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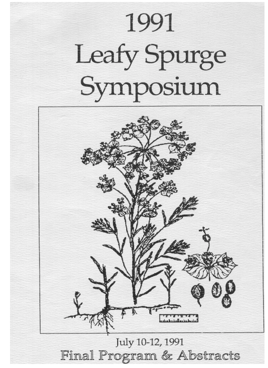

Great Plains Agricultural Council - 14 Crops and Soils Committee

Leafy Spurge Task Force Meeting and Symposium 10-12 July 1991

Radisson Metrodome Hotel, Minneapolis, Minnesota

Program

Wednesday, 10 July

7-00 - 10:00 pm All Symposium Reception and Registration. Pre-Function Area.

Thursday, 11 July

Plenary session Ballroom A

9:00 - 9:15 am	Welcome and Introductory Remarks - Dave Biesboer, University of Minnesota.
9:15 - 9:45 am	**Leafy spurge, a problem on Minnesota roadsides.** - Leo Holm, Minnesota Department of Transportation, St. Paul, Minnesota.
9:45 - 10:15 am	**Aspects of the biology of leafy spurge.** - Dave Biesboer, Department of Plant Biology, University of Minnesota, St. Paul, Minnesota.
10:15 - 10:30 am	Coffee Break
10:30 - 11:00 am	**Chemical control of leafy spurge.** - Rod Lym, Department of Crop and Weed Sciences, North Dakota State University, Fargo, North Dakota.
11:00 - 11:30 am	**The biological control of leafy spurge: past, present, and future.** - Neal Spencer, USDA/ARS, Biological Control of Weeds Research Unit, Sidney, Montana.
11:30 - 12:00 am	**The future of Perennial weed control.** - Don Wyse, Department of Agronomy and Plant Genetics, University of Minnesota, St. Paul, Minnesota.
12:00 - 1:00 pm	All Symposium Luncheon. Ballroom B

Paper session - biological control and related topics
Ballroom A

1:20 - 1:40 pm	**Laboratory colonies of *Aphthona flava* and *Oberia erythrocephala* fed on cell culture-based artificial diets.** - Hogan*, M. E. and G. D. Manners. USDA/ARS, Western Regional Research Center, Albany, California.
1:40 - 2:00 pm	**Leafy spurge propagation and herbicide-insect interaction for leafy spurge control.** – Mihelich*, C. A. and Rod Lym. Crop and Weed Sciences Department, North Dakota State University, Fargo, North Dakota.
2:00 - 2:20 pm	**Quarantine pass through activities and procedures for biological control agents of leafy spurge. –** Parker*, Paul E., E. J. Salinas, and J. D. Vasquez. USDA/APHIS-PPQ, Mission Biological Control Laboratory, Mission, Texas.
2:20 - 2:40 pm	**USDA, APHIS biological control of leafy spurge redistribution activity 1990.** - Richard R. D., L. E. Wendel*, and R. W. Hansen. Bozeman Biological Control Facility, Bozeman, Montana.
2:40 - 3:00 pm	Poster and Coffee Break - **Evaluating potential pathogens for biological control of leafy spurge.** – Yang*, S. M., DR. Johnson, and W. M. Dowler. USDA-ARS Foreign Disease-Weed Science Research, Fort Detrick, Frederick, Maryland.

Paper session - biology, chemistry, & economics
Ballroom A

3:00 - 3:20 pm	**Effect of temperature and sucrose concentration on hydroquinone toxicity in leafy spurge suspension culture cells. -** Hogan*, M. E. and G. D. Manners. USDA/ARS, Western Regional Research Center, Albany California.
3:20 - 3:40 pm	**Chemical composition of leafy spurge on alfalfa at four growth stages.** - Kirby, D. R., D. Fox, R. G. Lym*, J. S. Caton, and D. D. Krabbenhoft. Animal and Range Sciences Department and Crop and Weed Sciences Department, North Dakota State University, Fargo, North Dakota.
3:40 - 4.00 pm	**Economic impact of leafy spurge infestations on North Dakota grasslands.** - Leistritz*, F. Larry, Flint Thompson, and Jay A. Leitch. Department of Agricultural Economics, North Dakota State University, Fargo, North Dakota
4:00 - 4:20 pm	**Comparison of restriction fragment length polymorphisms in the chloro-plast DNA of five leafy spurge accessions.** - Nissen, S. J., D. J. Lee, and R. A. Masters*. Department of Agronomy and USDA-ARS, University of Nebraska, Lincoln, Nebraska.
4:30 - 5:15 p.m.	GPAC-14 Leafy Spurge Task Force Business meeting.
5:15 p.m.	Depart from Radisson Hotel lobby for Mississippi River boat river cruise

12 July, Friday

Paper session – control
Ballroom A

7.30 - 8:30 am	All symposium breakfast Ballroom B.

8:40 - 9:00 am	**First year results of leafy spurge control with sequential spring and fall herbicide applications.** - Beck*, K. G., and J. R. Sebastian. Department of Plant Pathology and Weed Science, Colorado State University, Fort Collins, Colorado.
9:00 - 9:20 am	**Leafy spurge control in North Dakota.** - 1991 - Christianson*, K.M., R. G. Lym, and C. G. Messersmith. Crop and Weed Sciences Department, North Dakota State University, Fargo, North Dakota.
9:20 - 9:40 am	**Control and leafy spurge with retreatments of Picloram and 2,4-D LVE.** - Ferrell, M. A. and T. D. Whitson. Department of Plant, Soil and Insect Sciences, University of Wyoming; Laramie, Wyoming.
10:00 am	**Enhancement of herbicide activity by *Alternaria angustiovoidea*.** - Jordahl, J. G., L. J. Francl, K. M. Christianson, and R. G. Lym Departments of Plant Pathology and Crop and Weed Sciences, North Dakota State University, Fargo, North Dakota.
10:00 - 10:20 am	Coffee Break
10:20 - 10:40 am	**Leafy spurge response to rate and time of application of imidazolinone herbicides.** - Masters*, R. A., R. N. Stougaard, and S. J. Nissen. USDA-ARS and Department of Agronomy, University of Nebraska, Lincoln, Nebraska.
10:40-11:00am	**Leafy spurge control with imidazolinone and sulfogylurea herbicides.** - Stougaard, R. N., R. A. Masters*, and S. J. Nissen. USDA-ARS and Department of Agronomy, University of Nebraska, Lincoln, Nebraska.

Workshops and field tour

11:15 - 12:15 pm	**Control of leafy spurge with herbicides**. Panel discussion. Rod Lym, University of North Dakota and Bruce Maxwell, University of Minnesota, will lead a discussion and answer questions about the control and management of spurge in the midwest. If you are a park manager, county weed control officer, or other individual responsible for the control of leafy spurge, this will be an opportunity to get some specific advice about your control problems. Ballroom A.
11:30 - 1:30 pm	**Grass identification workshop**. This workshop is for people interested in learning about or brushing up on the taxonomy and identification of grasses common to the Minnesota and the middle western states. The workshop is a hands-on introduction to floral structure, diversity, and terminology of the grasses. Dr. Anita Cholewa, Curator of the University of Minnesota herbarium, is the instructor. The classroom is on the St. Paul campus and a bus will leave for that campus shortly after 11:00 a.m. and return you to the Radisson at about 2:00 p.m. Cost. $7.
11:30 - 3:00 pm	**Field tour.** A field tour will be made of some of the herbicide control and biological control plots of various researchers of the University of Minnesota and other agencies. Dr. Roger Becker, Agricultural Extension and Weed Scientist at the University of Minnesota will be your guide.
6:00 pm	Bus or private vehicles leave from the Radisson lobby for the Metrodome for the game between the Minnesota Twins and the Boston Red Sox.

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Leafy spurge: A problem in Minnesota roadsides

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Leafy spurge, a deep-rooted perennial weed, presents a major control problem on Minnesota Department of Transportation roadsides. As desirable roadsides vegetation declines in vigor, weeds such as leafy spurge invade and take over large areas. Traditional methods of weed control are ineffective or unacceptable. Mowing scatters the plants and seed by physically dragging plant portions from one location to another. Control by spraying is questionable because high rates of persistant herbicides are required. All too often, desirable roadside grasses or landscape materials are injured by herbicide applications. Of major concern are the number of small, scattered patches of leafy spurge observed on roadside areas since the drought years of 1989 and 1990.

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Aspects of the biology of leafy spurge

D. D. BIESBOER

Department of Plant Biology, University of Minnesota, St Paul, Minnesota 55108.

Aspects of the evolution, origin, distribution, anatomy, reproductive biology, and physiology of leafy spurge will be presented.

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Chemical control of leafy spurge

R. G. LYM

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Herbicides commonly used to control leafy spurge include 2,4-D, dicamba, glyphosate, and picloram. Picloram is the most effective herbicide, while a combination of picloram plus 2,4-D is the most cost-effective treatment. Most herbicides are applied during the leafy spurge true-flower growth stage but glyphosate is most effective in the fall. Dichlobenil can be used to suppress leafy spurge growth under trees, while fosamine, glyphosate, and 2,4-D can be used adjacent to water. Sulfonylurea and imidazolinone herbicides control leafy spurge but may cause grass injury. Herbicide absorption in leafy spurge generally is less than 15% of applied with 5% or less translocated to the roots. Few new herbicides are available for weed control in pasture and rangeland. Thus, the effectiveness of herbicides presently available must be enhanced using techniques such as optimal application timing, use of spray additives to increase absorption, and herbicide combinations applied as a tank-mix or sequentially.

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The biological control of leafy spurge: Past, present and future

NEAL R. SPENCER

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Leafy spurge is a perennial weed of the northern U.S. and Canada reproducing by seeds and vegetative root buds. The dense stands of leafy spurge replace grasses and forbs on rangeland. Cattle generally avoid gazing in areas where spurge is present because it causes scours and mouth blistering. Nine Eurasian insect species attacking leafy spurge are currently approved for release and have become established in the United States. Additionally, eight insect species are in various stages of U.S. clearance procedures. More than twelve insect species have been approved for release in Canada and many are established there. The presentation presents information on the history of the leafy spurge biological control program and looks into the future for the impact of this technology on the weed target.

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The future of perennial weed control

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The direction of weed science research has been influenced greatly by a single development, the introduction of highly effective herbicides into the production of all major crops produced in the world. The impact of this technological development has been so dominating that weed science is currently perceived by many to be the science of herbicides rather than the science of weeds and their interaction with activities deemed beneficial by society. Weed science research can be separated into two major categories. The first is weed control science and technology research, which includes chemicals, tillage, biological control and other methods of weed control. The second is weed science principles research, which is primarily weed biology and weed ecology research. A high percentage of weed science effort has been devoted to the development and support of weed control methods. The early research on mechanical weed control gave way to an emphasis on chemical weed control research. Research in chemical weed control technology has received most of the resources available for weed science research over the last 25 years, with only a limited emphasis on biocontrol. Weed science principle research is needed to provide the basic knowledge needed to understand weed problems. This includes research on weed biology and ecology that would lead to the development of the basic principles needed to develop new weed control practices and improve the weed control practices that are already in place.

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Laboratory colonies of *Aphthona flava* and *Oberea erythrocephala* fed on cell culture-based artificial diets

M. E. HOGAN and G. D. MANNERS

USDA/ARS, Western Regional Research Center, 800 Buchanan St, Albany, CA 94710.

Larvae of *Aphthona flava* and *Oberea erythrocephala* have been maintained through all larval instars on a diet composed solely of freeze-dried suspension culture cells of leafy spurge. Five percent (5%) of the *Aphthona flava* larvae were observed to reach the third instar on the cultured cells and survival rates of 35% into the second instar were observed. *Oberea* larvae fed leafy spurge suspension culture cells formulated with corn cob grits progressed through all larval instars. However, no pupation of either species has yet been observed. Current efforts have focused on formulating a diet based on previously published diets for generalist Chrysomelid beetles with the addition of cultured cells of the target plant, leafy spurge. Preliminary results indicate that the presence of anti-feedants in the generalist insect diet formulations inhibit the larvae from feeding on cells, and/or artificial diet components.

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Leafy spurge propagation and herbicide-insect interaction for leafy spurge control

C. A. MIHELICH and R. G. LYM

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Propagation of leafy spurge in the greenhouse for insect biocontrol agents was evaluated. Leafy spurge plants grew best at 27º C, fertilized when 20 days old using a balanced fertilizer at a rate of 70 Kg N/ha weekly or 135 Kg N/ha biweekly in a potting media at pH 7 and a 16 hour photoperiod. Leafy spurge can be propagated to a size adequate for use in chemical and/or biocontrol experiments in approximately 6 weeks.

Aphthona spp. larvae failed to complete development to pupation when propagated with greenhouse-grown leafy spurge. Delayed development may be due to an imbalance or deficiency in the root nutrient content. Greenhouse-grown leafy spurge had a similar starch reserve to field grown plants but only 50% of the water soluble carbohydrate (sucrose) content. Greenhouse-grown plants that were senesced naturally or artificially had similar carbohydrate concentrations to field grown plants.

It has been hypothesized that biocontrol agents brought from Europe may not establish on North American biotypes. *Aphthona* spp. were exposed to one Austrian and six North American biotypes. No feeding preference was observed and eggs were found in pots of each biotype. Larvae development and adult emergence will be monitored.

The effect of herbicide treatment on insect feeding was evaluated. The treatments were 2,4-D at 140 g/ha, picloram plus 2,4-D at 70 plus 150 g/ha, and girdling the stem to deplete the latex. *Aphthona nigriscutis* and *A. czwalinae* were placed in separate cages and feeding behavior was monitored for 2 weeks. Insects fed on the herbicide treated plants until the leaves desiccated and only stems remained. Eggs have been found in pots of treated, girdled, and control plants. Larvae development and adult emergence will be monitored.

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Quarantine pass through activities and procedures for biological control agents of leafy spurge

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The Mission Biological Control Laboratory has responsibilities for pass through quarantine activities for various biological control programs including biological control of weeds. These activities are in support of implementation projects and allow additional numbers of approved agents to be properly identified and screened for pathogens and hyper-parasites before being released. Procedures, techniques for clearing and current and proposed activities for leafy spurge are discussed.

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USDA, APHIS biological control of leafy spurge redistribution activity 1990

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*Bozeman Biological Control Facility, Bozeman, MT 59717-0278, and *Mission Biological Control Laboratory.*

In 1990, USDA, APHIS, PPQ continued its three-year-old release program of six species of introduced insects attacking leafy spurge, *Euphorbia esula* L. The purpose of these release efforts is to establish domestic field insectary sites (FIS) for future collection and redistribution activities. All six species have been previously screened and approved for release by the USDA. The insects were collected from domestic, Canadian, and European locations for redistribution. Insect releases over a broad area of the U.S. will provide the basis for domestic population development and future collections for redistribution.

In 1990, APHIS and state cooperators initiated a total of 71 FIS in the states of Colorado (3), Idaho (4), Minnesota (18), Nebraska (6), North Dakota (10), Oregon (7), South Dakota (6), Washington (4), and Wyoming (3). For all states, the total number of individuals released was: *Aphthona cyparissiae* (root boring flea beetle) 3,934 adults; *A. czwalinae* (root boring flea beetle) 117 adults; *A. nigriscutis* (root boring flea beetle) 55,465 adults, *A. flava* (root boring flea beetle) 13,121 adults; *Spurgia esulae* (shoot tip gall midge) 452 galls; and *Oberea erythrocephala* (stem and root boring longhorn beetle) 140 adults.

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Evaluating potential pathogens for biological control of leafy spurge

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Fifteen genera of fungi were identified among 200 selected isolates (not including rust pathogens) which were obtained from diseased leafy spurge collected in People's Republic of China and U.S.A. (Maryland, Montana, Nebraska, and North Dakota) in 1989 and 1990. One of the 200 isolates (*Myrothecium* sp.) appears to be a good potential pathogen of leafy spurge. Among six inoculation methods tested, the inoculation method involving placement of an agar block with mycelium on untreated leaves on intact leafy spurge plants was the most rapid, dependable, and effective for preliminary screening of potential fungal biocontrol pathogens. This method has been adopted for use in our laboratory for screening fungal pathogens for biocontrol of leafy spurge and also for maintaining the pathogenicity of the potential pathogens. *Alternaria alternata* and *A. angustiovoidea* could infect and kill leafy spurge plants in the absence of dew in the greenhouse when conidia in emulsion were atomized on the plants. The control plants which received only emulsion, either remained uninjured or showed yellowing and defoliation of lower leaves and/or browning of the tips.

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Effect of temperature and sucrose concentration on hydroquinone toxicity in leafy spurge suspension culture cells

M. E. HOGAN and G. D. MANNERS

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Hydroquinone, a simple phenol identified in the low-growing forb, *Antennaria microphylla*, has been established to be phytotoxic to leafy spurge in a number of *in vitro* bioassays. Both leafy spurge and *Antennaria microphylla* have the capacity to enzymatically detoxify hydroquinone via glucosylation, however the glucosylating enzyme is substrate-induced in leafy spurge and was found to be six-fold less efficient than the same enzyme constituitively expressed in *Antennaria*. Detoxification of hydroquinone requires a readily available carbohydrate pool. Reports that leafy spurge roots accumulate unusually high amounts of free sucrose at the end of the growing season have promoted tissue culture assays to determine if sucrose accumulation enhanced the glucosylation of hydroquinone. Such an enhancement could provide seasonal amelioration of the allelochemical effects of hydroquinone on leafy spurge. Preliminary research results indicate that cold temperatures and exogenous hydroquinone represent a dual stress on the cells which can be only partially ameliorated by metabolism of exogenous sucrose. This chronic susceptibility of leafy spurge suggests the possibility of using hydroquinone-producing forage plants as natural competitors.

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Chemical composition of leafy spurge and alfalfa at four growth stages

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Leafy spurge (*Euphorbia esula*) is a long-lived perennial weed estimated to infest over 1 million ha in the northern Great Plains (1). Leafy spurge primarily infests pasture and rangeland where it severely decreases herbaceous production and livestock carrying capacity (2). Annual losses in herbage and livestock production in North Dakota are estimated at $8.6 million (3).

Efforts to control the rapid spread of leafy spurge have proven to be either too expensive or ineffective. Herbicides can provide partial control of the plant but effective treatment costs are prohibitive for use on wide spread infestations. Biological control methods using insects or pathogens have long-range potential but much research still needs to be conducted before these agents can be efficiently utilized.

A more traditional approach to leafy spurge control has been the grazing of sheep or goats in infested areas. Numerous ranchers are using this method and report various degrees of effectiveness (4). However, there is disagreement concerning the effect of leafy spurge on grazing animals and the forage value of leafy spurge. The objectives of this study were to: a) examine the chemical composition of leafy spurge at four phenological growth stages and four locations in North Dakota, and b) compare leafy spurge to alfalfa (*Medicago sativa*), harvested at similar growth states and locations.

Leafy spurge and alfalfa samples were collected in 1990 near Dickinson, Minot, Valley City and Fargo at vegetative (May 15), flowering (June 15), mature (July 15) and regrowth (September 1) phenological states. Samples were dried, ground and analyzed for % crude protein (CP), % acid detergent fiber (ADF), % in vitro dry matter digestibility (IVDMD) and % phosphorus (P).

Chemical composition of leafy spurge and alfalfa were averaged by vegetative and mature growth stages across the four collection locations. Percentage CP, IVDMD and P decreased in both leafy spurge and alfalfa with advancing maturity. Percentage CP and IVDMD tended to be greater in alfalfa regardless of vegetative stage when compared to leafy spurge. However, P percentage was consistently higher in leafy spurge. Nutrient requirements for lactating 150 lb ewes are 10.7% CP, 59% TDN (similar to IVDMD), and 0.23% P. Nutrient requirements for lactating 100 lb angora goats are 12.4% CP, 66% TDN, and 0.22% P. Both plant species exceed these requirement levels even at maturity.

Table 1. Chemical Composition of Leafy Spurge and Alfalfa.

Species	Growth Stage	% Crude Protein	% Acid detergent fiber	% In vitro dry matter digestibility	% Phosphorus
Leafy spurge	Vegetative	27.3	17.9	80	0.53
	Mature	19.5	28.5	66	0.39
Alfalfa	Vegetative	32.8	18.1	84	0.44
	Mature	25.6	25.3	74	0.32

1. Dunn, P.H. (1979) Weed Sci. 27,509-516.

2. Lym, R.G. and D.R. Kirby (1987) Weed Tech. 1, 314-318.

3. Thompson, F., L. Leistritz and J. Leitch (1990) NDSU Agr. Econ. Rpt. No. 257.

4. Lacy, C.A., R.W. Kott and P.K. Fay (1984) Rangelands 6,202-204.

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Economic impact of leafy spurge infestations on North Dakota grasslands

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The objectives were (1) to develop a function that relates the increase in leafy spurge infestation to the decrease in livestock carrying capacity for North Dakota pasture and rangeland, (2) to estimate the economic effects of leafy spurge infestation on landowners, and (3) to estimate the impacts of leafy spurge infestation on the regional economy. The carrying capacity function was developed through literature review and consultation with agronomists and range scientists involved in leafy spurge research. Two alternative measures of the value of lost carrying capacity (measured in animal unit months or AUMs) were developed using (2) an analysis of historical rental rates for pasture and (2) a ranch budget analysis. Statewide, the present leafy spurge infestation is estimated to cause a reduction of 577,000 AUMs, valued at $8.6 million. The secondary impacts of leafy spurge infestations, on the state's economy arise from two sources: (1) the reduction in income of ranch operators and land owners ($8.6 million annually) and (2) decreases in production expenditures, which are also decreases in revenues for input suppliers ($14.4 million annually). The secondary and total impacts were estimated using an input-output model. The total impact of the present level of leafy spurge infestation includes a reduction in personal income of $25 million, or about $44 per lost AUM. Substantial impacts were also shown for the retail trade sector ($19 million) and the agriculture-crops sector ($11 million). The total reduction in business activity for all sectors was almost $75 million. When the initial reduction in livestock sales of about $30 million that induced the subsequent economic changes is added, the total economic impact of leafy spurge on the state economy exceeds $100 million annually.

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Comparison of restriction fragment length polymorphisms in the chloroplast DNA of five leafy spurge accessions

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Chloroplast DNA (cpDNA) restriction fragment length polymorphisms (RFLPs) were analyzed to assess genetic variation and relatedness among selected individuals representing North America and Eurasian leafy spurge. Leafy spurge accessions from Nebraska, Montana, Russia, Italy, and Austria were evaluated. Total DNA was extracted from young leaves and digested with the restriction endonuclease, Eco Rl. CpDNA fragment patterns were determined by Southern blot analysis using mung bean (*Vigna radiata*. L.) cpDNA probes. Colinearity between the mung bean and leafy spurge chloroplast genomes was indicated by the observation that common overlapping fragments were hybridized by pairs of adjacent probes. Estimates of chloroplast genome size for the five leafy spurge accessions, which ranged from 130 to 132 kb, were within the size range of most terrestrial plants. Structural colinearity and reasonable estimates of chloroplast genome size provided evidence that the mung bean cpDNA library was suitable for characterizing leafy spurge cpDNA. Eight of the 13 mung bean probes hybridized to polymorphic leafy spurge cpDNA fragments. Based on number of polymorphisms unique to each Eurasian accession, the Austrian accession appeared to be most divergent followed by the Italian and Russian. The North American accessions seem to be most closely related to each other and to the Russian leafy spurge accession.

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First-year results of leafy spurge control with sequential spring and fall herbicide applications

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Leafy spurge was sprayed in spring with the amine salt of 2,4-D [(2,4-dichlorophenoxy)acetic acid] or the isopropyl amine salt of 2,4-D plus glyphosate [N-(phosphonomethyl)glycine]. Sequential fall treatments included the isopropyl amine salt of 2,4-D plus glyphosate, dicamba (3,6-dichloro-2-methoxybenzoic acid), 2,4-D plus picloram, or dicamba plus picloram. Leafy spurge control and Kentucky bluegrass injury were visually evaluated on August 9, 1990 and May 16, 1991. Spring applications of 2,4-D or 2,4-D plus glyphosate did not provide effective leafy spurge control 3 months after treatment (MAT). Spring applied 2,4-D plus glyphosate caused up to 25% bluegrass stand reductions 3 MAT. Spring applications of 2,4-D or 2,4-D plus glyphosate followed by 2,4-D plus glyphosate in fall did not provide effective leafy spurge control in May 1991. Kentucky bluegrass injury with these treatments ranged from 8 to 14%. Spring applications of 2,4-D followed in fall by picloram, picloram plus 2,4-D, dicamba, or dicamba plus picloram ranged from 82 to 100% leafy spurge control, and Kentucky bluegrass injury with these treatments ranged from 15 to 20% in May 1991. Split applications of 2,4-D in spring with fall applied picloram, picloram plus 2,4-D, Dicamba, or dicamba plus picloram did not provide better control than picloram, dicamba, 2,4-D plus picloram or dicamba applied in spring only when evaluated in May 1991.

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Leafy spurge control in North Dakota - 1991

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Evaluation of spray additives with picloram, screening of new herbicides and various glyphosate plus 2,4-D combinations for leafy spurge control have been the primary emphasis of the research program in 1991.

Compounds that appeared to increase picloram absorption in greenhouse and previous field trials were tested in the field in 1990. The additives MAPEG 400 MO, X-77, L-77, UI-700, Tetronic 504, and Triton CS7 increased leafy spurge control when applied with picloram all at 0.5% (v/v) compared to the herbicide applied alone regardless of application date. Leafy spurge control was not increased when the additives were applied with picloram plus 2,4-D. More additives were evaluated in the greenhouse in the winter 1990-91. The best additives will be field tested in 1991 including Scoil, Sunit II, Raider, Raider L (pH), BAS 090.

Many labeled and unlabeled herbicides were evaluated for leafy control in greenhouse and field experiments in 1990. The herbicides imazethapyr (Pursuit), imazaquin (Scepter), and BAS-514 averaged greater than 80% control with no grass injury when applied alone or with an additive at 0.5% (v/v) or in combination with 2,4-D and an additive at 0.5% (v/v). DPX-V9360 (Accent) and imazethapyr (Pursuit) provided greater than 80% control with 38% to 78% grass injury when applied with X-77 at 0.5% (v/v) or in combination with 2,4-D and X-77 at 0.5% (v/v).

Glyphosate plus 2,4-D as commercial formulation (Landmaster BW) provided greater then 64% control when applied alone and 98% control when combined with picloram. Grass injury was variable due to location and application date.

The 2,4-D formulations 2,4-D mixed amine (Hi-Dep) and 2,4-D alkanolanin were evaluated for leafy spurge control. When applied alone there was no leafy spurge control 12 months after application regardless of formulation and similar control when applied with picloram.

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Control of leafy spurge with retreatments of picloram and 2,4-D LVE

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This research was conducted near Devil's Tower, Wyoming to compare the efficacy of retreatments of picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) and 2,4-D [(2,4-dichlorophenoxy)acetic acid] low volatile ester (LVE) on the control of leafy spurge. The original herbicide treatments (picloram at 0.25 through 2.0 at 0.25 lb ai/a increments; picloram at 0.25 + 2,4-D LVE at 1.0 lb ai/a; and 2,4-D LVE at 1.0 and 2.0 lb ai/a) (were applied May 28, 1987. Original plots with less than 80% control were retreated with picloram at 0.5 lb, except for picloram at 0.25 lb, picloram at 0.25 + 2,4-D at 1.0 lb, and 2,4-D LVE at 1.0 and 2.0 lb which were retreated with the original rates. Retreatments were applied July 6, 1988 and June 6, 1990. Visual weed control evaluations were made June 8, 1988, May 25, 1989, and June 6, 1990.

Leafy spurge control in 1988 was 80% or better with picloram at rates greater than 1.0 lb ai/a. No 1988 retreatments increased leafy spurge control to 80% or better. Picloram at 0.25 lb ai/a and 2,4-D LVE at 1.0 and 2.0 lb ai/a were the only 1989 retreatments that didn't increase leafy spurge control to 80% or better. Picloram at 2.0 lb ai/a continues to be the only original treatment maintaining 80% or better shoot control in 1990. Plots with less than 80% control were retreated again June 6, 1990. Retreatments will be applied as needed to maintain or attain 80% leafy spurge shoot control.

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Enhancement of herbicide activity by *Alternaria angustiovoidea*

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Eight postemergent herbicides for leafy spurge control were tested on greenhouse-grown plants with or without the foliar pathogen, *Alternaria angustiovoidea.* Plants were inoculated with 100,000 conidia of isolate 85-7921, held in a moist chamber for 24 hours, and returned to the greenhouse. One day later, plants were sprayed with sublethal rates of picloram, 2,4-D, picloram+2,4-D, glyphosate, glyphosate+2,4-D, dicamba, imazaquin, or imazethapyr. Plants were rated for percent defoliation 11 days after applying the herbicides. *A. angustiovoidea* alone caused 22% defoliation, not significantly different ($P <= 0.01$) than picloram, dicamba, glyphosate, imazaquin, and imazethapyr without the fungus. The activity of these herbicides as well as picloram+2,4-D was enhanced by pretreatment with *A. angustiovoidea.* Glyphosate+2,4-D and 2,4-D alone exhibited high rates of defoliation (85-95%) and were not affected by the fungus. In a separate experiment where reduced rates of 2,4-D were applied one week before *A. angustiovoidea,* there was an additive interaction between herbicide and fungus for percent damage and reduction of regrowth. The combination of a fungal biocontrol agent and herbicide may permit reduced chemical rates while maintaining equivalent leafy spurge control.

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Leafy spurge response to rate and time of application of imidazolinone herbicides

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Field experiments were conducted to determine the response of leafy spurge and associated vegetation to imazapyr, imazethapyr, and imazaquin applied at rates of 0.07, 0.14, and 0.28 kg a.i./ha in early June and September 1989. Experiments were conducted on a subirrigated meadow range site near Ainsworth, Nebraska. A visual estimate of leafy spurge control and leafy spurge and grass dry matter yields were determined in July 1990 to assess herbicide efficacy. Herbicides applied in the fall provided better control of leafy spurge than those applied in the spring. Averaged across herbicides, the fall application of 0.28 kg/ha provided 85% control of leafy spurge by late June 1990. Ten months after the fall application, leafy spurge yield was reduced to 338 kg/ ha on areas treated with 0.28 kg/ha as compared to 2144 kg/ha harvested from areas not treated with herbicide. Grass yields in June 1990 were unaffected by treatment with imazethapyr and imazaquin, regardless of rate or time of application. In contrast, grass yields were reduced 54 and 71% 10 months after fall application of imazapyr at rates of 0.14 and 0.28 kg/ha, respectively. Spring applied herbicides had a negligible effect on leafy spurge. The lack of control by treatments in the spring resulted in part from severe drought conditions throughout the 1989 growing season. There was a 309 mm precipitation deficit in 1989, which was 56% below the long-term average. Despite adverse growing conditions, herbicides applied at a rate of 0.28 kg/ha in the fall of 1989 provided good control of leafy spurge through the summer of 1990.

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Leafy spurge control with imidazolinone and sulfonylurea herbicides

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Spring and fall applications of imazapyr, sulfometuron, imazapyr + sulfometuron, imazethapyr, chlorsulfuron, and imazethapyr + chlorsulfuron were evaluated for the control of leafy spurge. Fall-applied herbicides were more effective than spring applications. Averaged over years, all fall-applied treatments, with the exception of chlorsulfuron, afforded greater than 80% control of leafy spurge 8 months after application. Imazapyr afforded 100% control of leafy spurge and associated forage grasses. A similar response was observed with fall-applied sulfometuron. In contrast to the other fall-applied treatments, imazethapyr provided greater than 80% control of leafy spurge and did not injure associated forage grasses.