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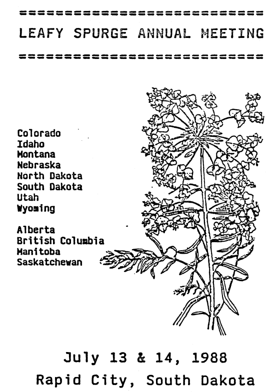
Published by GPC-14: Leafy Spurge Control in the Great Plains.

Leafy spurge annual meeting: Introduction / Agenda / Minutes



July 13-14, 1988
Rapid City, South Dakota
Howard Johnson's Motor Lodge

GPC-14 TASK FORCE

EXECUTIVE COMMITTEE

Chairman - Dennis C. Clarke, SD Dept. of Agriculture

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.

Introduction

DENNIS C. CLARKE

Chairman, 1988 GPC-14 Committee, South Dakota Department of Agriculture, Anderson Building, 445 East Capitol, Pierre, SO 57501. (605) 773-3796.

Research and control programs that have been completed and are in progress as weed scientists, county noxious weed control personnel and regulatory agencies attempt to solve the puzzle of leafy spurge control have all yielded one indisputable conclusion – the plant is extremely difficult to control. The plants comprising an infestation at a particular location may be managed to apparently 100% control only to seemingly reappear as if by spontaneous generation as soon as frequent retreatment of the area is discontinued. Because of its expansive root system, numerous root buds and large carbohydrate sink, an infestation can never be assumed totally eradicated. It can be likened to cancer in this respect and only considered to be in remission. Once established in an area, a leafy spurge infestation can never be forgotten.

The research and program progress reports presented at the 1988 GPC-14, Leafy Spurge Symposium, demonstrate the emergence of a new philosophy in leafy spurge control. It has evolved as leafy spurge workers at all levels have come to the realization of the difficulty of control; documented the vast acreage infested in the plains states, calculated the economic feasibility of control on many lands and met with difficulty in insuring infestations are treated. The philosophy involves the use of solid IPM principles to build a resource management approach aimed at containing existing large infestations and reducing their impact, stemming the spread of spurge to new areas, and the eradication of new small infestations.

It is hoped that using the information contained in this record of the 1988 Leafy Spurge Symposium can be used to build on past research findings and control program successes and serve as a springboard to the eventual answer to leafy spurge control.

1988 Leafy Spurge Annual Meeting Agenda

	Tuesday, July 12	
7:00-9:00 p.m.	Registration - Black Hills Foyer	
	Wednesday, July 13	
7:00 a.m.	Group Breakfast - Roosevelt, Jefferson, Lincoln Rooms	
7:30 a.m.	12:00 Registration - Black Hills Foyer	
8:30 a.m.	**SESSION I WASHINGTON ROOM** Dr. Lloyd E. Wendel, Mission Biocontrol Laboratory Presiding	
8:30 a.m.	Opening Remarks	
8:45 a.m.	David J. Ode - *Plant Habits of SD*	
9:00 a.m.	David O. Biesboer, *et. al.* - *Translatable mRNA's in Crown and rootbuds of Leafy Spurge*	
9:20 a.m.	David G. Davis and Prudence A. Olson - *Organogenesis of Leafy Spurge from Hypocotyl Segments*	
9:40 a.m.	Willard L. Koukkari, *et. al.* - *Inhibitory Effects of Smooth Brome Leachates*	
10:10 a.m.	Coffee - Black Hills Foyer	
10:30 a.m.	David G. Hein - *Single and Repetitive Picloram Treatments an Leafy Spurge (Euphorbia esula L.) and Resulting Changes in Shoot Density, Canopy Cover, Forage Production and Utilization by Cattle*	
10:50 a.m.	Orval R. Swenson and Rodney G. Lym - *Sulfometuron for Leafy Spurge Control*	
11:10 a.m.	Ann D. Haines, *et. al.* - *Methods for Estimating Leafy Spurge and Canada Thistle Populations*	
11:30 a.m.	Roland R. H. Kroos - *The Cause and Effect of Noxious Weeds*	
11:50 a.m.	Lunch - Howard Johnson's	
1:00 p.m.	**SESSION II - WASHINGTON ROOM** Verne Brakke, Director, Regulatory Services, SD Dept. of Agriculture Presiding	
1:00 p.m.	Leon Wrage - *South Dakota Leafy Spurge Program*	
1:20 p.m.	Rodney G. Lym and Calvin G. Messersmith - *Leafy Spurge Control in North Dakota - 1988*	
1:50 p.m.	John L. Baker and Donald L. Kosteh - *A Comparison of Different Herbicides and Application Techniques for the Control of Leafy Spurge*	

2:10 p.m.	Kevin A. Madsen, Mark A. Ferrell, Stephen D. Miller and Thomas O. Whitson - *Mow/Fertilization Treatments and Their Effect on Leafy Spurge Euphorbia esula control with Herbicides*
2:30 p.m.	M. D. Parman and E. E. Foss - *Treating Leafy Spurge as a Successional Problem in Eastern Montana*
3:30 p.m.	Leave for plot tour, chuckwagon supper and Mt. Rushmore lighting ceremony - Tim Chicoine, DuPont, and John Kitchell and Mark Peterson Dow Chemical, coordinating

Thursday, July 14

7:00 a.m.	Group Breakfast - Roosevelt, Jefferson and Lincoln Rooms
7:30 a.m.	Registration - Black Hills Foyer
8:00	**SESSION III - WASHINGTON ROOM** Dr. David Davis, USDA, ARS, Fargo, Presiding
8:00 a.m.	Rodney G. Lym and Calvin G. Messersmith **-** *Noxious Invaders of North Dakota - VCR*
8:20 a.m.	J. R. McCord - *Mapping Leafy Spurge From Light Aircraft*
8:40 a.m.	K. Dalsted, J. Nelson, and J. McCord - *Optimizing the Use of Aerial Photography to Map Leafy Spurge*
9:00 a.m.	Dr. Lloyd E. Wendel - APHIS - *Biocontrol Project of Leafy Spurge, A Report*
9:20 a.m.	Neal R. Spencer - *Biological Control of Weeds Research Goals - USDA/ARS, Sidney, Montana*
9:40 a.m.	G. D. Manners, M. E. Hogan, B. C. Campbell, and R. A. Flath - *Leafy Spurge Research at WRRC/ARS*
10:00 a.m.	Coffee - Black Hills Foyer
10:20 a.m.	R. B. Carlson and D. A. Mundal - *Biological Control Agents Released in North Dakota*
10:40 a.m.	Jeff Teerink and Dr. Robert B. Carlson - *Sparganothis sulfureana as a Possible Model for Introduced Biological Control Agents*
10:50 a.m.	Norman E. Rees - *Two Aphthona spp. Releases on Leafy Spurge in Montana*
11:20 a.m.	S. M. Yang, D. R. Johnson, W. M. Dowler, and J. M. Krupinsky - *Reaction of Different Biotypes of Leafy Spurge and Other Plant Species to Alternaria tenuissima f. sp. euphorbiae*
11:40 a.m.	R. M. Hosford, Jr. and G. O. Statler - *Fungal Diseases of Leafy Spurge, A Report*
12:00 p.m.	Lunch - Howard Johnson's Roosevelt, Jefferson, Lincoln Rooms
1:00 p.m.	Business Session - Washington Room

Minutes of the GPC-14 meeting

Howard Johnson's, Rapid City, SD July 14, 1988. The meeting was called to order at 11:45 a.m. by Dennis Clarke. Cal Messersmith moved that the minutes from the 1987 GPC-14 meeting be approved as printed in the 1987 Proceedings. Seconded by Tim Chicoine. Motion passed.

Administrative Director's Report - Don Anderson

Dr. Anderson explained that the purpose behind the Great Plains Council was to provide a forum for discussion and problem solving by Extension and research individuals for problems unique to the western and north central Great Plains region. This group is a subcommittee of the Crops and Soils Committee. Our subcommittee was recently given a 3-year extension since it is not considered a permanent committee. Discussion of a more structured committee should be discussed at the 1989 business meeting. Discussion should include: 1) the need to continue to communicate and coordinate research and education on leafy spurge, and 2) how to structure our current meetings to improve communications due to the different perspectives of the group. There is a need to continue the interest in this problem in view of budget cuts in many areas. It is also important for the committee to make the effort to include new states that are interested in the leafy spurge problem in the West, including Nebraska, Idaho, Utah, South Dakota, and Minnesota. Researchers from these states should be invited to present papers at upcoming meetings. The group also needs to go forward with the concept of integrating chemical, biological and other management techniques in the control of leafy spurge.

Other Reports

Jim Parochetti, Lloyd Wendel and Eldean Gercoft were invited to give their impressions of the meeting. Mr. Gercoft indicated that the ARS has 5 scientist years being spent on leafy spurge research.

Business

Newsletter – Russ Lorenz

Russ requested more detailed articles for the newsletter. His goal is to include more detailed, technical articles on the control and research of leafy spurge. The mailing list is up to 1,000 names and anyone wishing to add names should submit them to him. He noted that NDCES pays for the printing and a grant from Dow pays for the mailing. Grant monies left should pay for approximately 5 to 6 more issues. It has been difficult to stay with a specific schedule for printing, but that is another goal this year. The next issue will target biocontrol efforts and should be out in the next two months.

Future Meetings

The 1989 meeting is scheduled to be in Bozeman, Montana. Barbra Mullin and Norm Rees offered to work with President, Bob Nowierski to plan the meeting.

The schedule for future meetings and officers is as follows:

1989 - Bozeman, Montana

President - Bob Nowierski

Vice-President - Tom Whitson

Secretary - Dave Biesboer (Since Dave indicated that he could not make this meeting, he needs to appoint a replacement to take care of his duties, unlike Tom Whitson for 1988, who allowed Barbra Mullin to get conned into doing his job and he owes her for this.)

1990 - Wyoming

President - Tom Whitson

Vice-President - Dave Biesboer

Secretary - to be elected

1991 - Minnesota (Moved - Rod Lym; seconded - Dave Davis; passed)

President - Dave Biesboer

Vice-President - Secretary from 1990

Secretary - to be elected

The meeting adjourned at 12:15 P.M.

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Organogenesis of leafy spurge from hypocotyl segments

DAVID G. DAVIS and PRUDENCE A. OLSON

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Leafy spurge cell suspension cultures have been regenerated into plants (Davis *et al*. 1988). Successful regeneration depended on the accession used to originate the cultures. Numerous attempts were made to routinely and consistently manipulate the cultures to determine critical pathways in organogenesis that might be regulated by application of specific chemicals at certain stages in the life cycle of the plants. The results from cell cultures were often variable and inconsistent. Therefore, alternate systems were tested for these studies. In preliminary experiments, hypocotyl segments were more useful than cell suspension cultures for regenerating leafy spurge plants.

The conclusions outlined in this abstract may be tenuous, partly because of inconsistent experimental results between duplicate experiments and partly because of the long time periods required for data analysis: typical experiments lasted 60 days.

Roots and shoots formed on the hypocotyls were observed microscopically in unopened Petri dishes four time periods before harvest, usually at 60 days. In some experiments hypocotyls were pulse treated with chemicals and transferred at various time periods to fresh control media.

Root segments of germinated seedlings were compared to hypocotyl segments for their ability to regenerate leafy spurge plants. The root segments were capable of organ formation, but they were difficult to work with due to their small size and the limited amount of material compared to hypocotyl segments. In general, root segments produced greater numbers of new roots than hypocotyl segments, whereas hypocotyls formed more shoots than root segments.

The basic salt and vitamin formulations of B5 (Gamborg *et al*. 1968) and MS (Murashige and Skoog 1962) media were the standard media chosen for the early experiments. A modified B5 medium was also tested and contained a reduced/oxidized nitrogen ratio that was adjusted to the same ratio as for MS medium; all other components remained the same as the original B5 formulation. The B5 formulation was chosen for later experiments because the other media tested had no advantage compared to it.

Hypocotyl segments of dark-grown seedlings formed roots and shoots on media lacking exogenous growth regulators. Segments less than 0.5 mm long produced few organs, while those 1.5 cm long produced an average of 2 shoots/segment and 0.66

roots/segment. One cm long segments were used for the experiments described in this report. Shoots formed on about 40% of the hypocotyl segments within 10 days, while 10 to 20 days were required before roots were visible. The numbers of hypocotyls forming roots were consistently less than those forming shoots.

The results to date indicate that:

1. The auxins indoleacetic acid and indolebutyric acid stimulated root formation when added exogenously in concentrations of 0.17 mg/L for 2 to 5 days followed by transfer to the same medium without auxin. Naphthalene acetic acid gave variable results, whereas 2,4-dichlorophenoxyacetic acid inhibited roots at higher concentrations. Shoot formation was inhibited by auxins at higher concentrations (>0.l mg/L) but in some experiments were slightly stimulated at lower concentrations (<0.l mg/L).

2. Cytokinins at concentrations of 0.6 to 6 mg/L stimulated shoot formation by 40 to 200%, but effects on root formation varied.

3. Light had little or no effect on shoot formation, but it inhibited root formation (even at low fluences of 0.4 to 9.0 2×11×E/m2/s). Light quality had no consistent effect on the formation of either organ.

4. There is no evidence that ethylene plays a role in organ formation in leafy spurge hypocotyls in the described system. Hypocotyls treated with the ethylene inhibitors AgN03 and aminovinylglycine or with 1-aminocylopropane-1-carboxylic acid (a precursor of ethylene in plants) did not differ from the controls.

5. Gibberellic acid (0.1 to 2.0 mg/L) inhibited shoot formation by 50% in one experiment. Because few roots were present on control or treated plantlets, gibberellic acid effects on rooting could not be detected.

6. Abscisic acid gave inconsistent results, although fewer shoots were formed at 1 to 3 mg/L if the hypocotyls were exposed to ABA continuously. Lower concentrations of abscisic acid had no effect.

The search is continuing to discover the key media components and environmental factors that influence organogenesis. The concentration of endogenous growth regulators will be quantified to determine more precisely the relationships of those compounds on root and shoot formation in leafy spurge.

References

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Published by GPC-14: Leafy Spurge Control in the Great Plains.

Single and repetitive picloram treatments on leafy spurge (*Euphorbia esula* L.) and resulting changes in shoot density, canopy cover, forage production and utilization by cattle

DAVID G. HEIN

Ph.D., Department of Plant, Soil and Insect Sciences, August, 1988.

Research was conducted during 1985, 1986, 1987 and 1988 in central Montana, on a cool season, native grass pasture, to evaluate the response of leafy spurge shoot density, canopy cover, forage production and utilization by cattle to single and repetitive treatments of picloram (4-amino-3,5,6 trichloropicolinic acid).

Single picloram treatments of 0.28, 0.56, 0.84 and 1.12 kg a.e./ha reduced leafy spurge shoot density from 43% to 97% one year following treatment. Leafy spurge shoot control at these treatment levels dropped to 17% to 75% in the second year. Picloram treatments of 1.68 and 2.24 kg/ha maintained leafy spurge control above 90% for 2 years.

Leafy spurge canopy cover was reduced for 2 years from 32% to 15% or less following single applications of 1.68 and 2.24 kg/ha picloram. The 1.12 kg/ha treatment rate was intermediate in effect while the 0.28, 0.56 and 0.84 kg/ha treatments did not reduce leafy spurge canopy cover below pretreatment levels.

Forage production and utilization of forage by cattle increased significantly compared to the untreated control with all picloram treatments at or above 0.84 kg/ha. A 259% increase in forage production resulted from single picloram treatments of 2.24 kg/ha. Forage utilization increased from 0% in tile untreated control to an average of 43% in the treated plots.

A 0.56 kg/ha retreatment of 0.28 and 0.56 kg/ha treated plots significantly decreased leafy spurge shoot density and canopy cover and increased forage production and utilization compared to the single treatment alone. Retreatment of the 1.68 kg/ha rate with 0.56 kg/ha picloram was similar to the single treatment in its effect on leafy spurge shoot density, canopy cover, forage production and utilization of forage by cattle.

Single picloram treatments of 1.12, 1.68 and 2.24 kg/ha compared to split treatments with the same total application rate resulted in similar leafy spurge shoot density, canopy cover, forage production and utilization.

Leafy spurge canopy cover exerted the greatest influence on grazing behavior and forage utilization by cattle. Leafy spurge canopy cover of 10% or less and shoot control of 90% or more were necessary to achieve 50% forage utilization by cattle.

Table 1. Picloram treatments applied from 1985-1987 at Grassrange, Montana

Treatment Rate (kg a.e./ha)		
1985	*1986*	*1987*
0.28	----	----
0.28	0.56	----
0.28	0.56	0.56
0.56	----	----
0.56	0.56	----
0.56	0.56	0.56
0.84	----	----
0.84	0.56	----
0.84	0.56	0.56
1.12	----	----
1.12	0.56	----
1.12	0.56	0.56
1.68	----	----
1.68	0.56	----
2.24	----	----
Untreated	----	----

Table 3. Leafy spurge shoot density and control in response to single picloram treatments.

Treatment Rate[a]	Density [b]				Control [b]		
(kg/ha)	(shoots/ m^2)				(%)		
	1985 [c]	*1986*	*1987*	*1988*	*1986*	*1987*	*1988*
0.28	260	145	312	357	43	12	0
0.56	338	82	282	390	74	17	5
0.84	363	62	205	299	83	45	22
1.12	441	16	108	197	97	75	61
1.68	436	5	37	102	98	91	83
2.24	404	4	16	31	99	96	92
Untreated	282	276	471	396	7	0	0
LSD (0.05)	NS	92	215	134	12	6	10
CV (%)	27	40	55	32	13	21	20

[a]Treatments applied May 16, 1985.
[b]Data collected in May of each year.
[c]Pretreatment leafy spurge shoot counts.

Table 4. Leafy spurge canopy cover in response to single picloram treatments.

Treatment[a]	Canopy Cover			
(kg/ha)	(%)			
	1985[b]	*1986*	*1987*	*1988*
0.28	27	28	52	49
0.56	28	19	41	46
0.84	28	9	39	43
1.12	36	2	12	26
1.68	29	1	5	14
2.24	34	1	2	6
Untreated	21	34	49	47
LSD (0.05)	NS	9	13	9
CV (%)	29	38	40	16

[a]Treatments applied May 16, 1985.
[b]Pretreatment leafy spurge canopy cover

Table 5. Leafy spurge shoot density, control and canopy cover in 1987 and 1988 with single and repetitive picloram treatments.

Treatment Rate[a]			Density		Control		Canopy	
(ka/ha)			(shoots/m^2)		(%)			
1985	*1986*	*1987*	*1987*	*1988*	*1987*	*1988*	*1987*	*1988*
0.28	--	--	312	357	12	0	52	49
0.28	0.56	--	61	201	79	47	14	33
0.28	0.56	0.56	--	104	--	76	--	15
0.56	--	--	282	390	17	5	41	46
0.56	0.56	--	30	163	94	60	10	29
0.56	0.56	0.56	--	61	--	84	--	12
0.84	--	--	205	299	45	22	39	43
0.84	0.56	--	37	121	90	72	6	23
0.84	0.56	0.56	--	32	--	92	--	8
1.12	--	--	108	197	75	61	12	26
1.12	0.56	--	12	33	97	86	5	12
1.12	0.56	0.56	--	35	--	94	--	8
1.68	--	--	37	102	91	83	5	14
1.68	0.56	--	4	36	98	90	4	9
2.24	--	--	16	31	96	92	2	6
Untreated			471	395	0	0	49	47
LSD(0.05)			164	93	7	11	11	8
CV(%)			70	34	13	12	48	19

[a]Treatments applied May 16,17,14 in 1985, 1986, and 1987 respectively.

Table 7. Production and utilization of forage in response to single picloram treatments in 1985.

Treatment [a]	Production [b]		Utilization	
	(kg/ha)		(%)	
	1986	1987	1986	1987
0.28	813	1002	8	5
0.56	1087	1086	55	0
0.84	1474	1565	50	28
1.12	1612	1756	53	44
1.68	1773	1658	57	48
2.24	1495	1780	50	52
Untreated	660	496	3	0
LSD (0.1)	603	604	27	14
CV (%)	39	37	55	47

[a]Treatments applied May 16, 1985.
[b] Production data collected August,1986 and 1987.

Table 11. Leafy spurge shoot density, control and forage utilization in 1987 following single picloram treatments.

Treatment[a]	Density	Control	Utilization
(kg/ha)	(shoots/m^2)	(%)	
0.28	274	15	5
0.56	265	17	0
0.84	183	46	28
1.12	119	76	44
1.68	24	92	48
2.24	11	97	52
Untreated	404	--	0
LSD (0.05)	234	13	18
CV (%)	86	18	47

[a] Treatments applied May 16,1985.

Table 13. Leafy spurge canopy cover, forage production and utilization in 1987 following single picloram treatments.

Treatment [a]	Canopy Cover	Production	Utilization
(kg/ha)	(%)	(kg/ha)	(%)
0.28	50	1002	5
0.56	38	1086	0
0.84	30	1565	28
1.12	9	1756	44
1.68	6	1658	48
2.24	1	1780	52
Untreated	43	496	0
LSD (0.05)	16	732	18
CV (%)	44	37	47

[a]Treatments applied May 16,1987.

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Sulfometuron for leafy spurge control

ORVAL R. SWENSON and RODNEY G. LYM

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Two field experiments were conducted at Chaffee and Dickinson, North Dakota to evaluate the effect of sulfometuron alone and in combination with 2,4-D, dicamba, and picloram for leafy spurge control. Sulfometuron at 70 and 140 g/ha spring- or fall-applied provided an average of 12 and 41% leafy spurge control, respectively. Grass injury from sulfometuron averaged 9 and 24% from spring and fall application, respectively.

Sulfometuron in combination with picloram generally provided better leafy spurge control than sulfometuron alone or applied with dicamba or 2,4-D regardless of the application date. Sulfometuron at 70 g/ha plus picloram at 0.56 kg/ha provided 83% leafy spurge control 9 MAT and was similar to picloram at 2.2 kg/ha. Leafy spurge control did not improve following sulfometuron retreatments but grass injury increased an average of 37% compared to a single application.

Sulfometuron at comparatively low application rates (18 and 35 g/ha) in combination with an auxin herbicide provided an average of less than 31% leafy spurge control. Grass injury from all treatments was 4% or less. Retreatments 12 MAT generally did not increase leafy spurge control compared to the original treatments.

The effect of sulfometuron spring- and fall-applied on pasture and rangeland forage production was determined at Fargo and Manning, North Dakota. Spring-applied sulfometuron alone or in combination with an auxin herbicide tended to injure bluegrass spp. and reduce yield 3 but not 12 MAT. In contrast, smooth brome production was similar to the control 3 MAT for all sulfometuron treatments but tended to be less than the control 12 MAT following sulfometuron at 140 g/ha and sulfometuron plus picloram at 70 + 560 g/ha.

Fall-applied sulfometuron alone and in combination with an auxin herbicide did not reduce bluegrass spp. production. However, smooth brome yield was reduced an average of 52% compared to the control 9 MAT. Bluegrass spp., smooth brome, green needlegrass, and wheatgrass spp. production was not affected by sulfometuron alone at 70 g/ha or in combination with 2,4-D or dicamba. Sulfometuron at 140 g/ha or at 70 g/ha in combination with picloram tended to reduce combined bluegrass, green needlegrass and wheatgrass production.

The lateral movement of sulfometuron from slopes to non-target areas was evaluated at Valley City and New England, North Dakota. Sulfometuron was not found more than 120 cm down-slope from the treated area on 2, 8, or 16% slopes. The highest sulfometuron concentration found down-slope from the treated area was less than 1 ppbw regardless of the slope.

Sulfometuron soil movement was similar in Fairdale silty loam, Felor loam, and Barnes stony loam when leached for 48 hours and was detected the entire column length (65 cm) for all soils. Sulfometuron was detected 50 cm deep in Fairdale silty loam and 35 cm deep in Barnes stony loam and Felor loam, respectively, when leached for 9 weeks.

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The cause and effect of noxious weeds

ROLAND R. H. KROOS

As indicated by the title of this paper, I will discuss the cause and effect of noxious weeds. In this paper you will not find the traditional approach by stating and restating various facts, figures, or statistics that are available on noxious weeds. Rather you will find a holistic approach to the management of noxious weeds.

Noxious weeds have been reported to cause the death of other native plant species, reduce carrying capacity of the land for domestic livestock, interfere with agronomic crops, cause the decline of wildlife populations, and even cause the erosion of our soils. Weeds by themselves cannot cause such problems. There are a whole host of interrelationships and interactions that must occur before any of these things can happen. By using the Holistic Resource Management model we will be able to diagnose the effects of noxious weeds.

In the limited amount of time and space that I have for this paper I will not be able to cover all aspects of Holistic Resource Management. I will be able to introduce you to the Holistic Resource Management model and how it can be used in managing noxious weeds.

What is the cause of the current outbreak of noxious weeds – particularly leafy spurge? In examination of the program at this conference, I have concluded that most of you must know what causes leafy spurge. I base this conclusion on the fact that most of the papers to be presented here are talking about controlling leafy spurge, and to have control you must have identified the causes.

To test this hypothesis I will use one of the testing guidelines on the HRM model called Cause and Effect. This guideline helps determine whether our planned use of a particular tool to control noxious weeds will treat the cause or the effect of the problem. Let me use this simple analogy to demonstrate and better understand the cause and effect guideline.

I ask you to play this simple game with me. You sit in this chair, and every minute I hit you along side the head with this stick. The rules are straightforward in that you have only two choices. One, you can ask me to stop hitting you, or your second choice is that you can take some aspirin from the bottle sitting beside you. What would you do?

After several blows to the side of the head you will have a headache. Is the headache the cause or the symptom of the problem? In this simple scenario it is easy to understand that treating the headache with any aspirin or stronger drug is simply treating the symptom or the effect of the problem.

Of course in real life situations such as leafy spurge, the cause and effect relationships are much more complex. We are usually looking at multiple causes or a chain of events that have led up to the problem today. Man through the last century has changed the successional complexity by using various tools. These changes in the successional complexity have created a perfect niche for such plants as leafy spurge.

I would like to quote Keith Kelly, the director of the Montana Department of Agriculture, who states "I consider knapweed a disease of the land and we are helping to spread that disease." Kelly goes on to state that overgrazing and other poor management practices of our resources really contribute to the spread of noxious weeds. Without changing these poor management practices can you effectively treat the cause of the problem of leafy spurge or other noxious weeds?

Another indication that past mismanagement is one of the causes of noxious weeds is that they appear to be only a problem in certain areas. Initially we have a weed problem in a localized area or only on one side of the fence. How did we affect the successional community in this one area so that it provided the perfect conditions to germinate, thrive and reproduce? These are some of the questions that we should be asking in our search for the causes of the noxious weeds.

How successful have you been in controlling leafy spurge? Once treated does the problem go away or does it come back time and time again, much like that headache. This is an indication of whether you are treating the cause or the effect of the problem. We have been tempted by modern science to take the quick fix solutions in solving our problems.

These quick fixes have been expensive and for the most part ineffective when dealing with things that are alive and non-mechanical. Modern science has for the most part been unable to deal with the non-mechanical aspects of our world. In examining Table 1 you will find that I have broken things down as to mechanical and non-mechanical.

On the mechanical side you will finds things that reflect ever increasing success stories. Sure there have been problems, but science has been able to quickly determine the cause of these problems and progress even faster. This side really does reflect the marvels of science.

On the non-mechanical side we find things that have ever increasing complexity. The more we try to deal with this complexity using our current management, the more complex and difficult our problems appear. On this side, we have very few success stories and most of our time has been spent on treating the symptoms rather than the cause of the problem.

TABLE 1. REDUCTIONIST SCIENCE	
MECHANICAL* ASPECTS	NON-MECHANICAL** ASPECTS
Transportation	Agriculture
-Air	Rangelands
-Land	Forests
-Water	Oceans
Communication	Watersheds
-Radio	Erosion
-TV	Economies
-Phone	Wildlife
-Satellite	Human Relationships
Weapons	Human Health
-Conventional	Insect Predations
-Nuclear	Weed Infestations
Space Exploration	Air and Water Quality
Computers	Weather
Homes and Appliances	Etc.
Chemical Developments	Etc.
Medical Technology	
Etc.	

*__Mechanical__ - in this area of science we find ever increasing success stories. The true marvels of sciences occur here.
**__Non-Mechanical__ - in this area science has found increasing complexity and development of problems.

If you will examine Graph 1 you will find a graph that depicts insect damage from 1948 to 1984. It shows that insect damage has doubled despite a 12-fold increase in the use of insecticides. The same could be said about noxious weeds. Do we have more or less problem weeds today than we had 40 years ago?

For the last three hundred years we have used a mechanistic approach in managing and studying our natural world. We have ignored the incredibly complex interrelationships and have treated each part of our natural world as a machine part that could be removed or exchanged at will.

I am not trying to blame anyone or say that all this research is wrong. You and I did the best we could with the information that we had. Now the good news, there is a way to manage our natural resources in a holistic manner. In managing our natural resources in a holistic manner we will still need a lot of the research that has been derived through the reductionist approach.

With the development of the Holistic Resource Management model we have the ability to determine the cause and effect of noxious weeds. Using the HRM model we can treat the cause of the problem, which many times is not the weed itself, rather it is a successional problem. Many farmers, ranchers, and other resource managers have been able to reduce weed problems through methods that are socially, economically and ecologically sound. You can find a copy of the model at the end of this paper.

The model is goal driven and thus you are required to develop a three-part goal. These three parts are defined as follows:

Quality of Life - What do you want and need out of life for yourself, your family and the other people you associate with. Quality of life could include things such as freedom, time for vacation and personal growth, quality education for children, clean air and water, a healthy dependable food supply, a healthy prosperous local community where local services can be obtained.

Production - Here you would define what you need to produce to support that Quality of Life. It could be profit from crops, livestock, recreation, etc. You could also describe the quality of the product you're producing, recreational opportunities, the aesthetics of the land, other cultural aspects that you’re trying to protect and produce.

Landscape Description - Here you would define what the landscape must look like to support and sustain that production. Our ability to attain our production and quality of life rests on the Ecosystem Foundation Blocks. Here we describe how the ecosystem must be functioning to attain those goals. What must the soil surface look like to have effective mineral and water cycles. What kind of successional complexity do you need to harvest the sun on a sustainable basis?

When describing the successional complexity for the landscape description you do not describe the current problems such as noxious weeds. What you describe is a successional community of plants, animals, insects and microorganisms that does not favor those weeds.

Many of you have a goal to eradicate leafy spurge. Such a goal can be described as a non-goal. If you were successful at eradicating leafy spurge in the short term, what would it be replaced with? A native plant or possibly another noxious weed only to begin the process again. You must describe what you want the land to look like before you use any tool to change the landscape.

Once you have a three-part goal developed then your next step is to determine the health of the ecosystem. You do this assessment in relation to the four ecosystem processes. How are the minerals and water cycling within and above the soil? Determine the successional community in relationship to all the plants, animals, and microorganisms. How effectively are we harvesting sunlight and how is this energy flowing through the food chain?

To attain the production and landscape parts of the goal will require you to use tools. These tools can be found on the model below the ecosystem blocks. How do we know which tool to use and in what fashion a tool should be used?

The testing guidelines help you determine whether a particular tool will indeed help you attain your goal and whether it is financially, socially, and ecologically sound. I have already discussed the testing guideline *Cause and Effect*. I would quickly like to review the other testing guidelines with you.

Whole Ecosystem is the testing guideline that keeps the whole ecosystem in balance. In the United States we have pushed up energy flow by using petroleum products and have damaged the other three blocks with our current farming practices. Today, on average, to produce one calorie of food requires 30 calories of petroleum products. In controlling noxious weeds by using chemicals we often destroy other living organisms, reduce the effectiveness of the mineral and water cycle, and reduce the energy flow.

Weak Link is the testing guideline that checks every facet of the operation for weak links continuously. Every organization and operation has a weak link. If the operation becomes stressed enough the weak link will break. This guideline helps you pinpoint the weak link and then strengthen this link by taking appropriate action. Many times the weak link is not weed control, but poor management of the resources. I have never seen a rancher or farmer have to leave the land because of noxious weeds, I have seen them leave because they could no longer achieve profitability.

Highest Marginal Reaction is the testing guideline that indicates which tool will help you attain that three-part goal the quickest using the least input. This guideline would allow you to compare the costs of chemical control verses biological control of noxious weeds. You could also use it in comparing the cost of controlling weeds verses improving the management of the entire ranch through more training in Holistic Resource Management.

Energy/Wealth Source and Use is the testing guideline that determines the source of energy that a tool would require if it was implemented and if the use of this tool will increase the overall wealth of the operation. To produce and use herbicides requires the use of petroleum products of which we have a finite supply. Biological control such as insects or goats used to control spurge would eat plants which are produced from the sun, a renewable source of energy.

Society and Culture is the testing guideline that directs the attention back to our quality of life and others. Will the use of this tool enhance my quality of life and the society that I live in? People may not accept the noxious weeds that I have on my place, but are they willing to accept contaminated water and food supplies if they force me to spray? Most states and counties have legislated control of noxious weeds. This legislation usually requires that people apply chemicals on the land. Simultaneously, many states are passing legislation to control chemical contamination of water and food supplies.

The last testing guideline, *Gross Margin*, does not test the use of a particular tool. It tests the profitability of various enterprises -that you may be involved with now or in the future. No single testing guideline determines whether you should or should not use a particular tool. Should you find a tool not passing several guidelines, it is a warning that this tool may not be the best one to use if your goals involve long-term success. Many times tremendous amounts of human creativity are required to find different methods and tools that will accomplish that three-part goal.

Once a tool has been selected we must develop a plan that describes how this tool is to be used. You develop a plan-monitor-control-replan procedure that will ensure the successful use of those tools. The Management Guidelines found on the model assist in developing such a planning procedure.

In summary, the cause of noxious weeds is the result of complex interrelationships resulting from man's management of the ecosytem processes. We have changed the successional complexity, the effectiveness of mineral and water cycles, to such a point that noxious weeds have found a perfect niche. Unless we begin to change our management of the ecosystem processes we will always be treating the effect of our poor management such as noxious weeds.

The Center for Holistic Resource Management has developed a model that allows you to handle the complex interrelationships that occur in managing our natural resources. It does this by guiding your thoughts through the model to handle all the complex variables such as determining the cause and effect of noxious weeds. Our experience has shown that with a little training, all resource managers can learn to use this model effectively.

I would like to relate one success story from a rancher in New Mexico using Holistic Resource Management. In 1983, the Bowes Ranch was faced with a severe snakeweed infestation. Their choices were to begin spraying the snakeweed at $8.00 per acre every five years or look for other alternatives. The Bowes chose to look for other alternatives and attended an HRM in Practice course in 1983.

In using the HRM model the Bowes have been able to accomplish the following things:

Production Results:

Annual Beef Produced

1983 ………………………………..15 LBS/ACRE
1987 ………………………………..25 LBS/ACRE

Cost of Production

1983 ……………………………….66 CENTS/LB
1987 ……………………………….32 CENTS/LB

Improvement in Landscape Results

Soil Surface Cover	1984	1987
Bare ground	46%	30%
Litter	44%	54%
Basal	8%	16%
Plant Type		
Grass	80%	88%
Forbs	10%	4%
Snakeweed	10%	8%
Perennial Plant Spacing	1.8"	.96"
Number of Grass Species	6	16

The Bowes Ranch discovered several things. 1) That snakeweed was only the effect of previous mismanagement of the ecosystem and that by improving the ecosystem blocks they could slowly reduce the population of snakeweed. 2) That snakeweed did not suppress livestock production as previously reported. 3) If they would have begun spraying the snakeweed as suggested the production costs would have increased to 75 cents per lb.

Another success story using HRM can be found by reading the paper "Treating Leafy Spurge as a Successional Problem in Eastern Montana" by Parman and Foss in these proceedings.

References

Quote from Keith Kelly was taken from the Bozeman Daily Chronicle, Titled Weed Invasion, Sunday edition, July 3, 1988.

The Center for Holistic Resource Management is a non-profit organization headquartered in Albuquerque, New Mexico. The Center is dedicated to improving the quality of life and human environment through the application of Holistic Resource Management. In particular, we seek to halt the desertification and the deterioration of land and human resources on a world-wide basis. For more information write P.O. Box 7128, Albuquerque, NM 87194 or phone 505/242-9272.

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Published by GPC-14: Leafy Spurge Control in the Great Plains.

Noxious weed control in South Dakota

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Leafy spurge is one of six weeds designated as noxious statewide in South Dakota. Control programs include emphasis on each weed in areas or local situations where the weed is a problem. Leafy spurge ranks third in acreage following field bindweed and Canada thistle (Table 1).

Legislation established the noxious weed program in the early 1940's. Soon after enacting enabling legislation, funding soon followed to provide the first operational monies designated for noxious weed control and enforcement. The program includes coordinated enforcement, education, and organizational efforts. It is based on county financial support and is based on program development at the county level. Statewide policy is determined by the South Dakota Weed and Pest Control Commission. This provides statewide representation from agencies and producers.

Table 1. Noxious Weed Acres.

Field bindweed	1,767,000
Canada thistle	350,000
Leafy spurge	150,000
Perennial sow thistle	30,000
Hoary cress	9,000
Russian knapweed	4,000

Over 90% of the leafy spurge infestation is located in the eastern one half of South Dakota. The acreage of leafy spurge has shown a gradual but continual increase during the past 25 years. The increase in acres infested or mapped has been approximately 5000 acres each year. (Table 2).

Effectiveness of control programs initiated during the past years varies based on the site. Control has prevented spread, reduced the stand, and eliminated some infestations in certain situations; however, the acreage continues to expand in other sites where there is less commitment to control.

Table 2. Leafy Spurge Acres.

1986	1,500,000
1976	99,000
1966	54,000
1960	32,000

Rights-of-way, grass pasture/range

These areas receive the most attention and control efforts. Infestations are highly visible. Public demands for control are high. Herbicide programs have been most effective in these situations. Local governmental units have reduced control costs at least 90% where efforts have been continued for 5 to 7 years. This also includes an intensive herbicide program in pasture and rights-of-way to prevent seeding and to reduce the stand. Herbicide effectiveness is demonstrated from data presented in Table 3.

Pasture or range areas with environmental limitations or other restrictions that reduce the herbicide program remain a problem.

Table 3. Percent leafy spurge data control - annual treatments. 1978-82.

	lb/A act.		1979	1981	1983
Picloram*	(2)	Sp	86	94	88
Picloram+2,4-D	(.25+1)	Sp	55	78	94
Dicamba	(.5)	Sp&F	37	30	59
2,4-D ester	(1.5)	Sp	39	42	75
2,4-D ester	(1.5)	Sp&F	62	75	93
2,4-D ester	(3)	Sp	50	67	82

* 1978 only; 2,4-D 1979-82.

Cropland

Integrated approaches utilizing crop rotation, cultivation, and selective herbicides are one of the most practical control programs for leafy spurge. Crop rotations were evaluated at the South Dakota Agricultural Experiment Station. The level of competition is reduced as the result of adapting best practices.

These practices remain an option to individuals who have not yet initiated control programs in cropland. Continued educational efforts are needed to improve control in cropland. Examples of stand reduction with one-year and three-year rotations are presented in Tables 4 and 5.

Table 4. Leafy spurge - 1 year.

	% Control
Cult, alfalfa or brome	82
Oats, 1/3 lb 2,4-D, cult	68
Cult, sudan	79
Cult, sudan, rye	90
Oats, cult	19

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Table 5. The average percentage of leafy spurge killed in 3 years.

First year		Second year		Third year	
Treatment*	% kill	Treatment*	% kill	Treatment*	% kill
Cult-alfalfa	82	Alfalfa	81	Alfalfa	82
Cult-brome	82	Brome 1 lb & 1 lb	95	Brome 1 lb & lb	98
Cult-brome	82	Brome 1 lb & 1 lb	95	Wheat 1/2 lb & 1 lb	96
Oats-brome-1/3 lb.	-62	Brome 1 lb & 1 lb	24	Wheat 1/2 lb & cult	31
Oats 1/3 lb, cult	68	Cult-sudan	91	Wheat 1/2 lb & cult	94
Cult-sudan	79	Oats 1/3 lb, cult	96	Wheat 1/2 lb & cult	98
Cult-sudan-rye	90	Rye 1/2 lb, cult	94	Wheat 1/2 lb & cult	89

*"Lb." refers to pounds of 2,4-D ester applied per acre and "cult" to intensive cultivation.

Noncrop areas

The acreage in noncrop areas is relatively limited compared with other sites. However, the weed presents a serious problem where it exists. Infestation from these sites often include environmental or plant limitations. These sites often form a seed nursery to reinfest adjacent areas. Several herbicide treatments are available for noncrop areas with special limitations (Table 6).

Table 6. Non-Crop Herbicides and Site Limitation

Herbicide	Special Uses
Krenite	Near aquatic
Oust+2,4-D	Noncrop-trees
Oust+Tordon	Noncrop
Weedar 64A	Aquatic

Biological control offers a potentially effective and economically feasible approach to reduce infestations in many of these areas with sites restrictions. Initial release of the leafy spurge hawkmoth became established during the initial season, but have not been confirmed as established at this point.

Future needs

The acreage of leafy spurge continues to expand in spite of control efforts. New approaches must be designed if the trend is to be reversed. It is essential to develop effective and practical control options for infestations where limitations restrict the implementation of current technology. Certain of these sites and limitations include:

1) Forest, tree plantings – including grazing areas with trees present. This substantially reduces the herbicide options based on present products available. Herbicides for these sites must be selective for forage grasses and appropriate residue tolerances for these sites must be established. In addition, the inaccessibility and high cost of control limits herbicide application potential.

2) Aquatic sites – includes marshes, farm ponds, and public water that may have uses for irrigation, livestock watering, recreation and domestic use. There is need for research that will give new information regarding the plant's physiology, growth and development, as well as biological control and evaluation of new herbicides and management schemes that will implement all of these controls in an integrated approach.

Meanwhile efforts to educate the public both regarding the problem and in the use of current control technology must continue. This in the short term will reduce the rate of spread and increase control efforts in the public and private sector. The implementation of current technology can effectively reduce the rate of spread, reduce the infestation and reduce the cost on certain sites for private individuals and for governmental units.

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Published by GPC-14: Leafy Spurge Control in the Great Plains.

Leafy spurge control in North Dakota - 1988

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Annual picloram plus 2,4-D treatments, leafy spurge control along ditchbanks and optimum application timing of sulfometuron with auxin herbicides have been the emphasis of the leafy spurge control field research in 1988.

Picloram at 0.25, 0.375 and 0.5 lb/A provided 49, 69 and 77% leafy spurge control, respectively, in August 1987 when averaged across the Dickinson and Valley City locations (Table 1). Control had declined by approximately 10% compared to 1986. 2,4-D alone provided approximately 50% control of leafy spurge after biannual applications for 7 years.

Table 1. Leafy spurge control from annual picloram or picloram plus 2,4-D treatments and biannual 2,4-D treatments at two locations in North Dakota.

		Site and 1988 evaluation date		Months after treatment				
		Dickinson	Valley City					
Herbicide	Rate	June	May	12[a]	24	36	48	60
	(lb/A)	(% control)						
Picloram	0.25	30	46	39	48	48	58	49
Picloram	0.375	26	76	65	62	52	77	69
Picloram	0.5	46	74	65	71	81	86	77
2,4-D bian	1	29	28	22	30	38	50	39
2,4-D bian	1.5	28	42	22	24	26	45	49
2,4-D bian	2	25	49	19	30	26	54	54
Pic+2,4-D	0.25+1	63	76	52	66	63	85	73
Pic+2,4-D	0.25+1.5	71	59	58	66	70	85	77
Pic+2,4-D	0.25+2	51	82	57	62	66	83	76
Pic+2,4-D	0.375+1	58	86	69	72	70	90	84
Pic+2,4-D	0.375+1.5	70	81	68	74	76	93	84
Pic+2,4-D	0.375+2	76	85	68	59	76	91	86
Pic+2,4-D	0.5+1	75	91	71	75	84	94	87
Pic+2,4-D	0.5+1.5	80	97	64	73	80	97	91
Pic+2,4-D	0.5+2	78	94	76	75	81	95	91
LSD (0.05)		20	20	18	14	19	14	14

[a] Mean values include data from the Sheldon location which was discontinued after 1985.

Leafy spurge control in May, 1988 increased by an average of 29, 25, and 26% when 2,4-D at 1 to 2 lb/A was applied with picloram at 0.25, 0.38, or 0.5 lb/A, respectively, when compared to the same picloram rate applied alone (Table 1). Picloram at 0.5 lb/A plus 2,4-D provided an average of 90% leafy spurge control 60 months after treatment (MAT) but had declined slightly compared to the previous year. The greatest enhancement with 2,4-D plus picloram seems to be with 2,4-D at 1.5 lb/A or less and picloram at 0.375 lb/A or less. In general, leafy spurge control has been similar at all sites and does not seem to be influenced by soil types, pH, or organic matter. However, leafy spurge control at Dickinson had declined in 1988 compared to 1986 and 1987 which probably was due to above average precipitation and excellent growing conditions in 1986 following several years of below average precipitation.

The experiment to evaluate leafy spurge control with herbicides that can be used near water was established on June 27, 1986 along a ditchbank in Fargo. There were four replicates per treatment and the experiment was a randomized complete block design. All plots were treated with 2,4-D at 1 lb/A in June 1987 to control leafy spurge seedlings.

Amitrole at 4 lb/A provided 91 and 82% leafy spurge control 12 and 24 months after treatment (MAT), respectively, but there was 64% grass injury (Table 2). Increasing the application rate to 8 lb/A increased grass injury but not leafy spurge control. Unfortunately, amitrole is no longer cleared for use near water. Fosamine at 8 lb/A provided 90 and 74% leafy spurge control 12 and 24 MAT but also 57% grass injury. No other fosamine treatment provided satisfactory control and evaluation varied considerably from plot to plot indicating this herbicide may provide inconsistent control.

Table 2. Leafy spurge control along ditchbanks, Fargo, North Dakota.

		Evaluation date				
		Aug 86	May 87		Aug 87	June 88
Treatment	Rate	Control	Control	Grass injury	Control	Control
	(lb/A)	(%)				
Amitrole	2	99	69	23	80	63
Amitrole	4	100	91	64	95	82
Amitrole	8	100	87	81	96	78
Fosamine	2	5	14	3	59	54
Fosamine	4	19	58	10	55	59
Fosamine	8	40	90	57	82	74
LSD (0.05)		19	17	42	28	23

An experiment to evaluate leafy spurge control with sulfometuron plus 2,4-D, dicamba or picloram was established at Chaffee and Dickinson, North Dakota in 1986. The treatments were applied annually in the spring or fall at each location. Leafy spurge control and grass injury was evaluated prior to retreatment.

Sulfometuron alone did not control leafy spurge regardless of application date (Table 3). Grass injury from sulfometuron at 1 and 2 oz/A averaged 16 and 31%, respectively, following 2 annual spring applications but increased to 79 and 94%, respectively, when fall applied. Leafy spurge control was better when picloram was applied with sulfometuron, then with dicamba in the spring, but both treatments provided 98% control following two fall applications. Sulfameturon plus 2,4-D provided poorer leafy spurge control than the other treatment mixtures and was similar to sulfometuron at 2 oz/A alone. Grass injury was 20 and 86% when averaged over all sulfometuron spring and fall treatments, respectively.

Table 3. Leafy spurge control with sulfometuron in combination with dicamba, picloram and 2,4-D applied annually in the spring and fall at two locations in North Dakota.

		Evaluation date						
		Sept 1986		June 1987	Aug 1987		May 1988	
Treatment and application date	Rate	Control	Grass injury	Control	Control	Grass injury	Control	Grass injury
	-(oz/A)-	(%)						
Spring								
Sulfometuron	1	4	12	4	0	32	0	16
Sulfometuron	2	9	9	4	23	46	4	31
Sulfometuron+picloram	1+8	82	10	33	64	38	52	18
Sulfometuron+dicamba	1+32	27	17	0	45	35	30	21
Sutfometuron+2,4-D	1+16	58	6	3	52	40	10	13
Fall								
Sulfometuron	1	---	---	18	3	11	38	79
Sulfometuron	2	---	---	65	2	35	62	94
Sulfometuron+picloram	1+8	---	---	83	26	24	98	94
Sulfometuron+dicamba	1+32	---	---	61	13	25	98	90
Sutfometuron+2,4-D	1+16	---	---	56	3	16	69	74
Picloram	32	---	---	92	70	30	99	42
LSD (0.05)		11	12	26	27	27	18	29

An experiment to evaluate the optimum timing for application of sulfometuron combination treatments for leafy spurge control was established at Chaffee, North Dakota in 1987. Treatments were applied 8 times during the growing season to leafy spurge in various growth stages (Table 4). Control was evaluated visually on May 23, 1988 when leafy spurge was in the yellow bract growth stage.

Leafy spurge control with sulfometuron averaged less than 10% regardless of the auxin herbicide mixture when applied in the vegetative growth stage (Table 4). Control gradually increased and averaged 92% or more when applied from August 3, to September 15, 1987. Sulfometuron applied with picloram or dicamba provided better leafy spurge control then when applied with 2,4-D regardless of treatment date. However, the late summer and fall sulfometuron + 2,4-D treatments provided similar leafy spurge control to picloram at 16 oz/A but at approximately 25% of the cost.

Table 4. Leafy spurge control with sulfometurom plus an auxin herbicide applied at various leafy spurge growth stages.

1987 application date	Leafy spurge growth stage	Treatment/application rate (oz/A)			
		Sulfometuron + 2,4-D 1.25 + 16	Sulfometuron + dicamba 1.25 + 32	Sulfometuron + picloram 1.25 + 8	Picloram 16
		(% control)			
11 May	Vegetative-yellow bract	0	0	8	53
26 May	Flower development	14	24	59	70
8 June	True flower - seed set	21	31	72	67
29 June	Filled seed	14	44	82	67
17 July	Seed dispersal	42	79	96	93
3 August	Summer dormancy	85	95	99	91
26 August	Dormancy-regrowth	78	99	99	95
15 September	Fall regrowth	90	96	99	73
LSD (0.05)			20		

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Published by GPC-14: Leafy Spurge Control in the Great Plains.

Mow/fertilization treatments and their effect on leafy spurge *Euphorbia esula* control with herbicides

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Abstract:

Leafy spurge has spread throughout southern Canada and the northern United States. Wyoming alone has over 19,000 ha of leafy spurge infested land, most of which is rangeland. Because leafy spurge is difficult to control with herbicides alone, research was conducted to evaluate the influence of mowing and/or fertilization treatments on herbicide effectiveness.

Main-plot mow/fertilizer treatments included different timings of mowing followed by different timings of herbicide treatment combined with fertilization or no fertilization in the fall. Picloram at 1.1 kg/ha provided the greatest control of leafy spurge regardless of main-plot treatment based on both stem numbers and ocular yield. No treatment reduced grass yield, however, grass yields were increased by fertilization in all cases. Mow/fertilizer treatments increased leafy spurge stem numbers prior to spring herbicide application.

Introduction

Chemical control of leafy spurge is difficult since it has a deep and extensive root system with numerous root buds which serve as a means of vegetative reproduction (3,7,9). Many of the root buds remain dormant and this combined with viable seed reserves in the soil make chemical control difficult with single applications.

Considerable research has been conducted to improve herbicide effectiveness on leafy spurge. Several studies have been conducted to increase herbicide translocation to the root buds, through clipping/mowing, addition of nitrogen, and the use of growth regulators (1,4,5,6,8). In addition, studies have been published on the effect of mowing on herbicide effectiveness (2), however, no research has combined mowing, fertilization, and herbicide treatments in one study. The mow/fertilization study was initiated to evaluate the interaction of mowing, fertilization, and herbicide treatments on leafy spurge control.

Materials and methods

Field studies were established in 1986 in the northeast corner of Wyoming, NW of Sundance. The mow/fertilization study and the mow-June/spray August study were located on a high density stand of leafy spurge (160 stems/m^2) while the fertilization/no fertilization study was located on a low density stand of 40 stems/m^2.

Initial counts of leafy spurge stems were taken in each study by utilizing two permanently marked 0.37 m^2 quadrants located in each subplot. Counts were also taken in the spring and one year after application of herbicides. Visual (ocular) evaluations of leafy spurge and grass yield were taken at peak vegetative production. Only perennial grasses were included in grass yield estimation and consisted primarily of *Agropyron intermedium* and *Poa pratensis.*

Field study 1. The experimental design for the mow/fertilization study was a randomized complete block with a split-plot arrangement with four replications. The main plot treatments were: mow-June, with or without fertilizer; mow-July, with or without fertilizer; fertilizer only, and nonmowed unfertilized check. The subplot herbicide treatments were: picloram at 0.56 and 1.1 kg ai/ha, fluroxypyr at 0.28 and 0.56 kg ai/ha, 2,4-D LVE at 4.48 kg ae/ha, dicamba at 2.24 kg ae/ha, and a nontreated control.

Individual subplots were 2.7 by 9.1 m. Soil samples were taken to determine a fertilization recommendation for a 4.5 MG/ha dryland hay crop. All of the fertilization was done in the fall with a Gandy fertilizer spreader applying 105 kg/ha N and 56 kg/ha P_2O_5 on September 19, 1986. Mowing was done with a brush-hog type mower to a height of 8 to 10 cm. 1986 herbicide treatments were applied with a six-nozzle knapsack type sprayer delivering 180 L/ha at 276 kPa.

The mow-June and mow-June + fertilizer treatments were mowed when leafy spurge was at the flowering to soft-dough stage on June 25, 1986. Herbicide treatments were applied July 24, 1986. Leafy spurge was in the vegetative stage with an average height of 9 cm and lateral growth of 15 cm.

Field study 2. An area adjacent to the above plot area also mowed on June 25, 1986 was sprayed on Aug. 24, 1986. The leafy spurge was in the flowering to seed-fill stage at the time of herbicide treatment with an average height of 15.5 cm and lateral growth of 9.5 cm. The mow-June/spray August study was a randomized complete block with four replications.

The mow-July and mow-July + fertilizer plots were mowed July 24, 1986 (approximately two weeks after leafy spurge seed dehiscence). The application of the herbicide treatments was postponed until the spring of 1987 because of the lack of fall regrowth.

Field study 3. A third field experiment was established Sept. 19, 1986, on an area adjacent to the mow/fertilization study. The experimental design was a randomized complete block with a split-plot arrangement with four replications. The main plot treatments were fertilization vs. no fertilization. The herbicide treatments were applied in the spring of 1987. The fertilization and herbicide treatments were the same as described in the mow/fertilization study.

Table 1. Influence of mow or mow/fertilization treatments on leafy spurge and grass yield when averaged over herbicide treatments in 1987.

Treatment	Leafy spurge yield	Grass yield
	(% yield)	
Mow-June/spray July	95	76[2]
Mow-June/spray July + fertilization[1]	100	100
Mow-June/spray August	95	79

[1]Yield of this treatment was used as the basis to compare other yields (100%).
[2] Significant from fertilization at $p = 0.072$, F-test.

Results and discussion

Long-term control of leafy spurge can only be properly assessed the year following treatment. At this time, only herbicide applications in the mow-June treatments can be evaluated for long-term leafy spurge control.

Grass yield was increased 24% with fertilization in the mow-June treatments, while leafy spurge yield was not influenced by fertilization (Table 1). Picloram at 1.1 kg/ha was the only treatment which reduced leafy spurge yield (Table 2). In the mow-June/spray August study all herbicide treatments, except picloram at 1.1 kg/ha and fluroxypyr at 0.56 kg ai/ha, tended to increase leafy spurge yield. Further, picloram at 1.1 kg/ha was the only herbicide treatment which significantly reduced leafy spurge stem numbers the year following herbicide treatment. Leafy spurge stem counts were reduced 3.5 and 4.7 fold in the mow-June/spray July and mow-June/spray August treatments, respectively. In the mow-June/spray August study all herbicide treatments tended to decrease leafy spurge stem numbers, whereas, with the mow-June/spray July treatments fluroxypyr at 0.36 kg/ha and 2,4-D at 4.48 kg/ha tended to increase stem numbers.

Table 2. Leafy spurge and grass response to herbicide treatments in 1987.

Treatment	rate	Mow-June/spray July: Leafy spurge yield	Mow-June/spray July: Grass yield	Mow-June/spray July: Change in stem counts	Mow-June/spray August: Leafy spurge yield	Mow-June/spray August: Grass yield	Mow-June/spray August: Change in stem counts
	(kg ai/ha)	(% change from the control)					
Picloram	0.56	-6	-8	-133	+10	-3	-144
Picloram	1.1	-46[1]	+4	-350	-10	-16	-467[1]
Fluroxypyr	0.28	+2	-5	-133	+11	-9	-144
Fluroxypyr	0.56	+4	+1	+50	-6	-14	-111
2,4-D LVE	4.48	-16	-2	+100	+16	-11	-211
Dicamba	2.24	+6	-9	-83	+13	-28	-200
LSD (0.10)		267					

[1]Significant from control at Student-Newman-Keul's Test, ALPHA = 0.01.

Grass yields were over 20% higher when fertilizer was applied after the June mowing (Table 1). In the fertilization/no fertilization study fertilizer increased grass yields 39% without influencing leafy spurge yield (Table 3). The reason for the greater grass response to fertilization in this study cannot be attributed to the absence of mowing alone, since this area also had a lower leafy spurge density.

Herbicide treatments did not significantly reduce grass yields (Table 2). However, picloram at 1.1 kg/ha tended to increase grass yields when applied in July. All herbicide treatments applied in August tended to decrease grass yields, especially, dicamba at 2.24 kg ae/ha.

Table 3. Leafy spurge and grass response to fall fertilization in the fertilization/no fertilization study in 1987.

Treatment	Leafy spurge yield	Grass yield
	(% yield)	
Fertilization[1]	100	100
No fertilization	94	61[2]

[1]Yield of this treatment was used as the basis to compare other yields (100%).
[2]Significant from fertilization at $p = .002$, F-test.

The influence of mow/fertilization treatments on control of leafy spurge with spring applied herbicide treatments will be assessed in the spring of 1988. However, mow/fertilization treatments significantly influenced leafy spurge stem numbers prior to herbicide treatments in the spring of 1987 (Table 4.). The mow-July plus fertilization treatment increased leafy spurge stem numbers by 95/m^2 from fall to spring, while the nonmowed unfertilized check increased stem numbers by only 24/m^2, nearly a fourfold difference. The mowing and fertilization treatments were similar in their effect on leafy spurge stem numbers and were intermediate between the mow-July + fertilization and nonmowed unfertilized treatment.

Table 4. Influence of mow-July and/or fertilization treatments on leafy spurge stem numbers prior to spring herbicide treatment in 1987[1].

Treatment	Increase in stem numbers from 8/12/86 to 5/19/87[1]
	(stems/m^2) [2]
Mow-July + fertilization	95[a]
Fertilization only	65[b]
Mow-July	60[b]
Nonmowed unfertilized	24[c]

[1]Original stand had -160 stems/m^2
[2]Means followed by same letters are not significantly different (Student-Newman-Keul's Test, ALPHA = .01).

Increasing leafy spurge stem numbers prior to herbicide application may have its benefits. Hunter *et al*. (4) saw two advantages to increasing stems; 1) the number of dormant buds from which regrowth can occur is reduced and 2) there is a greater amount of foliage to intercept the herbicide.

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Published by GPC-14: Leafy Spurge Control in the Great Plains.

Noxious invaders of North Dakota

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A video to promote weed identification and control among the general public has been produced by the Cooperative Extension Service at North Dakota State University. How noxious weeds affect the lifestyle, jobs and health of the general public is explained. Six of the primary noxious weeds in North Dakota are identified and shown in various growth stages and habitats. The six weeds emphasized are leafy spurge, field bindweed, spotted knapweed, Canada thistle, perennial sowthistle, and absinth wormwood. The video is 15 minutes long and can be rented or purchased from the NDSU Extension Service.

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Published by GPC-14: Leafy Spurge Control in the Great Plains.

Optimizing the use of aerial photography to map leafy spurge

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Introduction

Leafy spurge occurrence is a well known and pervasive problem throughout the Northern Great Plains. As a noxious weed, most states require landowners to undertake control of the spurge, generally through application of herbicides.

The acreage of spurge by state is summarized annually. The methods of providing these acreage figures vary according to thoroughness of the county-based ground survey; additional data used in the estimation of acreage may include acres sprayed, acres observed during representative transects and landowner participation in supplying data. Understandably, the county estimations of spurge acres can fluctuate in accuracy due to variability in the data collection methods and due to lack of funding and time to complete systematic ground surveys.

The spurge acreage appears to be expanding. It is therefore imperative that accurate estimations of spurge acreage are compiled. This information can then be used to identify “hot spots” and secure additional action, especially intensified state and federal commitments to research and control programs.

Aerial photography offers a timely and cost-effective means of surveying vegetation types. A spurge mapping project in Crook County, Wyoming provided accurate mapping of leafy spurge over 36 square miles through a computer-based analysis of color infrared aerial photography taken at 6,000 feet above mean ground (AGL) elevation. The cost however, was prohibitive at 40 cents per acre (personal communication with Roeland Elliston, supervisor, Crook County Weed & Pest).

The Nebraska Leafy Spurge Task Force expressed an interest in a similar aerial photography approach to leafy spurge mapping, but at an optimal intersection of cost and accuracy. Consequently, this project was undertaken to address the following questions:

(1) can leafy spurge be identified on aerial photography,

(2) if yes to (1), which film/altitude gives optimal results, and

(3) what factors are important in detection of leafy spurge on the various film/altitudes?

Study Area

The main site within Rock County, Nebraska was selected by the personnel at the North Central Nebraska RC & D and Planning Council. Rainfall was near normal in May and cool season grasses were actively growing throughout the site. Figure 1. Location of the test site within Rock County, Nebraska. (unavailable)

Methods

A given variable is that data collection during spurge bloom provides the best opportunity to distinguish the affected areas.

To evaluate the aerial photography variables, the following data collection parameters were selected:

(1) 70 mm aerial films--color, color infrared (CIR), and CIR with enhanced processing, and

(2) four flight altitudes—1,500 ft., 3,000 ft., 4,500 ft., and 6,000 ft. AGL.

The aerial flight took place under clear sky conditions on May 24, 1988.

Coincident with the aerial overflights, the following ground activities took place at the main site (the control site):

(1) four-4x4 ft. resolution panels were placed near a spurge patch,

(2) 8 spurge stands were identified within the site and measured for dimension (shape and area),

(3) general observations by stand included range of plant height, average plant densities (plants/square foot), and other descriptive factors (as relevant), and

(4) representative ground photographs (color and CIR photography) were taken.

Results and discussion

The ground data are denoted by 8 spurge stands (Figure 2 - unavailable). The characterizing data by stand are shown in Table 1.

The aerial photography over the site was evaluated by an aerial photo interpreter who had not been involved in the ground data collection. The CIR photography did not adequately portray the spurge stands due to confusion with other light-colored objects. The spurge stands appeared on the aerial color photography in yellowish colors and were distinct from other objects on the 1,500 and 3,000 ft AGL color photography.

Table 1. Characterization of eight leafy spurge stands within the Rock County test site.

Site	Dimension feet	Estimated Range of Plant Height Distribution (inches)	Plant Density (plants/ft^2)	Notes
1	33x34 (1,122 ft^2)	12-20	1-3	patch continued outside defined site
2	10x18 (180 ft^2)	14-20	4-6	lower densities at NE and SW edges
3	14x20 (280 ft^2)	16-22	1-3 NE 4-8 SW	density is variable as indicated
4	10x12 (120 ft^2)	16-22	6-10	denser in center and eastern side with circular shape
5	30x36 (1,080x ft^2)	14-20	2-4	mixture of other weeds and occurs on well-rotted manure mounds
6	20x30 (600 ft^2)	20-24	6-10	(same notes as for #5)
7	96x115 (11,040ft^2)	16-20	5-8	plant height had extremes of 12 to 26 inches and density was as high as 30 plants/ft^2 some areas with non-blooming spurge
8	4x4 (16ft^2)	12-20	3-6	nearly circular “control plot”, density lower on edges, density peaked at 8 plants/ft^2)

The results accomplished from evaluation of the color aerial photography are shown in Table 2. Only stand 7 was visible on the 4,500 ft and 6,000 ft AGL color photography.

The interpretation of the 1,500 ft color photography provided 80% accuracy of the spurge area without any misidentification. Low density of spurge (viz., fewer plants than 4 plants per square foot) was the main contributer to not being able to delineate spurge stands on the 1,500 ft color photography. One exception to the density consideration was other weeds and growth an old manure piles (a rare site factor in relation to overall spurge occurrence); size and shape were also factors on the 3,000 color photography. A 4×4 foot patch was visible on the 1,500 ft photography, but overlooked by the aerial photographic interpreter, since it was at the edge of the site and was a small point.

Color enhancements are possible and could potentially allow for better results in the 3,000 ft and possibly 4,500 ft color photography. Since this was an experiment with limited data collection, exact costs could not be estimated per unit area. A comparison of the costs for collecting photography at 1,500 ft AGL verses 3,000 ft is listed as follows:

(1) flying time--doubled

(2) aerial photography (film length, processing, and printing) 4× increase, and

(3) aerial photographic interpretation 4× increase.

Table 2. Results of color aerial photographic interpretation.

Site	Correction Identification (Yes or No)		Mitigating Factors/Comments
	1,500 ft	3,000 ft	
1	N	N	low density stand
2	Y	N	small size
3	Y	Y	
4	Y	N	small size
5	N	N	low density and other weeds
6	N	N	other weeds
7	Y	Y	density differences were apparent across the stand
8	N(Y)	N	Interpreter overlooked this stand on the 1,500 ft photography, but could see it on photography when the ground verification map was later examined.

Conclusions and recommendations

The following conclusions were reached:

(1) a high percentage of leafy spurge area can be accurately delineated on 1,500 ft AGL color photography, if plant densities are >4 plants/ft^2 under blooming condition,

(2) 3,000 ft AGL color photography can be used to delineate the larger plant with stated density, as above, and

(3) color infrared photography did not record leafy spurge stands such that accurate identification could take place, the spurge bloom was confused with bare ground and other areas that also appeared in whitish colors.

We recommend that further photographic enhancement be evaluated to bring out the color associated with the spurge stands, especially on the 3000 ft and the 4500 ft AGL color photography. The 1500 ft AGL color photography would appear to be too costly for full area surveys. This photography could, however, be a useful tool for trend evaluation and limited surveys over known problem areas.

Acknowledgements

We are thankful to the North Central Nebraska RC & D and Planning Council for funding this project. Mr. Gene DeBolt and Mr. Gene Lehnert were extremely helpful throughout the project. We are also grateful to the Nebraska Leafy Spurge Task Force and the South Dakota State Weed Commission, especially Dr. Dennis Clark, for their support.

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Published by GPC-14: Leafy Spurge Control in the Great Plains.

APHIS - Biocontrol project of leafy spurge, a report

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1988 is the first year for Animal and Plant Health Inspection Service (APHIS) to become involved in the biological control of leafy spurge. Prior to this time, a planning committee had developed ideas on the best approach to implement a project with minimal fiscal support and few biological control agents. Although several State and Federal scientists were working on the biological control of leafy spurge, a major drive to implement a program was not initiated until this year. Fortunately, with the help of State cooperators, an increased interest in the biological control of leafy spurge provided for significant congressional support. This type of support enhances committee activity so that a definite plan can be developed for a period of time.

Project organizers realized the major problem in implementing a biological control project on leafy spurge was the lack of biological control agents. The number and diversity of biological control agents needed to be expanded. Second in importance was the need for quarantine capability in providing pass-through services for introducing biocontrol agents previously cleared for release in the United States (U.S.).

Third, because many of the insects known to attack leafy spurge are univoltine the ability to mass produce each species must be addressed. It was these major concerns that initiated our goal to set in place a major effort in the biological control of leafy spurge. Cooperative agreements have been negotiated with State cooperators, the Commonwealth Institute of Biological Control (CIBC), and Agricultural Research Service (ARS) to address many of these areas of concern.

Currently ARS personnel at the Rome laboratory and CIBC scientists in Delmont, Switzerland, are collecting in Austria, Italy, and Yugoslavia, *Aphthona flava*, *A. cyparissiae*, *A. czwalinai*, *Bayeria capitigena*, and *Oberea erythrocephala*, all of which have been cleared for release in the U.S. As soon as these insects have undergone a quick screen, they are sent to cooperators in Nebraska, North Dakota, Montana, Oregon, and South Dakota for field cage releases. APHIS has staffed and based portions of the Biological Control of Weeds quarantine facility in Albany for the quick screen activity. In conjunction with State cooperators in North Dakota, several different release strategies are being evaluated. The need to deliver the biocontrol agents into a specific niche greatly enhances the success rate for field insectary establishment. Once these parameters for successful establishment have been determined, insectary sites will be set up and the biocontrol agents made available for distribution to other locations.

Another important aspect of our program is the ability to propagate large numbers of biocontrol agents for release purposes. Research is being conducted by ARS and North Dakota State University (NDSU) scientists on methods of providing a host plant that can be utilized for mass production of insects. Currently discussions are underway to begin research on development of a defined diet for mass production of certain species of insects that attack leafy spurge. This research could have a very positive impact on mass production of biological control agents.

A need exists to increase the diversity of the biological control agents currently available for release in the U.S. An agreement has been finalized with CIBC to collect and screen approximately four additional species of insects; however, availability of plants for this work is limited at this time. APHIS, in conjunction with the Center for Plant Conservation, is collecting fifteen species of *Euphorbia* including seven species which are listed as endangered or threatened. These plants will be propagated by the Mission Biological Control Laboratory and made available for use in host specificity testing. Current plans are to provide this material to Delmont, Switzerland, for screening purposes. Once the specificity work has been accomplished the insects will be cleared through a quarantine laboratory in the U.S. and made available for field evaluation.

Equally important is the need to know how successful we have been in reducing the problem of leafy spurge to privately owned land and national rangeland. In an attempt to quantify the impact of leafy spurge in these areas, an economic evaluation will be conducted. Economists at NDSU will initiate this study and develop models that will address each area of concern.

Finally, efforts to increase the effectiveness and reduce the cost of survey for leafy spurge are underway. More research in this area will greatly increase our awareness of the spread and distribution of leafy spurge in the U.S.

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Published by GPC-14: Leafy Spurge Control in the Great Plains.

Leafy spurge research at WRRC/ARS

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The following report summarizes continuing research efforts conducted at the Western Regional Research Center, Agricultural Research Service, Albany, California.

Artificial diets for *Aphthona*

Research observations (1) have led to the projected use of the flea beetle (*Aphthona* sp.) as a biological control agent for leafy spurge. The projected introduction of this biocontrol insect has defined a need to develop an artificial diet for the mass rearing of this insect to provide sufficient quantities for large releases in spurge infested areas. In this report we will summarize the initial attempts to formulate an effective artificial diet for these insects in the WRRC laboratory. It should be noted that the diapause of *Aphthona* represents a major obstacle in the continuous evaluation of potential diets for these insects since only one generation is available each year.

Eleven artificial diets have been reported (2) for members of the Chrysomelidae family of which *Aphthona* is a member. These diets were formulated in the WRRC laboratory and applied to *Aphthona* sp. None of these formulations were found to be effective. Chemical extractives of leafy spurge roots were considered as a possible source of feeding stimulants for the flea beetle and four extracts of the roots were evaluated as additives to a base diet for *Aphthona flava* (Table 1). The results of these feedings show no phagostimulatory effects for the total extracts.

Table 1. Effect of extracts of leafy spurge on survival of larvae of *Aphthona flava*[*].

Extract	Yield (% dry wt.)	Survival (mean no. of days)
Hexane	10.9	1.6[a]
Acetone	1.4	1.4[a]
Methanol	4.4	1.8[a]
Water	0.6	0.8[a]
Hexane + acetone	-	0.6[a]
Methanol + water	-	0.6[a]
Control diet	-	3.8[b]

[*]2nd Instar Larvae, 10 replicates/treatment of 2 larvae/container.

When freeze dried secondary leafy spurge roots were ground and added to a 1.7% agar media, larval feeding was observed to increase with increasing concentration of the ground root material (Table 2). A mean survival of 4.2 days was observed at a concentration of 100 mg/ml of agar. Higher concentration of ground root material could not be suspended in the agar.

Table 2. Effect of leafy spurge root powders in agar on survival of larvae *Aphthona flava.*

Conc. (mg root powder/ml)	Survival (Mean No. of days)
100	4.2[a]
50	3.8[a]
10	3.0[a]
5	2.2[b]

*Freeze-dried secondary roots in 1.7% agar.

Fresh root material proved to be most suitable material for rearing the *Aphthona flava* larva (Table 3). Both chopped and ground fresh root material exposed to larva on filter paper produced many pupae and 20 or more day survival times. Chopped and ground fresh root material added to 1.7% agar showed fewer pupae or no pupae and shorter survival times. It is apparent that the agar media does have some adverse effect on the feeding ability of larva.

Table 3. Effect of leafy spurge fresh root preparations on survival of larvae of *Aphthona flava.*

Root Preparation	Survival (Mean No. of Days)
Chopped Fresh .25-.50 cm. (on filter paper)	20+ (many pupae)
Ground by Polytron (on filter paper)	20+ (many pupae)
Chopped Fresh .25-.50 cm. (in 1.7% agar)	15+ (few pupae)
Ground by Polytron (in 1.7% agar)	10+ (no pupae)

The results of these preliminary investigations indicate that fresh root tissue contain the phago-stimulants and nutrients necessary for flea beetle development. A closer examination of this tissue for specific chemical or biochemical factors is planned.

Characterization of Leafy Spurge Volatiles

The introduction of monophagous insect predators to North American leafy spurge has been complicated by the inability to correlate susceptible leafy spurge accessions to insect predation. The diverse morphological character of North American spurge accessions has thwarted definitive taxonomic differentiation of the plant by classical means. Chemical taxonomic investigations of leaf waxes (3), latex (4) and root (5,6) extractives of leafy spurge have shown variations in diterpenes and triterpenes among spurge accessions which may be useful in their taxonomic separation. Information about the volatile constituents of leafy spurge accessions could offer additional chemo-taxonomic information and provide baseline data relative to insect attraction or feeding on leafy spurge plants.

Aerial plant tissue from field grown (mixed accessions) and greenhouse-grown (accessions 1979ND1, 1978A1 and 1978OP1) leafy spurge plants were blended in water, vacuum codistilled, liquid-liquid extracted (ether) and concentrated. The concentrated distillate was subjected to GC/MS analysis and separated components were compared to reference library data. Preliminary identification of compounds was verified by comparison to authentic reference compounds.

A total of 119 volatile compounds were found to be present in trace or greater levels for one or more of the four leafy spurge concentrates. Six-carbon alcohols were the predominate constituents in the concentrates and major differences (mostly quantitative) were found between the field-grown and greenhouse samples. The greenhouse samples contained higher concentrations of specific components while the field-grown samples had more trace-level components. The 17 components present in 1% or greater concentration in at least one of the four concentrates are included in Table 4. Greenhouse-grown plants produced 11-13 compounds that occurred in concentrations > = 1%. Field-grown plants produced 5-8 compounds that were > = 1%.

Table 4. Major components (> = 1% of total FID area) of leafy spurge concentrates.

	Greenhouse		Field	
Component	G-1 Area %	G-2 Area %	F-1 Area %	F-2 Area %
Alcohols				
ethanol	0.4	1.2	0.7	1.8
pentanol	1.2	0.7	tr	0.3
hexanol	5.1	3.8	3.7	5.5
heptanol	5.5	3.8	tr	tr
octanol	2.8	1.4	tr	0.1
nonanol	19.0	12.4	tr	0.1
methylbutanol,3-	1.5	1.4	1.1	3.1
cyclohexanol	11.0	18.9	tr	
hex-2-enol, (E)-	7.1	7.9	22.6	21.5
hex-3-enol, (Z)-	28.6	24.5	63.5	51.4
Aldehydes				
heptanal	1.0	0.2		tr
nonanal	7.4	1.1		tr
hex-2-enal,(E)-	0.8	0.4	1.7	1.2
Esters				
ethyl formate	tr	6.4		tr
ethyl acetate	0.3	7.4	0.5	2.4
hex-3-enyl acetate,(Z)-	0.9	1.9	0.8	1.7

tr=concentration <0.12% from GC/FID area percent measurements.

Alcohols were the predominant volatiles detected in the spurge concentrates with (Z)-hex-3-enol occurring as a major component in all concentrates. (E)-Hex-2-enol and hexanol were also detected as major components in both the field-grown and greenhouse concentrates. Cyclohexanol and nonanol were abundant in the greenhouse samples but were essentially absent in the field samples. Cyclohexanol is not commonly found in plant tissue concentrates and its presence in spurge will be confirmed in later studies of the volatiles in this plant. The homologous series of normal primary alcohols and a number of branched acyclic primary and secondary alcohols occur in low concentrations. Several unsaturated alcohols were identified and with the exception of the abundant hexenols, their yield was less than 1%. Three aldehydes derived from prominent alcohols were detected and three esters, several ketones, pyridine, limonene and p-cymene, several non-terpene hydrocarbons and carboxylic acids were found in the concentrates.

The results of this investigation show that reproducible volatile profiles can be obtained from leafy spurge shoots. They further indicate differences in the volatile constituents of the greenhouse accessions and the field-grown samples which include the effect of the growing environment. The results provide the framework for an examination of individual accessions grown under identical conditions and also describe chemical components occurring in leafy spurge which should be evaluated in insect tests as attractants or feedants.

The biochemical basis of the allelopathic interaction of leafy spurge and small everlasting

The early observation that the low-growing plant small everlasting produced allelochemicals which inhibited the spread of leafy spurge (7) prompted a cooperative investigation (ARS/WRRC and NDSU) (8) which characterized phenolic compounds (arbutin, hydroquinone and caffeic acid) occurring in the chemical extractives of small everlasting. Hydroquinone, which occurs in low yield in small everlasting, was shown to be a potent phytotoxin to leafy spurge and lettuce seedlings. The research findings suggested that hydroquinone, derived from a large arbutin pool by hydrolysis, may serve as a chronic allelochemical toward leafy spurge. The chemical investigation indicated that more conclusive evidence of the mode of action of allelochemicals toward leafy spurge might be obtained through an examination of the biochemical processes of phytotoxicity at the cellular level. A cooperative investigation (ARS/WRRC, MRRL and NDSU) has now been undertaken to investigate these processes.

Suspension culture cells, obtained from ARS/MRRL stock, have been treated with varying concentrations of hydroquinone and arbutin to confirm prior toxicity data and determine the appropriate concentration level to assess chronic exposure. Exposure of the cells to hydroquinone (Table 5) clearly confirm the toxicity of hydroquinone at the cellular level and establish 5×10^{-4}M as the concentration level for chronic exposure. Toxicity results for exposure of leafy spurge cells to arbutin at the same concentrations showed no difference from control at all levels.

Table 5. Summary of initial concentration experiments with leafy spurge suspension culture cells.

	Mean fresh weight (g)	
Treatment	Day 4	Day 8
1% Methanol Control	10.92	19.61
10^{-5} M Hydroquinone	11.16	15.90
10^{-4} M Hydroquinone	7.35	14.44
10^{-3} M Hydroquinone	1.35	1.46
10^{-2} M Hydroquinone	cells dead	

Notes:
Based on these experiments, 5×10^{-4} M hydroquinone was chosen as a reasonable concentration for further experiments.
Ether extractions of the media from the above samples showed no traces of hydroquinone, with the exception of the 10^{-2} M treatment, in which the cells appeared brown and dead.

Based upon the exposure results, the ability of leafy spurge to detoxify hydroquinone through glucosylation at 5×10^{-4} M and 10^{-3} M at the cellular level was evaluated (Table 6). The results show that hydroquinone is successfully glucosylated to form arbutin but that the efficiency of the detoxification is reduced at increased concentrations. Enzyme assays with extracts from the treated cells suggest the presence of a UDPG-dependent glucosyltransferase enzyme capable of catalyzing the hydroquinone to arbutin reaction. At higher concentrations, the glucosylation reaction efficiency is reduced; suggesting the presence of toxic levels of the phytotoxin. Based upon these preliminary results, cell culture experiments have been designed to evaluate the effect of chronic exposure of hydroquinone to leafy spurge. Further purification of the glucosyltransferase catalyzing the hydroquinone to arbutin transformation should yield specific characterization of the enzyme.

Table 6. Conversion of hydroquinone to arbutin in leafy spurge suspension culture cells.

Treatment	Fresh Weight	Arbutin (ug/l0 ul)	Percent Conversion
Methanol Control	18.35	0	--
5×10^{-4} M Hydroquinone	12.67	11.53	85%
1×10^{-3} M Hydroquinone	10.46	19.31	71%

Notes:
Hydroquinone was added to the cells 24 hours after innoculation. Fresh weight was measured seven days after innoculation.
Arbutin was chromatographed on a C18 reverse phase HPLC column and detected by UV absorbance (280 nm).

Evaluation of the phytotoxicity of secondary metabolites produced by small everlasting toward leafy spurge at the cellular level would substantiate field and laboratory observations and would allow access to biochemical observations which could describe the mode of action of the phytotoxins. Callus derived from small everlasting leaf tissue has now been successfully cultured in our laboratory thereby providing the means for the evaluation of secondary metabolites produced at the cellular level as phytotoxins to leafy spurge. The evaluation of lettuce seed germination on media supporting small everlasting and leafy spurge (Table 7) indicates that small everlasting culture exudes phytotoxic material into the support media.

Table 7. Lettuce seed germination bioassay on callus culture media.

Treatment	Percent germination
Control	97%
Leafy spurge agar	85%
Antennaria agar	19%

Notes: Data were collected after sterile seeds had been placed on the agar for 48 hours and the emerging radicals were at least 2 mm long.
Attempts are now being made to isolate a bioactive fraction from this *Antennaria* agar.

Co-culturing experiments with small everlasting and leafy spurge callus (Table 8) reveal that leafy spurge callus growth is reduced by about 50% when co-cultured with small everlasting or grown on media (on which small everlasting was grown.

Table 8. Co-culturing experiments with callus cultures of *Antennaria microphylla* and *Euphorbia esula.*

	Treatment	Percent increase in growth
I.	leafy spurge control	27.21 [c]
II.	leafy spurge, co-cultured with *Antennaria*	13.84 [b]
III.	leafy spurge on agar from which *Antennaria* was removed after one week	14.25[b]
IV.	*Antennaria*, co-cultured with leafy spurge	31.45[c]
V.	*Antennaria* control	27.70 [c]

Notes:
[a]After one week of growth at 28° C in 24 hour darkness.
[b]Significantly different from the leafy spurge control at the 0.05 percent level.
[c]The controls are not significantly different from each other, or from treatment IV. The same experiment set up in divided petri dishes produced no significant differences between any of the treatments, i.e. there is not a volatile phytotoxin (data not shown).

Small everlasting, in contrast, is not affected by the presence of leafy spurge in the same culture media. These data are consistent with the earlier reports of similar experiments with whole plants and provide substantial evidence of small everlasting's ability to produce phytotoxins which are particularly effective against leafy spurge. Analysis of the media on which the small everlasting is grown is presently underway in an effort to characterize specific compounds which are present and compare them to the phenolics obtained from the whole plant. The successful isolation and characterization of specific allelochemicals from cultured plant cells would provide the first information relative to the definitive description of allelopathic mechanisms at the cellular level.

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Published by GPC-14: Leafy Spurge Control in the Great Plains.

Sparganothis sulfureana as a possible model for introduced biological control agents

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Few native insects attack leafy spurge. One species of particular interest is *Sparganothis sulfureana* (Clemens). Study of *S. sulfureana* biology, field populations, predators and parasites may be influential in establishing other biological control agents having similar life cycles and biologies.

Sparganothis sulfureana is a native Tortricid moth that attacks leafy spurge, *Euphorbia esula* L., causing minor damage to the upper part of the plant, possibly affecting seed formation. *S. sulfureana* is an external feeder and leaf tier. It is bivoltine in the northern part of the U.S. and overwinters as a first instar larva in a hibernaculum. *S. sulfureana* has been reported feeding on a wide variety of plants which includes celery, corn, red cedar, jack pine, Scotch pine, strawberry, willow, elm, alfalfa, blueberry, cranberry and apple. *S. sulfureana* is considered economically important on apple (Chapman & Lienk, 1971). The overwintering first instar larvae begin feeding on the emerging shoots as early as April. The larvae feed mostly on new leaves and terminal buds. As the spurge develops the larvae web together new leaves, feeding extensively from the tie-ups. The adults appear in mid to late May in North Dakota.

Egg masses of the second generation contain as many as 100 eggs per egg mass to as few as 1; most egg masses contain between 15 - 30 eggs. A single female, on average, lays about 220 eggs. The egg stage lasts from 9 to 12 days. The larvae upon eclosion, start feeding on the foliage. Adults of the second generation appear during the latter half of August. The eggs laid by the adults produce the overwintering first instar larvae.

While laboratory and greenhouse studies indicate a high level of fecundity, with females capable of laying 200+ eggs, field studies show a larval population of less than 5/sq m. A study was conducted at the Bald Hill Dam site whereby egg masses were placed at release sites prior to or shortly after hatching. The release sites were checked weekly for tie-ups. 93% of the point releases contained less than 5 tie-ups/100eggs, indicating a high rate of mortality. The actual cause of mortality is not known, but dessication, predation and parasitism are possible explanations.

Predators and parasites play an important role in limiting the population of *S. sulfureana*. Tie-ups were collected weekly at Lisbon, ND to note adult emergence. The tie-ups were placed in 5cm x 3.5cm plastic specimen containers; adult *S. sulfureana* and parasitoid emergence was noted. In 1986, parasitoids emerged from 90% of the first generation tie-ups collected. The percentage of parasitoids emerging in 1987 was about the same, 83.3%. In a survey of insects associated with leafy spurge, Julian (1984) collected over

50 species of parasitoids. 22 species were known to attack Lepidoptera and 8 species were reared from *S. sulfureana* alone. In addition, 50 species of predaceous insects were collected. The findings from the above studies give an indication of the pressure exerted by predators and parasitoids upon leaf feeding insects on leafy spurge.

While *S. sulfureana* is a polyphagous feeder, causing minimal damage to leafy spurge, certain aspects of its biology can be of some importance to the biological control effort. Studies of *S. sulfureana* can be used to better understand the effects of foliage and pod feeders on leafy spurge. Population studies may give some indication of the number of biological control agents needed in order to stress leafy spurge plants. Predator and parasitoid studies will shed some light on the type of pressure that is being exerted on the biological control agent by the natural population. Also, parasitoid studies may be helpful in introducing other biological control agents with similar life cycles and feeding habits. Most importantly, *S. sulfureana* contributes to the stress placed upon leafy spurge in the field.

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Published by GPC-14: Leafy Spurge Control in the Great Plains.

Reaction of different biotypes of leafy spurge and other plant species to *Alternaria tenuissima* f. sp. *euphorbiae*

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The noxious weed leafy spurge (*Euphorbiae esula*) continues to pose a serious problem in rangelands and pastures throughout several western states. Satisfactory chemical control has not been established, and use of insects for biological control is still developing stage. The use of fungi for biocontrol offers another possible control mechanism which could be used alone or in combination with herbicides, plant growth regulators, and insects. We report some results from studies with a fungus, *Alternaria tenuissima* f. sp. *euphorbiae* (ATE), which has been shown by Krupinsky and Lorenz (2) to be pathogenic on leafy spurge.

Materials and methods

Conidia of ATE were produced on surface sterilized, detached leaves of leafy spurge on sterile moistened filter paper in petri dishes at 20ºC (12 hour light). Conidia were obtained by flooding the leaves with sterile distilled water containing 0.1% polyoxethylene sorbitan monolaurate and gently rubbing the surface with a spatula. The conidial suspension was filtered through two layers of cheesecloth and adjusted to contain about 10^6 spores per ml. Inoculum was sprayed on to plants until runoff. The inoculated plants were incubated in dew chambers at desired temperatures ranging from 12-25ºC and for 12 to 24 hours. Severity of disease was recorded six days after inoculation.

Temperature and dew period

The optimum temperature for infection at a 12 hour dew period occurred between 15-20ºC (59-68ºF) with some infection occurring from 12-25ºC. Increasing the dew period to 24 hours resulted in heavier infection. This effect was more pronounced on plants other than leafy spurge (see section on Host Range).

Table 1. Reaction of leafy spurge collections to *Alternaria tenuissima* f. sp. *euphorbiae*. After inoculation plants were held for 12 hours in a dew chamber at 20ºC.

Slightly infected[a]	Moderately infected[a]	Severely infected[a]	No infection
#11 (North Dakota)	MI-13 (Michigan)	IC (Italy)	BC-25 (Br. Col.)
#50 (North Dakota)	#12 (North Dakota)	TU1 (Turkey)	ID-5 (Idaho)
1A (Iowa)		MT-6 (Montana)	#10 (No. Dakota)
NJ-1 (New Jersey)		YU-1 (Yugoslavia)	CIT-1, (Italy)[b]

[a] Slightly infected: Brown spots on leaves at lower and middle parts of stems, or edge of leaves becomes straw colored; Moderately infected: Leaves at lower and middle part of stems were severely discolored, or tips of young shoots died; Severely infected: More than 80% of leaves discolored, or plants died.
[b] Cypress spurge

Biotypes of leafy spurge

Several biotypes of leafy spurge have been collected during the past few years. Examples of the reaction of several of these collections to inoculation with ATE is presented in Table 1. These results indicate the variability present in leafy spurge, and underscores the need for rapid, accurate methods of biotype identification.

Host range

The fungus used in this study infected plants other than leafy spurge as shown in Table 2. It should be noted that these results were obtained under ideal conditions for the fungus (48 hours in the dew chamber at 20ºC). It will be important to compare infection rates and severities under field conditions to determine the relative safety of using ATE for biocontrol of leafy spurge on a large scale.

Table 2. Reaction of different plant species to *Alternaria tenuissima* f. sp. *euphorbiae*. After inoculation plants were held for 48 hours in dew chamber at 20ºC.

Plant	Reaction
Corn	Straw-colored spots on leaves
Roma bean	Straw-colored spots on leaves
Wheat	No infection
Cucumber	Straw-colored spots on leaves of some plants
Red clover	Edge of leaves straw-colored
Lettuce	Straw-colored spots on leaves
Hot pepper	No infection
Soy bean	Straw-colored and brown necrotic spots on leaves
Safflower (Gila)	Leaf blight on some first and second leaves
Okra	Leaf spots on colyledons
Artichoke	Necrotic spots on leaves of some plants
Cantaloupe	No infection
Zinnia	Tip burn on lower four leaves of some plants
Velvet leaf	No infection
Marigold	Infected plants died
Leafy spurge	Infected leaves turned straw-colored, plants died

Additional studies confirmed that plants other than leafy spurge may be less susceptible to infection under conditions less than ideal for the fungus (Table 3). The fungus could be isolated from infected plants, but more than 12 hours dew was required to reinfect the same host. When combined inoculum from these plants was used to inoculate YU-1 leafy spurge, plants were severely infected when held in the dew chamber for 12 or 24 hours.

Table 3. Results of inoculating *Alternaria tenuissima* f. sp. *euphorbiae* isolated from infected plants to the same host.

Host	To Same plant species	
	12 hour[a]	24 hour[a]
Corn	No infection	Moderate-severe infection
Safflower	No infection	Slightly infected
Artichoke	No infection	(Not tested)
Zinnia	(Not tested)	Slightly infected

[a]Number of hours incubated at 20ºC after inoculation.

Conclusions

Results obtained from this study and by other scientists (1) indicate ATE has potential as a mycoherbicide for biological control of leafy spurge. However, limited field trials (2) have not been encouraging, and there are many things we need to know about this organism before considering large scale field trials. We need to know 1) how to increase the effectiveness of ATE on leafy spurge, 2) how to overcome the biotype problem, 3) plant parts affected by ATE, particularly damage caused to the root system, 4) potential spread of the fungus, 5) overwintering ability, and 6) the potential for damage to non-target crops under field conditions. Limited field trials might be considered under specified conditions without having answers to all the questions raised above.

The most likely role for ATE may be as an additional tool for use in a management approach, such as integrated pest management. Such an approach might include use of herbicides/plant growth regulators, introduced insects, introduced fungal pathogens, and grazing management. It appears that it is not too early to begin planning preliminary cooperative studies to determine how well ATE might play its part in this scheme.

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