In Search of Leafy Spurge Control Herbicides

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Picloram (Tordon), dicamba (Banvel), glyphosate (Roundup and Landmaster BW) and 2,4-D are the most commonly used herbicides for leafy spurge (*Euphorbia esula* L.) control (2). Picloram was first evaluated for leafy spurge control in North Dakota in 1963 (3) and remains the most effective herbicide for long-term control. Very few herbicides have been labeled for leafy spurge control since picloram (Table 1). Dicamba was first labeled in the 1970s, and glyphosate and fosamine (Krenite) in the 1980s. Sulfometuron (Oust) was labeled in December 1987 but the label was withdrawn by the company in February 1988. Other herbicides such as fenac and borax are no longer used.

There are several reasons so few new herbicides are available for leafy spurge control. A primary limitation is that no pesticide manufacturing company evaluates new compounds specifically for leafy spurge control. Currently it costs $30 to $50 million for a company to register a new herbicide before any income is received. The new herbicide must be useful for weed control in the major crops of corn, soybean, or wheat to be economically feasible for a company to manufacture. Thus, all herbicides used to control leafy spurge are major crop chemicals that also happen to be toxic to leafy spurge.

For example, picloram was first used for weed control in small grains, dicamba for use in corn, and glyphosate for general nonselective weed control including grass species. These herbicides were found to be effective for leafy spurge control by various university researchers in either a designed screening program or, based on a "hunch," just happened to be field tested.

Table 1. Herbicides previously or currently labeled for leafy spurge control.

Common name	Trade name	Manufacturer	Comment
Atrazine	Various	Various	Cropland use only.
Amitrole	Amitrol-T	Rhone-Poulenc	Withdrawn for use near water, which was the primary use.
Borax	Ureabor	Simplot	Non-selective, common treatment used in 1950s.
Dicamba	Banvel	Sandoz	High rates required to be effective.
Dichlobenil	Norosac	PBI-Gordon	Preemergece suppression only.
Fenac	Fenatrol	Rhone-Poulenc	Non-cropland general vegetation control.
Fosamine	Krenite	DuPont	Useful near water, high application rate required.
Glyphosate	Landmaster BW	Monsanto	Mixed with 2,4-D, expect some grass injury
Picloram	Tordon	DowElanco	Commonly used, most effective available herbicide.
Sulfometuron	Oust	DuPont	Label withdrawn in North Dakota.
2,4-D	Several	Several	Top growth control only.

The number of herbicides field tested for leafy spurge control has been very limited for several reasons. Few universities have a position dedicated to pasture and rangeland weed control. Also, generally very little funding is available for rangeland weed control research. Both researcher time and the funds for leafy spurge control research were often "bootlegged" from other research projects.

Efforts to screen new herbicides for leafy spurge control in the greenhouse were slow and often impractical. It generally took six to nine months to grow plants to maturity, and the greenhouse space required to propagate enough plants to conduct an effective screening program often was unavailable. These impediments were removed by 1990 when a system to propagate plants in about six weeks was developed as part of the leafy spurge biocontrol program (1). These plants had well developed woody root systems and responded similarly to herbicide treatment as plants in the field. Because the plants were grown in 8-inch long by 2-inch diameter cones instead of 8-inch diameter pots, a typical greenhouse table could hold nearly 2,000 plants grown in cones instead of 50 to 80 plants in pots.

Enough leafy spurge plants now can be grown in available greenhouse space to conduct a large scale screening program to rapidly evaluate many herbicides for leafy spurge control. The purpose of this research was to evaluate as many herbicides as possible for leafy spurge control and to identify those with potential to be labeled for leafy spurge control in North Dakota (Figure 1).

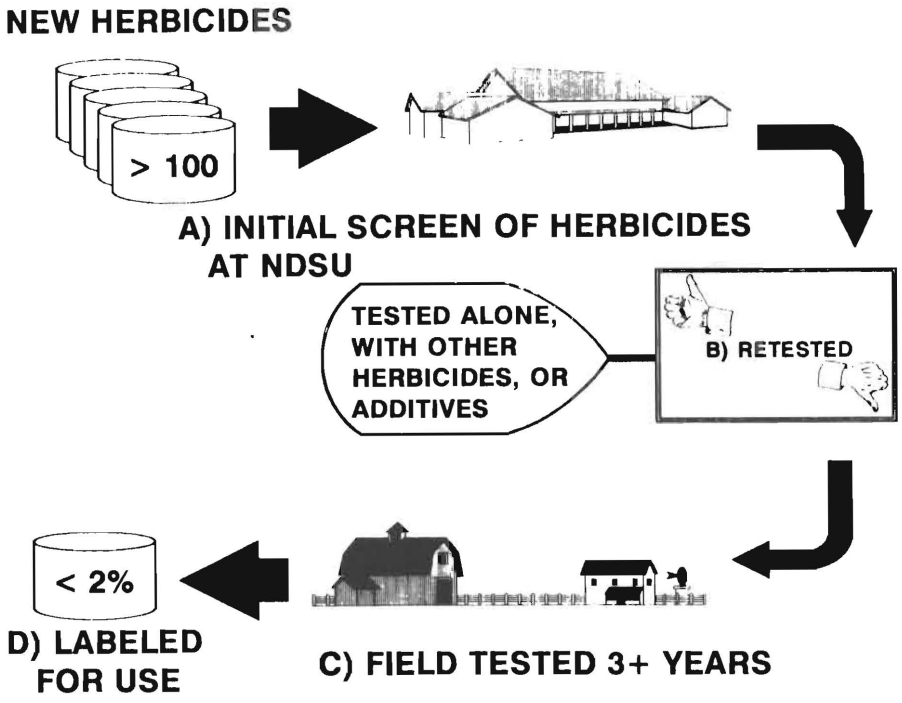

Figure 1. A) Over 100 herbicides were screened for leafy spurge control in the greenhouse; B) compounds that controlled leafy spurge topgrowth or roots (<12%) were further evaluated alone and with other herbicides, or with spray additives and if still found to be effective; C) the best treatments (7%) were then evaluated for leafy spurge control in a series of field tests; and D) only 2 to 3 of the over 100 compounds evaluated could be labeled in the next three to five years.

Materials and Methods

All herbicides currently labeled for use in North Dakota or available for research at North Dakota State University were evaluated for leafy spurge control in a series of greenhouse trials in 1990 and 1991, except compounds previously field tested. Herbicides were applied to leafy spurge plants 12 to 20 inches tall in the vegetative growth stage at 1X and 2X of the normal or experimental use rates in water at 17.5 gpa. Leafy spurge topgrowth was evaluated 1, 7 and 14 days after treatment for foliar injury. Then, all topgrowth was removed and the plants were allowed to regrow for four weeks. The number of plants that regrew was compared to the control. Herbicides that initially showed toxicity to leafy spurge were further evaluated either alone or mixed with herbicides already labeled for leafy spurge control. Additional trials were conducted to determine the optimal rates for field tests of chemicals likely to control leafy spurge.

Compounds evaluated in the field were applied with a tractor-mounted sprayer in water at 8.5 gpa. Herbicides were applied in June during the true-flower growth stage or in September during fall regrowth. The plots were 10 by 30 feet in a randomized complete block design with four replications. Leafy spurge control was evaluated visually as compared to the untreated control.

Results and Discussion

Herbicides screened for leafy spurge control represented 32 chemical families plus an unclassified group for a total of over 100 compounds (premixed combinations not shown) (Table 2). Several herbicides familiar to North Dakota farmers injured leafy spurge topgrowth but not the roots. For example, alachlor (Lasso), a corn and soybean herbicide, the wheat herbicide propanil (Stampede), and the soybean herbicide acifluorfen (Blazer) severely injured leafy spurge topgrowth but not the roots, so the plants rapidly recovered.

Some herbicides not expected to control leafy spurge reduced regrowth from the roots. For example, the grass herbicides of the aryloxyphenoxy family, diclofop (Hoelon) and quizalofop-p (Assure II), did not injure leafy spurge topgrowth but reduced regrowth to 75 percent of the untreated plants (Table 2). One of the most surprising results was

Table 2. Herbicides evaluated for leafy spurge control in initial screening trials.

Family/ herbicide	Trade name	Manu-facturer	Maxi-mum rate[a]	Leafy spurge Injury	Leafy spurge Regrowth
			oz/A	%	%
ACETANILIDES					
Alachlor	Lasso	Monsanto	48	80	100
Acetochlor	Harness	Monsanto	32	20	100
Dimethenamid	Frontier	Sandoz	48	10	100
Metolachlor	Dual	Ciba-Geigy	48	20	100
Propachlor	Ramrod	Monsanto	96	25	88
ALIPHATIC/ANALIDE					
Dalapon	Dowpon	DowElanco	160	35	100
Propanil	Stampede	Rohm & Haas	32	70	100
ARYLOXPHENOXY					
Diclofop	Hoelon	Hoechst-Roussel	16	1.5	75
Fluazifop	Fusilade	ICI	3	0	100
Fenoxaprop	Whip	Hoechst-Roussel	3	0	100
Haloxyfop	Verdict	DowElanco	4	0	88
Quizalofop	Assure	DuPont	2	0	75
Quizalofop-p	Assure II	DuPont	2	30	25
BENZAMIDE/BENZOFURAN					
Isoxaben	Gallery	DowElanco	3	25	75
Ethofumesate	Nortron	NOR-AM	48	55	69
BENZOIC ACIDS					
Benazolin	Benazalox	NOR-AM	8	60	100
Chloramben	Amiben	Rhone-Poulenc	48	20	100
BENZOTHIADIAZOLES					
Bentazon	Basagran	BASF	16	25	100
BIPYRIDYLIUMS					
Difenzoquat	Avenge	Amer. Cyan.	64	65	75
CARBAMATES					
Barban	Carbyne	United Ag	8	5	88
Desmedipham	Betanex	NOR-AM	16	3	50
CARBOXYLATE					
Cimectacarb	Primo	Ciba-Geigy	16	25	100
CINEOLE					
Cinmethylin	Cinch	DuPont	24	0	100
CYCLOHEXANEDIONES					
Sethoxydim	Poast	BASF	8	0	100
Clethodim	Select	Chevron	2	0	100
DINITROANILINES					
Ethalfluralin	Sonalan	DowElanco	32	0	100
Oryzalin	Surflan	DowElanco	64	0	81
Pendimethalin	Prowl	Amer. Cyan.	32	10	100
Trifluralin	Treflan	DowElanco	32	0	100
DIPHENYLETHERS					
Acifluorfen	Blazer	BASF	8	70	83
Lactofen	Cobra	Valent	6	60	100
Fomesafen	Reflex	ICI	8	40	100
FURANONE					
RE-40885	Benchmark	Chevron	16	0	100
IMIDAZOLINONES					
Busoxinone	None	Amer. Cyan.	2	60	100
Imazamethabenz	Assert	Amer. Cyan.	2	10	100
Imazapyr	Arsenal	Amer. Cyan.	8	50	0
Imazaquin	Scepter	Amer. Cyan.	2	60	100
Imazethapyr	Pursuit	Amer. Cyan.	2	30	16
ISOXAZOLIDINONES					
Clomazone	Command	FMC	32	10	100
NITRILES					
Bromoxynil	Buctril	Rhone-Poulenc	80	15	100
ORGANICS					
Diethatyl-ethyl	Antor	NOR-AM	80	10	100
Endothall	Herbicide-273	Pennwalt	16	0	100
Fluorochloridone	Racer	ICI	8	10	100
Propequizafop	Shogun	Amer. Cyan.	8	10	100
Tridiphane	Tandem	Dow	32	10	100
PHENYL/PHENYLUREAS					
Pyridate	Tough	Agrolinz	8	10	100
PHOSPHATES					
Glufosinate	Ignite	Hoechst-Roussel	16	70	100
SC-0224	None	ICI	0.1	40	38
PICOLINIC ACIDS					
Picloram TIPA	None	DowElanco	1.5	10	100
PYRIDINYL/PYRIMIDINE					
Flurprimidol	Cutless	DowElanco	8	10	100
SULFONYLUREAS					
Chlorimuron	Classic	DuPont	2	0	100
Chlorsulfuron	Glean	DuPont	0.5	10	100
DPX-79406	None	DuPont	2	50	13
DPX-A7881	Muster	DuPont	2	10	100
DPX-E9636	Titus	DuPont	2	50	100
Nicosulfuron	Accent	DuPont	2	20	50
Metsulfuron	Ally/Escort	DuPont	2	40	100
Primisulfuron	Beacon	Ciba-Geigy	0.5	30	94
Triasulfuron	Amber	Ciba-Geigy	0.2	0	100
Tribenuron	Express	DuPont	2	10	100
Thifensulfuron	Pinnacle	DuPont	2	10	100
THIOCARBAMATES					
Butylate	Sutan	ICI	32	0	100
Cycloate	Ro-Neet	ICI	64	10	100
Diallate	Avadex	Monsanto	48	0	88
EPTC	Eptam	ICI	96	0	100
Triallate	Far-Go	Monsanto	32	0	100
Vernolate	Vernam	ICI	64	0	100
TRIAZINES/TRIAZOLE					
Ametryn	Evik	Ciba-Geigy	32	40	100
Atrazine	Various	Various	32	50	100
Cyanazine	Bladex	DuPont	16	10	100
Hexazinone	Velpar	DuPont	160	0	100
Metribuzin	Lexone	DuPont	16	40	75
Prometryn	Caparol	Ciba-Geigy	16	0	100
Propazine	Milogard	Ciba-Geigy	48	0	100
UNCLASSIFIED					
AC-444606	None	Amer. Cyan.	2	50	100
BAS-09800	None	BASF	8	20	88
CGA-144155	None	Ciba-Geigy	16	0	88
Dietholate	None	ICI	16	0	100
DPX-K4891	None	DuPont	2	10	75
PPG-1013	None	PPG	2	20	75
PPG-1259	None	PPG	2	10	100
NCI-851013	None	Nisson	8	30	50
RH-0098	None	Rohm & Haas	2	0	100
S-23121	None	Sumitomo	2	70	100
S-63596	None	Sumitomo	0.1	20	100
S-53482	None	Sumitomo	0.1	60	100
SC-0098	None	ICI	0.1	30	100
UBI-A-1237	None	Uniroyal	0.1	80	100
UBI-C-4243	None	Uniroyal	0.1	60	100
U-53482	None	Valent	2	0	75
UREA/URACIL					
Chlortoluron	Dicuran	DuPont	32	0	100
Diuron	Karmex	DuPont	640	70	50
Siduron	Tupersan	DuPont	224	0	100
Linuron	Lorox	DuPont	48	30	100
Terbacil	Sinbar	DuPont	16	10	100

[a] Maximum application rate applied during initial screening.

[b] Visible injury evaluated 14 days after treatment; 0 = no injury, 100 = leaves senesced and stem dead.

[c] Plants that regrew 6 weeks after treatment (all topgrowth was removed 14 days after treatment).

from the thiocarbamate EPTC (Eptam), a herbicide with no previously reported postemergence activity. EPTC, which is volatile and must be soil incorporated, did not injure leafy spurge topgrowth and all treated plants survived. However, the regrowth was severely damaged and the plants grew slowly even though the herbicide only had been applied to the topgrowth. This was so unexpected that EPTC was kept in the screening trial for reevaluation.

In contrast, some herbicides expected to injure leafy spurge were ineffective (Table 2). Diuron (Karmex), a urea compound, is used in non-crop areas at high rates for total vegetation control. It does not leach and effectively prevents perennial plant regrowth. However, even when applied at 40 pounds per acre, 50 percent of the leafy spurge plants regrew. Atrazine provides some leafy spurge control, but greenhouse grown plants were unaffected when this triazine herbicide was applied at 2 pounds per acre. Clomazone (Command) did not control leafy spurge but did turn all the foliage white.

Only 12 of the over 100 compounds originally evaluated injured leafy spurge enough to be kept in the screening program for reevaluation (Table 3). The relatively new herbicide families, imidazolinones and sulfonylureas contained the most compounds that might be effective for leafy spurge control. Imazapyr (Arsenal) was very effective (100 percent control) (Table 1) but was not reevaluated because it severely injured grass in field trials.

Glufosinate (Ignite) severely injured leafy spurge topgrowth and is a relatively new non-selective herbicide similar to glyphosate. Two new formulations of picloram, an isooctyl ester (IOE) and triisopropylamine (TIPA), also were further evaluated. Only two unclassified herbicides showed promise for leafy spurge control NCI-851013 and SC-00224, experimental herbicides from Nisson and ICI, respectively. Only NCI-851013 was reevaluated because development of SC-0224 was halted by the company.

Table 3. Herbicides that injured leafy spurge in the initial trial and were reevaluated at various rates in the greenhouse.

Family/herbicide	Trade name	Rate[a]	Leafy spurge	
			Injury[b]	Regrowth[c]
		(oz/A)	(%)	(%)
Aryloxyphenoxy				
Quizalofop-P	Assure II	0.1 to 0.2	0	100
Imidazolinones				
Imazaquin	Scepter	1.5 to 3	25	100
Imazethapyr	Pursuit	1 to 2	10	60
Phosphates				
Gulfosinate	Ignite	8 to 16	50	88
Picolinic				
Picloram IOE[d]	None	0.5 to 1	70	100
Picloram TIPA[d]	None	0.5 to 1	40	100
Sulfonylureas				
Primisulfuron	Beacon	0.25 to 0.5	20	88
Nicosulfuron	Accent	1 to 2	20	50
DPX-79406	None	1 to 2	45	50
DPX-E9636	None	1 to 2	40	100
Thiocarbamates				
EPTC	Eptam	48 to 96	0	100
Unclassified				
NCI-851013	None	8 to 16	30	0

[a]Range from lowest to highest application rate applied during the second screening.
[b]Visible injury evaluated 14 days after treatment; 0 = no injury, 100 = leaves senesced and stem dead.
[c]Plants that regrew six weeks after treatment (all topgrowth was removed 14 days after treatment).
[d]IOE, isoctyl ester; TIPA, triisopropylamine.

Imazethapyr (Pursuit), nicosulfuron (Accent), DPX-79406, and NCI-851013 controlled 40, 50, 50, and 100 percent of the leafy spurge regrowth, respectively, when applied at rates intended for field use (Table 3). Quizalofop-p (Assure II), imazaquin (Scepter), and EPTC (Eptam) severely injured the leafy spurge regrowth even though most plants survived. The picloram (Tordon) IOE and TIPA formulations severely injured leafy spurge topgrowth even when applied at 25 percent of field use rate. Glufosinate and DPX-E9636 did not effectively control leafy spurge and were not further evaluated.

Unfortunately, the development of NCI-851013 was stopped by the company, thus, one of the most promising herbicides for leafy spurge control became unavailable for further research. DPX-79406, a mixture of nicosulfuron (Accent) and DPX-E9636, was not further evaluated because all injury seemed to be from nicosulfuron. The remaining seven herbicides were evaluated alone and with additives at various rates and with other herbicides known to control leafy spurge (data not shown). The addition of picloram or 2,4-D limited leafy spurge regrowth with imazaquin and imazethapyr compared to the herbicides applied alone. In general, no other herbicide combination limited regrowth better than the herbicides alone.

The last step in determining the potential of a herbicide for leafy spurge control is to evaluate the compound in the field. The seven herbicides that controlled leafy spurge in the greenhouse were applied to plants in the field in June or September (Table 4). The optimum application timing varies by herbicide so new compounds are often evaluated as spring- or fall-applied treatments.

Table 4. Field evaluation 3 and 12 months after treatment with herbicides that controlled leafy spurge in the greenhouse.

		Application date			
		June		September	
Herbicide	Rate	3 MAT	12 MAT	9 MAT	11 MAT
	(oz/A)	% control			
Quizalofop-P + X-77	1 + 0.5%	0	0	21	0
Quizalofop-P + X-77	2 + 0.5%	0	0	8	0
Quizalofop-P + X-77	1 + 16 + 0.5%	23	2	15	0
Imazaquin + X-77	2 + 0.5%	0	0	92	33
Imazaquin + X-77	4 + 0.5%	0	0	99	54
Imazaquin + 2,4-D + X-77	2 + 16 + 0.5%	20	8	69	28
Imazethapyr	1 + 0.5%	10	0	67	27
Imazethapyr	2 + 0.5%	1	0	79	11
Imazethapyr + 2,4-D + X-77	1 + 16 + 0.5%	10	6	59	8
Picloram IOE[a]	4	40	0	0	0
Picloram IOE[a] + 2,4-D	4 + 16	48	0	0	0
Nicosulfuron	1 to 0.5%	5	0	85	53
Nicosulfuron	2 + 0.5%	0	0	85	67
Nicosulfuron	2 + 16 + 0.5%	72	28	80	24
EPTC + X-77	96 + 0.5%	0	0	9	0
EPTC + picloram	96 + 8 + 0.5%	49	35	81	0
Primisulfuron + Agridex	0.3 + 1 qt	0	5	0	0
Primisulfuron + Agridex	0.6 + 1 qt	0	0	4	0
Primisulfuron + 2,4-D + Agridex	0.6 + 16 + 1 qt	11	5	23	0
Picloram + 2,4-D	4 + 16	24	10	76	19
Picloram + 2,4-D	8 + 16	41	34	94	25
LSD (0.05)		18	18	21	28

[a]IOE, isooctyl ester.

Three new herbicides, imazaquin (Scepter), imazethapyr (Pursuit) and nicosulfuron (Accent), provided control similar to picloram plus 2,4-D, the standard treatment, but only when fall applied (Table 4). Nicosulfuron is generally regarded as a grass herbicide and did cause about 30 percent grass injury (data not shown). Quizalofop-p (Assure II), EPTC (Eptam), and primisulfuron (Beacon) did not provide satisfactory leafy spurge control in the field and were not further evaluated. Picloram IOE caused rapid topgrowth kill but no root injury and the plants regrew within 30 days. This ester formulation of picloram caused rapid leaf kill and poor control when applied alone but may be useful at low rates in combination with picloram potassium salt (Tordon).

Once a compound is found to control leafy spurge in the field, a three- to five-year research program is initiated (Figure 1). The compound is further evaluated at various rates, application dates, and either alone or with various spray additives or other herbicides. Data from NDSU are combined with those of the manufacturers and results from other state universities. The potential sales of a new herbicide in pasture and rangeland must be determined by the manufacturer, and if economically feasible, feeding trials to establish grazing restrictions are initiated. All control, herbicide residue, and feeding trial data are submitted to the EPA for a label and if found environmentally safe, a new herbicide eventually is labeled for leafy spurge control. Of the over 100 compounds evaluated at NDSU, three may be useful for leafy spurge control (imazaquin, imazethapyr, and nicosulfuron) but likely only one or two will be marketed and join the list of herbicides currently used for leafy spurge control.

References

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