 17
	6	24	40(16)	22 to 58
	8	24	35(16)	34 to 38
	8	27	15(8)	12 to 19
Picloram	0.5	12	49(62)	0 to 94
	1	12	66(128)	5 to 98
	2	12	88(148)	0 to 100
	0.5	24	1(4)	0 to 3
	1	24	40(54)	11 to 73
	2	24	82(39)	57 to 100
	1	27	18(13)	6 to 28
	2	27	79(19)	53 to 95
Glyphosate	0.75	9	86(21)	78 to 95
	1	9	85(37)	65 to 98
	2	9	92(20)	79 to 98
	0.75	12	78(3)	68 to 79
	1	12	68(7)	53 to 83
	2	12	91(7)	88 to 94
	0.75	21	12(3)	...
	1	21	10(3)	...
	2	21	8(3)	...

¹Numbers in () are the number of observations in the mean.

Control with dicamba

Leafy spurge control with dicamba increased slightly with increasing application rates (Table 1). Control with dicamba at 4, 6 and 8 pounds per acre average 48, 49 and 72 percent, respectively, 12 months after application, but declined to 12, 40 and 35 percent, respectively, 24 months after application. Similar to 2,4-D, control varied widely even when dicamba was applied at 8 pounds per acre, ranging from 34 to 93 percent control after 12 months. Leafy spurge control declined rapidly regardless of dicamba application

rate, as 58 percent was the maximum control reported after 24 months following application of dicamba at 6 pounds per acre. Dicamba will provide moderate leafy spurge control for one year or more in North Dakota when applied at 6 to 8 pounds per acre.

Dicamba at 0.5 pounds per acre applied biannually (spring and fall) maintained leafy spurge control from 47 percent at three months to 52 percent at 27 months, while similar treatments with dicamba at 1 pound per acre increased leafy spurge control slightly from 50 to 68 percent, respectively (Table 2). Biannual applications of dicamba at 1 pound per acre meant that a total of 5 pounds per acre of dicamba had been applied to these plots in 27 months, and the control of 68 percent at 27 months was better than the 15 percent average with dicamba at 8 pounds per acre applied once (Table 1). There may be an advantage for applying dicamba at lighter rates twice yearly for several years compared to a larger rate applied once if application costs are not prohibitive. Biannual applications of dicamba at 0.5 to 1 pound per acre and 2,4-D at 1 to 2 pounds per acre generally provided similar leafy spurge control (Table 2), but 2,4-D is a less expensive herbicide than dicamba for rates that provide similar control.

Control with picloram

Picloram has been evaluated for leafy spurge control in North Dakota since 1964. Leafy spurge initial and long-term control increased with increasing picloram application rate (Table 1). Picloram applied at 0.5, 1 and 2 pounds per acre averaged 49, 66 and 88 percent leafy spurge control, respectively, 12 months following application. The maximum control reported after one year ranged from 94 to 100 percent; however, even picloram applied at 2 pounds per acre can occasionally fail to control leafy spurge with no control reported in two trials one year following application.

Picloram applied at 2 pounds per acre usually provides the best long-term leafy spurge control in North Dakota (Table 1). Picloram at 2 pounds per acre averaged 82 and 79 percent control 24 and 27 months after application, respectively, but did range as high as 100 and 95 percent, respectively. In general, picloram provides more consistent leafy spurge control in North Dakota than 2,4-D or dicamba.

Biannual (spring and fall) treatments of picloram at low rates gradually decreased leafy spurge infestations over time (Table 2). Picloram at 0.25 pound per acre applied biannually or at 0.5 pound per acre applied annually for two consecutive seasons provided 82 and 86 percent control, respectively, after 27 months (Table 2) which is similar to picloram at 2 pounds per acre applied once (Table 1). When picloram was applied at 0.25 pound per acre biannually, a total of 1 pound per acre of picloram had been applied after two years and provided 72 percent control at 24 months (Table 2); however, a single application of picloram at 1 pound per acre provided an average of only 40 percent control at 24 months (Table 1).

Annual treatment with picloram plus 2,4-D generally gave better leafy spurge control than picloram alone (Table 3). The largest increase in leafy spurge control occurred when picloram at 0.25 pound per acre was applied with 2,4-D at 0.25 pound per acre. Leafy spurge control with picloram at 0.25 pound per acre was 42 percent after 24 months compared to 83 percent control when 2,4-D at 0.25 pound per acre was added to the treat-

ment. As the 2,4-D and/or picloram rate increased, the enhancement of leafy spurge control declined. Annual application of picloram at 0.5 pound per acre gradually decreased leafy spurge stands but control was not improved by adding 2,4-D after the initial treatment. The greatest potential for synergism between picloram and 2,4-D for leafy spurge control occurred in a range of picloram at 0.25 to 0.5 pound per acre and 2,4-D at 0.25 to 1 pound per acre.

Table 2. Leafy spurge control with 2,4-D, dicamba or picloram applied both spring and fall for several growing seasons in North Dakota.

Herbicide and rate (lb/A)	Months after first treatment				
	3	12	15	24	27
	----- (%) -----				
2,4-D					
1.0	48(197) ¹	38(50)	43(47)	65(28)
1.5	47(108)	65(54)	50(35)	49(28)
2.0	50(190)	45(78)	58(102)	72(8)	55(12)
LSD (0.05)	13	28	Non-est ²	Non-est	Non-est
Dicamba					
0.5	47(34)	49(14)	39(14)	45(12)	52(8)
1.0	50(34)	57(18)	55(10)	58(12)	68(8)
LSD (0.05)	20	4	Non-est	Non-est	Non-est
Picloram					
0.25	56(41)	67(18)	69(10)	72(18)	82(14)
0.5 (Spring applied only)	58(62)	72(18)	87(10)	81(8)	86(8)
LSD (0.05)	16	12	11	Non-est	Non-est

¹Numbers in () are the number of observations in the mean.

²Non-estimable due to insufficient number of similar experiments across all means.

Some areas infested with leafy spurge are not easily accessible, so an annual or biannual herbicide treatment program is impractical. Also, leafy spurge eradication is a logical objective when a new infestation is discovered before the weed has developed an extensive root system. In these situations, picloram at 2 pounds per acre should provide at least 80 to 90 percent leafy spurge control for 15 to 24 months in North Dakota, whereas dicamba at 8 pounds per acre has provided similar control for only 12 to 15 months. Leafy spurge control by picloram and dicamba generally has been maintained at 80 percent or more for 12 to 15 months longer in Wyoming than North Dakota, based on reports by Alley *et al.* (1). Leafy spurge control declines rapidly with both herbicide treatments when the control falls below about 80 percent, so retreatment would be necessary. Generally, dicamba provides shorter residual leafy spurge control and is more expensive than picloram, but dicamba has a shorter residual in soil and water than picloram. The environmental advantages of dicamba over picloram may be the most important consideration at some sites infested with leafy spurge.

Table 3. Leafy spurge control with picloram plus 2,4-D combination treatments applied annually in the spring in North Dakota.

Herbicide rate		Months after first treatment					
Picloram	2,4-D	3	9	12	15	24	27
----- (lb/A) -----		----- (%)-----					
0.25	0	56(41)	20(20)	56(16)	24(8)	42(8)	...
0.25	0.25	79(14)	...	84(14)	80(14)	83(12)	83(12)
0.25	1.0	62(20)	39(8)	45(16)	31(8)	68(8)	...
0.25	1.5	74(8)	41(8)	57(20)	35(8)	71(8)	...
0.25	2.0	73(8)	52(8)	53(12)	36(8)	61(8)	...
0.375	0	78(4)	49(20)	66(8)	36(8)	61(8)	...
0.375	1.0	67(4)	59(8)	70(8)	39(8)	74(8)	...
0.375	1.5	61(4)	66(8)	70(8)	29(8)	81(8)	...
0.375	2.0	64(4)	54(8)	74(8)	42(8)	60(8)	...
0.5	0	58(62)	56(24)	72(18)	87(10)	81(8)	86(8)
0.5	1.0	88(31)	71(8)	84(39)	84(26)	86(12)	89(12)
0.5	1.5	91(8)	73(8)	68(12)	38(8)	84(8)	...
0.5	2.0	93(8)	66(8)	83(12)	40(8)	78(8)	...
LSD (0.05)		8	Non-est ²	16	17	Non-est	Non-est

Numbers in () are the number of observations in the mean.

Non-estimable due to insufficient number of similar experiments across all means.

Control with glyphosate

Spring applications of glyphosate generally gave leafy spurge control of 30 to 40 percent (data not presented); however, fall, applications of glyphosate at 0.75 to 2 pounds per acre averaged 79 percent control after 12 months (Table 1). Glyphosate applied at rates greater than 0.75 pound per acre provided only small increases in control. Further, the cost of herbicide would negate the benefit from more than 0.75 pound per acre of glyphosate. Control decreased rapidly after 12 months regardless of the original application rate, primarily due to leafy spurge seedling establishment. Glyphosate does not have a soil residual to control emerging seedlings, so an application of 2,4-D at 0.25 to 0.5 pound per acre is necessary in the spring following a fall-applied glyphosate treatment to control seedlings. Glyphosate is nonselective, so it is useful as a spot treatment or in shelterbelts but cannot be used in pasture or rangeland where perennial grasses must be maintained.

An overview of these experiments suggests that leafy spurge can be controlled for varying lengths of time depending on the herbicide treatment used. Eradication was not obtained with any treatment on established leafy spurge stands, although we have observed eradication of new leafy spurge patches that have not developed an extensive root system. Leafy spurge has deep roots with buds that can produce new shoots from 24 inches deep or more (7), so a herbicide treatment can give visible eradication for 24 months or more before the new shoots emerge. Also, leafy spurge produces seed that can remain viable for at least eight years, and seedlings can develop perennial characteristics

by the time the plant has six to ten leaves. Eradication of both roots and seed requires a thorough control program for several years.

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