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Economic analysis of sheep grazing of leafy spurge: Preliminary results

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Abstract:

Leafy spurge, a widely established exotic, noxious, perennial weed is a major threat to the viability of commercial grazing and to the beneficial outputs of wildlands in the Upper Great Plains. Treatments for leafy spurge are usually based on indicators of physical control, rather than economic criteria. A major benefit to land managers is the identification of economical control methods and an understanding of the economic factors influencing long-term treatment decisions.

The focus of this study was to evaluate grazing scenarios that would most likely be experienced by ranchers adopting sheep grazing as a control method for leafy spurge. The model starts with initial values describing the physical and economic characteristics of an infestation (e.g., infestation size, AUM value). The opportunity cost of no control is measured by estimating the loss of grazing from the initial infestation and the subsequent losses from expansion. The benefits of control include (1) recapturing grazing outputs from current infestations and (2) maintaining existing grazing outputs by preventing infestation expansion. The costs of control included either (1) material, labor, equipment, and lease expenses in the scenarios examining lease arrangements or (2) net returns from sheep enterprises. Net returns (revenues less expenses) from sheep enterprises could be positive or negative, depending upon profitability of the enterprise.

The model estimates the economic viability of using sheep to control leafy spurge by (1) comparing only treatment expenses with treatment returns (i.e., benefit-cost approach) and (2) comparing potential overall losses with sheep grazing versus losses without control (i.e., least-loss approach).

When a sheep enterprise produces positive net returns (enterprise revenues are greater than production costs), leafy spurge control will be economical. However, when a sheep enterprise has negative net returns (production costs exceed revenues), those costs (losses from the sheep enterprise) must be compared to the benefits of leafy spurge control. Likewise, costs of leasing sheep for leafy spurge control must be compared to the benefits of control.

To represent a reasonable range of production possibilities for a new sheep enterprise, eight enterprise scenarios were developed to consider different levels of enterprise performance, debt, and size. Initial budgeting analyses indicated that four out of the eight scenarios examined should/could produce positive enterprise net returns. The initial enterprise characteristics resulting in negative net returns included poor flock performance (e.g., low lambing percentage, light weaning weights) and enterprise debt (e.g., financing the purchase of breeding stock and equipment). Thus, analyses have focused on evaluating the feasibility of the scenarios with negative net returns.

With leafy spurge infestations of 50 to 250 acres, $15/AUM, 0.2 to 0.4 AUMs/acre carrying capacity, and a 15 percent leafy spurge canopy cover, preliminary results indicate that annual sheep enterprise losses down to ($2.30)/ewe would still result in control benefits exceeding control costs over a 10-year period. Adjusting for carrying capacity ranges of 0.4 to 0.6 and 0.6 to 0.8 AUMs/acre, annual enterprise losses down to ($3.85) and ($5.40)/ewe, respectively, would result in control benefits exceeding control costs.

Assuming the same initial conditions (50 to 250-acre infestations, $15/AUM, 0.2 to 0.4 AUMs/acre carrying capacity, and a 15 percent leafy spurge canopy cover), annual sheep enterprise losses down to ($4.70)/ewe would result in less economic loss than no control (i.e., doing nothing to control the infestation) over a 10-year period. Adjusting for carrying capacity ranges of 0.4 to 0.6 and 0.6 to 0.8 AUMs/acre, annual enterprise losses down to ($7.90) and ($11.00)/ewe, respectively, would result in less economic loss than no control.

Preliminary results indicate that using sheep to control leafy spurge can be economical in many situations found in the Upper Great Plains, even when net returns from sheep enterprises are negative. However, further refinement of the model is needed, as some model components are partially based on “best guesses” of range and weed scientists.

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Foreword/Program

In 1999, we celebrate the 20th year of the annual Leafy Spurge symposium and the most aggressive battle ever waged against a weed in the Northern Great Plains. On June 26 and 27th of 1979, more than 125 scientists, legislators, land managers, farmers and ranchers met in Bismarck, North Dakota to discuss the increasing threat of leafy spurge to the land and livelihood of people in the Northern Great Plains.

Leafy spurge had a good foothold by the time the first symposium was held. Introduced into North America from Europe and Asia, it had no natural enemies. A heavy seed producer and an aggressive root system allowed it to easily invade and become established on many sites. For about the first 50 years after introduction, it was primarily a problem in cropland, often spreading to new areas in seed grain. It did not cause much concern, particularly after WWII when herbicide use became common on cropland. Use of herbicides plus annual tillage generally kept leafy spurge from becoming an economic problem in cropland. It did become of greater concern in the 1960's and early 1970's when it began to appear in grasslands. Landowners found that the herbicides were not very effective on leafy spurge. But the attitude was that soon a new herbicide would be developed that would be the "magic bullet" for leafy spurge. In time, a "magic bullet" was available, but it was considered by most landowners to be too costly to use on low-value rangeland, and it did not always eradicate the treated plants. Landowners and public land managers did become concerned in the 1970's. In response to their concerns, a multi-state/multi-agency steering committee was formed, which organized the 1979 symposium. The symposium consisted of technical papers on everything that was known about leafy spurge, followed by group discussions on the leafy spurge plant, chemical control, cultural control, biological control, and social and economic impacts. The reports from these discussion groups served as the basis for beginning an organized plan for research, education, and control of leafy spurge.

The first five years after the 1979 symposium were not smooth sailing. General support for the program often slacked when funding was needed, particularly for research. Some agencies and institutions redirected funds to enhance or start programs. Legislators and administrators had to be convinced that the new funding was needed. The annual leafy spurge symposium brought researchers and others together to report on and discuss needed research and to report to potential users any positive results. Attendees included representatives of federal and state agencies, chemical companies, and private landowners.

To insure continuation of the symposium, a petition was sent to the Great Plains Agricultural Council (GPAC) requesting that they establish a Leafy Spurge Task Force (LSTF) as part of their program for addressing problems in the Great Plains. The proposal was accepted. The LSTF was the longest standing task force in GPAC, and the symposium has continued after GPAC was disbanded several years ago. (The symposium is now affiliated with the Weed Science Society of America).

In 1985, a proposal was prepared and submitted by LSTF to USDA-APHIS to enlist their help in the development of a biological control program on leafy spurge. The proposal was accepted and additional funding was provided by congress to enhance the APHIS program.

The Proceedings published following each symposium are an excellent history of the development of the leafy spurge control program. Early proceedings included work on evaluating the problem and on advances in chemical control. A real breakthrough was the finding that a small quantity of Tordon mixed with 2,4-D was a very effective herbicide at a lower cost. Best time of application and long-term plans for herbicide use were also very important. Use of sheep and goats as leafy spurge grazers and eventually the biological control program became a large part of the reporting in the Proceedings. Farmers, ranchers, and other users were many times part of the symposium.

"The Leafy Spurge News" has been published for over 20 years. It is another outlet for symposium reports and it has a very large circulation.

The 1999 combined symposium and Spurgefest is testimony that the leafy spurge research, education, and control programs are making a difference. Leafy spurge is still here, and it will probably always be here, but two things are certain: 1) we can control leafy spurge to keep it below a disastrous economic level and; 2) there are far less acres of leafy spurge now than there would have been without the dedicated efforts of everyone the past 20 years.

Russell J. Lorenz
USDA-ARS/NDSU-retired
Also past Leafy Spurge News editor
And past GPAC-LSTF facilitator-retired!

1999 Leafy Spurge Symposium Proceedings

Medora, North Dakota

June 29, 1999

Program

8:30 a.m. **Welcome and introduction** - Rod Lym**,** North Dakota State University, Fargo, North Dakota.

8:45 a.m. Perceptions of leafy spurge by ranch operators and local decision makers: an update. Randy Sell**,** Dean A. Bangsund, and F. Larry Leistritz, Department of Agricultural Economics, North Dakota State University, Fargo, North Dakota.

9:00 a.m. "Know thine enemy" - understanding weed management through biological research. James V. Anderson**,** David G. Davis, Michael E. Foley, and David P. Horvath, USDA, ARS, Fargo, North Dakota.

9:30 a.m. Imazapic for leafy spurge control. Denise M. Markle and Rodney G. Lym**,** North Dakota State University, Fargo, North Dakota.

9:45 a.m. Plateau (Imazapic) for leafy spurge control in Wyoming. Mark A. Ferrell and Tom D. Whitson, University of Wyoming, Laramie, Wyoming.

10:00 a.m. Discussion and break

10:30 a.m. Integration of the flea beetle, *Aphthona nigriscutis* Foudras, and herbicides for leafy spurge control. Jeff A. Nelson, Rodney G. Lym**,** and Robert Carlson, North Dakota State University, Fargo, North Dakota.

10:45 a.m. *Aphthona* flea beetle establishment determined by soil composition and root growth pattern. Donald A. Mundal and Robert B. Carlson, North Dakota State University, Fargo, North Dakota.

11:00 a.m. Sex ratio effects on fecundity and fertility of a leafy spurge flea beetle *Aphthona lacertosa.* Denise L. Olson and Donald A. Mundal, North Dakota State University, Fargo, North Dakota.

11:15 a.m. Change detection of leafy spurge *(Euphorbia esula)* infestations using aerial photography and geographic information systems. G. L. Anderson and C. W. Prosser, USDA, ARS, Sidney, Montana; and S. Hager and B. Foster, USDI, Medora, North Dakota.

11:30 a.m. AFLP analysis on individuals from leafy spurge populations characterized as resistant or susceptible to flea beetle biocontrol agents. David P. Horvath**,** USDA, ARS, Fargo, North Dakota.

11:45 a.m. **Discussion and lunch**

1:15 p.m. Comparison of companion grazing and single species grazing on leafy spurge infested rangeland.
– Jack D. Dahl and Timothy C. Faller, Hettinger Research Extension Center, Hettinger, North Dakota; Kevin K. Sedivec and Jerrold Dodd, Animal and Range Sciences Department, North Dakota State University, Fargo, North Dakota; and James Kam and Don Stecher, Northern Great Plains Agricultural Research Center, Mandan, North Dakota.

1:30 p.m. Removing the constraints of sheep as an alternative integrated pest management tool.
– Timothy C. Faller and Jack D. Dahl, Hettinger Research Extension Center, Hettinger, North Dakota.

1:45 p.m. Leafy spurge management with sheep and flea beetles.
– K. George Beck and Larry R. Rittenhouse, Colorado State University, Fort Collins, Colorado.

2:00 p.m. Progress update on toxic compounds in leafy spurge for ruminants.
– Fathi T. Halaweish and Scott L. Kronberg, South Dakota State University, Brookings, South Dakota.

2:15 p.m. Economic analysis of sheep grazing of leafy spurge: preliminary results.
– Dean A. Bangsund, Dan Nudell, Randall S. Sell, and F. Larry Leistritz, North Dakota State University, Fargo, North Dakota and Timothy C. Faller, Hettinger Research Experiment Center, Hettinger, North Dakota.

2:30 p.m. Discussion and break

3:00 p.m. Impacts of leafy spurge on local and landscape patterns of plant species diversity in Theodore Roosevelt National Park.
– Dan R. Cogan, U.S. Bureau of Reclamation, Denver, Colorado; and Jack L. Butler, Central Missouri State University, Warrensburg, Missouri.

3:15 p.m. Seedbank study of a leafy spurge infestation.
– John R. Sterling, Donald R. Kirby, and Rodney G. Lym, North Dakota State University, Fargo, North Dakota.

3:30 p.m. Effects of prescribed burning and herbicide treatments on leafy spurge *(Euphorbia esula* L.).
– Chadley W. Prosser, USDA, ARS, Sidney, Montana and Kevin K. Sedivec and William T. Barker, Animal and Range Sciences Department, North Dakota State University, Fargo, North Dakota.

3:45 p.m. Site characteristics of established flea beetle colonies in western North Dakota.
– Don Kirby, Mark Hayek, Dean Cline, Kelly Krabbenhoft, and Connie O'Brien, North Dakota State University, Fargo, North Dakota.

4:00 p.m. Discussion and summary

Poster: The response of glutathione reductase and glutathione-S-transferase to environmentally- and chemically-induced stress; amelioration by polyamines in leafy spurge *(Euphorbia esula* L.).
– David G. Davis, Harley R. Swanson, Kristi A. Biewer, Donald R. Rusness, and James V. Anderson, USDA/ARS, Fargo, North Dakota.

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Perceptions of leafy spurge by ranch operators and local decision makers: An update

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Abstract:

This study focused on a four-county area in North Dakota (Bowman and Slope counties) and Montana (Fallon and Wibaux Counties) and represents an update to a similar study, using the same survey that was conducted in 1998. A total of 521 ranch operators and local decision makers (LDM) were surveyed, and 177 completed questionnaires were obtained (34%). The previous questionnaire was distributed to 515 ranchers and LDM in a five-county area in North Dakota (Billings and Golden Valley Counties), Montana (Carter County), South Dakota (Harding County), and Wyoming (Crook County). The survey focused on weed management in general and specifically on the perceptions and attitudes of ranchers and LDM, who may have been directly and indirectly affected by leafy spurge.

Leafy spurge was recognized as the most important weed problem for ranchers and LDM in the four-county area. However, ranchers and LDM in the 1999 survey were less likely to indicate that weeds in general were a major problem for them, or in their area, than respondents to the 1998 survey. The percentage of ranchers in the 1999 survey who indicated having leafy spurge on their ranch was less than the 1998 survey, 41 percent versus 56 percent, respectively. Ranchers in the updated survey area had leafy spurge on approximately 2 percent of operated acreage.

Reasons for not using herbicides included environmental restrictions, inadequate funding, and too large of infestations. Biological control was often not used because the biological agents take too long to work, there was limited access to biological agents, and respondents did not know how to properly use agents. The main reason that ranchers and LDM were not using sheep or goat grazing as a control mechanism was that they lacked the

equipment or expertise to include them in their grazing strategies. Other methods such as tillage, planting competing grasses, burning, and mowing were not used because land is not suitable for these methods.

Overall, a vast majority of the respondents were concerned about controlling weeds on rangeland and understood leafy spurge is a long-term management problem. The LDM were more likely than the ranchers to believe that the weed problem in their area was a major problem and that leafy spurge was the most important weed.

The results of this survey indicate that financial constraints on weed control are prevalent. Also, the amount of knowledge needed to adopt various treatment programs appears to be a constraint for both ranchers and LDM. Education and awareness on how to use and where to find biological controls could facilitate more adoption of biological agents to control leafy spurge. Likewise, assistance in obtaining equipment and knowledge of sheep/goat management might enable some managers to use sheep and/or goats to curb further leafy spurge expansion.

The TEAM Leafy Spurge project could enhance adoption of all leafy spurge control methods by addressing concerns exhibited by each of the groups surveyed. By facilitating cooperative efforts between managers of adjoining lands and by pooling resources, perhaps many of the hardships created by leafy spurge can be reversed.

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"Know thine enemy" – Understanding weed management through biological research

JAMES V. ANDERSON, DAVID G. DAVIS, MICHAEL E. FOLEY, and DAVID P. HORVATH

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Abstract:

Leafy spurge (*Euphorbia esula* L.) is an invasive perennial weed which infests greater than 3 million acres of range land in the United States and prairie provinces of Canada. In the U.S., 36 of the 50 states report infestations with the Dakotas, Montana, Nebraska and Wyoming suffering the greatest environmental and economic impact. In the four-state area of the Dakotas, Montana and Wyoming, reports estimate the loss due to leafy spurge infestations of grazing land and wild land to be $129 million annually. Leafy spurge is a major concern to ranchers and environmentalists because left unchecked, leafy spurge can quickly out compete native vegetation in pastures, rangelands, and native habitats. In fact, The Nature Conservancy has termed leafy spurge as "one of the dirty dozen of America's least wanted invasive species of U.S. ecosystems."

Plants classified as weeds possess 12 or more unique characteristics that collectively impart a weedy growth habit. Several of these characteristics deal with reproductive behavior. Most annual weeds reproduce by seeds; however, perennial weeds like leafy spurge also have the ability to reproduce from vegetative root buds. It is the variable growth and development of reproductive organs (seeds and root buds) that allow weeds to avoid conventional weed control measures. Dormancy is a term used to denote variation in the growth and development of seeds and root buds and is a characteristic of most weeds. Reports have indicated that seeds of leafy spurge can remain in a dormant state for 5 to 8 years; however, most germinate within the first 2 years. Unfortunately, the fundamental basis for dormancy in plants is still poorly understood. To address this problem, the Plant Science Research Staff is currently investigating many facets of dormancy in leafy spurge, wild oats and red rice. To paraphrase the ancient Chinese philosopher Sun Tzu – "know thine enemy and victory will

be forthcoming." The impact of understanding dormancy in weeds, as well as the physiology, biochemistry, and genetics of weeds, will improve our knowledge and help us to develop new and useful strategies for weed management.

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Imazapic for leafy spurge control

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Abstract:

Imazapic has shown promise for leafy spurge control in North Dakota, but some injury to grasses has been observed. The objectives of this research were: a) to determine the effect of various adjuvants in combination with imazapic to maximize leafy spurge control and minimize grass injury, b) to determine the most cost-effective rate of imazapic for leafy spurge control when applied alone or with various adjuvants, c) to determine the most effective timing of imazapic application in the fall to maximize leafy spurge control and herbage production, and d) to evaluate the combined effect of imazapic and biological control agents on leafy spurge control. Imazapic applied alone or with various adjuvants injured grasses in greenhouse studies; however, imazapic did not decrease herbage production in field studies. Imazapic provided similar or better leafy spurge control than the standard treatment of picloram plus 2,4-D in the field. Imazapic at 0.14 kg/ha applied with a methylated seed oil (MSO) alone or with 28% N averaged 72% leafy spurge control 12 months after treatment (MAT) compared to 40% control with picloram plus 2,4-D. Imazapic provided maximum leafy spurge control when applied at 0.14 kg/ha with a MSO either alone or with 28% N. Imazapic applied with a MSO in mid-September provided the best leafy spurge control 12 MAT compared to application in August or October. For instance, imazapic at 0.14kg/ha applied with a MSO in mid September provided nearly 70% leafy spurge control 12 MAT compared to 50% or less leafy spurge control when applied in August or October. Imazapic applied over *Aphthona* spp. biological control agents improved leafy spurge control compared to the insects alone, but reduced *Aphthona* density from 25 or 35 adults/m^2 by picloram plus 2,4-D or the control, respectively, to 15 to 20 adults/m^2 by imazapic. These results are based only on one location and one year; further research needs to be conducted to determine if imazapic has a detrimental effect on *Aphthona* spp. flea beetle population. Imazapic will be a useful addition to a long-term leafy spurge control program.

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Plateau (imazapic) for leafy spurge control in Wyoming

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Abstract:

Leafy spurge continues to be a major problem in Wyoming. Its spread has been limited but has not decreased. There are infestations in every county. However, major infestations occur in the northeast corner of the state. The objective of these studies was to compare the efficacy of imazapic (Plateau) for leafy spurge control at two locations. One study was located in Crook County, Wyoming miles south of Devils Tower. The other in Cheyenne, Wyoming on Warren Air Force Base. The studies were a randomized complete block design with four replications. Crook County leafy spurge was 16 to 24 inches tall and Cheyenne leafy spurge was approximately 20 inches tall.

In Crook County imazapic regardless of rate provided excellent leafy spurge control 297 days after treatment (dat) (Table 1). Picloram at 0.5 lb/A also provided excellent control. Grass damage was severe especially at the higher rates of imazapic. The addition of methylated seed oil seemed to increase grass damage.

In Cheyenne leafy spurge control 288 (dat) found imazapic providing little or no control, however there was considerable shoot suppression at the 0.25 lb/A rate (Table 2). No other treatment was effective. Leafy spurge control 590 dat found imazapic providing little or no control, or shoot suppression. Grass damage 288 dat was severe where 0.25 lb/A of imazapic were applied. Grass damage 590 dat was not as evident but was still very noticeable where 0.25 lb/A of imazapic had been applied. The addition of BAS-662 did not increase control. It appears that more research is needed in order to make more accurate predications for control of leafy spurge with imazapic as well as timing of application to reduce grass damage.

Table 1. Leafy spurge control and grass damage in Crook County.

Treatment[a]	Rate	Shoot control[b]	Grass dam[b]
	lb/A	%	%
Imazapic	0.125	84	13
Imazapic+mso[c]	0.125	95	35
Imazapic	0.1875	95	23
Imazapic+mso	0.1875	99	31
Imazapic	0.25	100	43
lmazapic+mso	0.25	100	53
Picloram	0.5	98	0
LSD (P=0.05)		7	19
Cv		5	44

[a]Treatments applied Sept. 3, 1997.
[b]Evaluated June 27, 1998.
[c]mso = methylated seed oil at 0.25% v/v

Table 2. Leafy spurge control, suppression and grass damage in Cheyenne, WY.

Treatment[a]	Rate	Shoot control[b]		Shoot suppression[b]		Grass damage[b]	
		1998	1999	1998	1999	1998	1999
	lb/A	%		%		%	
lmazapic+mso[c]	0.125	0	0	46	3	21	3
Imazapic+mso	0.1875	5	0	55	4	31	3
Imazapic+mso	0.25	11	30	78	40	60	35
BAS-662	0.25	0	0	4	0	13	0
Picloram + 2,4-D arnine	0.25+1.0	20	5	45	20	18	0
Imazapic+BAS-662+mso	0.125+0.25	0	0	46	10	53	5
Imazapic+BAS-662+mso	0.1875+0.25	0	0	46	15	39	10
Imazapic+BAS-662+mso	0.25+0.25	13	20	80	48	66	41
Picloram + 2,4-D amine+BAS-662+mso	0.25+1.0+0.25	0	0	18	5	0	0
LSD (P=0.05)		12	10	23	22	35	21
CV		169	130	39	106	79	148

[a] Treatments applied October 22, 1997.
[b] Evaluated August 6, 1998 and June 4, 1999.
[c] mso = methylated seed oil at 0.25% v/v

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Integration of the flea beetle, *Aphthona nigriscutis* foudras, and herbicides for control of leaf spurge, *Euphorbia esula L.*

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Abstract:

The combined treatment of the biological control agent, *A. nigriscutis* plus the herbicide treatment picloram plus 2,4-D generally provided better leafy spurge control compared to either method used alone. Leafy spurge control from the combined treatment averaged 44% 12 months after application. Leafy spurge with *A. nigriscutis* was oversprayed with picloram plus 2,4-D with a minimal negative impact to the *A. nigriscutis* population. The number of *A. nigriscutis* adults collected in the field was similar regardless of herbicide application date. Leafy spurge root nutrient content was not affected by picloram plus 2,4-D applied in the fall. Soluble and insoluble carbohydrate and soluble protein concentrations in herbicide treated plants were similar to concentrations in the untreated control. Leafy spurge plants harvested within an insect confining screened cage had root nutrient concentrations similar to roots harvested outside the screened cage.

Uptake and translocation of ^{14}C-picloram and ^{14}C-2,4-D was similar in plants damaged or unaffected by *A. nigriscutis* larvae. Therefore, the observed increase in leafy spurge control from the combined treatment was likely from the combined effect of herbicide toxicity to root tissue plus *A. nigriscutis* larval feeding on leafy spurge root buds.

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Aphthona flea beetle establishment determined by soil composition and root growth pattern

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Abstract:

Aphthona spp. flea beetles have been used since 1992 as a control treatment of leafy spurge in North Dakota. The reduction in leafy spurge where biological control was used ranges from excellent to poor depending on location. The fair to poor location results prompted a study on the effects of soil composition and root growth patterns of leafy spurge on flea beetle population levels.

Forty one, four-year-old, *Aphthona* flea beetle release locations were sampled between 1996 and 1998 for soil composition and root growth pattern. The leafy spurge roots were extracted and measurements from the soil surface to the first laterial roots, and the number of filament roots on laterial and tap roots were recorded. The results were compared to adult flea beetle population levels at each location.

To use *Aphthona* spp. for leafy spurge control appears to require a soil composition that will result in root growth close to the soil surface. A silt loam, silt clay loam, clay loam, or loam soil with a ph of 6.8 - 7.9 and organic matter of 6.0 - 9.28% produced the most adult flea beetles. The fine sand, loam fine sand, or fine sand loam soils with a ph of 6.5 - 7.4 and organic matter of 0.90 -2.8% produced the fewest adult flea beetles. Leafy spurge root systems in soil habitats that do not produce sufficient numbers of filament roots and the laterial roots are more than two inches below the soil surface, will result in low *Aphthona* spp. population levels and little impact on spurge stands.

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Sex ratio effects on fecundity and fertility of a leafy spurge flea beetle *Aphthona lacertosa*

DENISE L. OLSON and DONALD A. MUNDAL

Assistant Professor and Research Specialist, Department of Entomology, North Dakota State University, Fargo, ND 58105.

Abstract:

Aphthona spp. flea beetles have been used to control leafy spurge throughout the north central Great Plains including North Dakota. However, *Aphthona* flea beetles have not been successful at controlling leafy spurge in all infested areas. These failures may be due to a number of factors including climate, soil and vegetative characteristics, or the insects biology. The flea beetles have been collected from field insectaries and redistributed to other leafy spurge sites. Some of these collections have shown a female bias, with as few as 4% males. A lack of sufficient male numbers may be a factor contributing to the failure of *Aphthona* flea beetles to establish in some of the leafy spurge infestations. A laboratory study was conducted to determine the impact of sex ratios on the fecundity and fertility of a leafy spurge flea beetle, *Aphthona lacertosa*.

Four sex ratios were established using newly emerged field collected *A. lacertosa.* The number of females remained constant among the experimental treatments, while the number of males was altered to establish the ratios of 0:1, 1:3, 1:1, and 3:1, male:female. The males in a fifth treatment of 1:1 were removed after 24 hours to determine if multiple matings are necessary for continued oviposition. Each treatment was maintained in plexi glass cylinder cages (9.3 x 4.1 cm). A 4.1 cm diameter piece of felt was placed in the bottom of each chamber for oviposition. In addition, each chamber was supplied with leafy spurge leaves for food and moisture. The experimental chambers were maintained in an environmental chamber (23° C, 12:12 L:D). Each day, for a duration of 30 days, the oviposition pads were examined for eggs. Pads with eggs were placed on moistened patching plaster in a sealed petri dish (4.1 cm diameter) and placed in an environmental chamber (23° C, 0:24 L:D) to observe for larval emergence. Also, the number of purged, dead, and prehatched eggs were recorded. Each experimental treatment consisted of 9 replications.

A low percentage of males in a population of *A. lacertosa* may not be a contributing factor to the failure of this species to establish in leafy spurge infested areas. The fecundity of *A. lacertosa* among the three sex ratios of 1:3, 1:1, and 3:1 was not significantly different. In addition, fertility did not differ among these three sex ratios. Females not exposed to males, or exposed to males for only 24 hours, oviposited significantly fewer eggs compared to females exposed to males during the 30 day oviposition period.

Table. The effects of sex ratio on the fecundity and fertility of *Aphthona lacertosa*.

	Mean total *A. lacertosa* eggs per day				
M:F sex ratio	Oviposited	Hatched	Dead	Purged	Prehatched
0:1	4.6a	0.04a	4.1 a	0.3a	0.04a
1:3	7.2b	0.5b	5. 1 bc	1.3b	0.2a
1:1	7.5b	0.4b	5. 1 abc	1.3b	0.7b
3:1	7.5b	0.4b	5.4c	1.4b	0.2a
1:1a	4.8a	0.04a	4.5ab	0.2a	0.04a

[a]Male flea beetles were removed after 24 hr.

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Change detection of leafy spurge (*Euphorbia esula*) infestations using aerial photography and geographic information systems

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Abstract:

Leafy spurge is a troublesome weed on the northern Great Plains of the United States that herbicides and grazing management have not consistently controlled. Remote sensing and geographic information system (GIS) technology have been used to detect and monitor numerous grassland-related problems. The objectives of this study were to use both technologies jointly to map and quantify the extent, distribution, and spatial-temporal dynamics of leafy spurge within Theodore Roosevelt National Park in 1993 and 1998. The five-year comparison provided a unique opportunity to understand how leafy spurge is impacting the park and identify how infestations are changing over time. The same basic methodology was used in 1993 and 1998 with some modifications resulting from improved data handling capabilities. Only the western 8,090 ha of the park were evaluated for both years because of problems with film and cloud contamination encountered in 1998. Data collected in 1998 were not validated prior to this analysis. Preliminary analysis of the data indicated that leafy spurge had doubled during the 5 year period. Leafy spurge extent was estimated to be 591 ha in 1993 and 1,194 ha in 1998. Most infestations were restricted to drainage channels, creek bottoms, and river bottoms. The extent of leafy spurge increased across all aspects and slopes, however, the rate of increase was slower on south facing aspects and flatter slopes. The faster rate of increase on slopes ranging from 6% to 20% indicate that leafy spurge is slowly moving out of the relatively flat drainage channels and butte tops unto steeper slopes. The difference in the rate of increase between the north and south facing aspects combined with the slope and proximate to drainage channel data indicate that water is likely the driving variable for leafy spurge establishment in the Badlands. The most impressive finding of the study was that the extent of leafy spurge appeared to have doubled within 5 years. What makes this finding even

more impressive is that the increase was accomplished under an aggressive weed management plan. Managers and administrators charged with the stewardship of federal or state lands and ranchers operating on private land must not delay in managing leafy spurge. Leafy spurge will only be controlled with aggressive and consistent application of integrated pest management tools specifically chosen to meet the individual requirements of each situation.

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AFLP analysis on individuals from leafy spurge populations characterized as resistant or susceptible to flea beetle biocontrol agents

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Abstract

Biocontrol agents are becoming a major part of integrated pest management. However, since the pest is a living organism, selection for resistance to the biocontrol agent will occur. A pest with more genetic variability is expected to evolve resistance mechanisms faster than a pest with less genetic variability. Several species of flea beetles (of the *Aphthona* genus) have been employed as biocontrol agents to help control leafy spurge. However, resistance to these beetles has been observed in some populations of leafy spurge. It is not known if the resistance is the result of environmental factors or genetic differences in the resistant populations. Also, the level of genetic variability present in wild populations of leafy spurge is unknown. Knowing the level of genetic variability present in leafy spurge and understanding the mechanisms by which this pest is adapting resistance strategies will aid in predicting the long term success of the flea beetles as a bio-control agent on leafy spurge. We have initiated an analysis of the genetic variability present in wild populations of leafy spurge and have begun to look for specific genetic markers that could be linked to genes involved in resistance to the flea beetles. Dr. Bob Nowerski, a researcher at Montana State University, provided us with dried leaf material for five individual leafy spurge plants each from 50 different populations. These populations were treated with various *Aphthona* species and Dr. Nowerski has characterized the populations as being either susceptible or resistant to these biocontrol agents. We extracted DNA from individual plants and initiated their genetic characterization using the small genome AFLP kit from Gibco/BRL (AFLP Analysis System II). An appropriate number of bands (20 to 100) were generated with the EcoRI (AA) and each of the seven different MseI primers tested. These data are consistent

with previous studies suggesting leafy spurge has a relatively small genome. Amplification generated an average of 41 bands per primer set of which 10 were major bands. There was an average of 1.6 clearly polymorphic bands between individuals from a single population per primer set. This average compares with three to five polymorphic bands per primer set from two closely related barley varieties (Foster and ND9712). These data are consistent with the hypothesis that the level of polymorphism is very low within a given population of leafy spurge.

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Comparison of companion grazing and single species grazing on leafy spurge infested rangeland

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Abstract:

A study was established near Mandan, North Dakota in 1996 to study the effects of companion and single species grazing on leafy spurge infested rangeland. The study evaluated the control of leafy spurge, grazing efficiency, and livestock performance among three grazing treatments; cattle only (CO), sheep only (SO), and cattle and sheep (CS). The research study consisted of three replicated 8 ha blocks. Each of the replicates was subdivided into four 2 ha plots and treated with either a CO, SO, CS, and a non-use control (NU). Treatments were randomly selected within each block. Each 8 ha research block had one plot grazed by two yearling steers (CO), one grazed by ten mature ewes (SO), and one grazed by one yearling steer and five mature ewes (CS). Stocking rates were approximately 3.7 AUM/ha for the CO, SO, and CS treatments, respectively. A significant reduction in leafy spurge stem density occurred after two grazing seasons on the SO treatment. Leafy spurge stem density was reduced from 10.4 ± 0.9 (S.E) stems/0.1 m^2 quadrat in 1996 to 2.5 ± 0.6 (S.E) stems/0.1 m^2 quadrat in 1998, a reduction of 75% after 2 years. No changes occurred in leafy spurge stem density on the CS, CO, and control (NU) treatments after 2 years. Herbage production was similar for graminoids, forbs, shrubs, and leafy spurge on the NU for the growing season of 1996, 1997, and 1998. Leafy spurge degree of disappearance increased on all treatments from 1996 to 1998. Degree of leafy spurge disappearance on the SO went from 76% to 98% and the CS went from 62% to 88% from 1996 to 1998. The CO also had an increase in leafy spurge disappearance with 23% in 1996 to 50% in 1997 and 1998. Graminoid degree of disappearance was similar within and between grazing treatments. Steer average daily gain (ADG) was not different between treatments (CO and CS) for either years

of the study. There was no change in steer ADG between years on the CS. The cattle only treatment, however, had an ADG of 0.80 ± 0.03 (S.E.) in 1996 and significantly decreased to 0.56 ± 0.03 (S.E.) in 1998. Ewe ADG was not different between treatments (SO and CS) for either years of the study, similar to the steer performance results. In both SO and CS treatments there was a decrease in ewe ADG between years 1996 and 1998; 0.07 ± 0.01 (S.E.) to 0.02 ± 0.01 (S.E.) on the SO and 0.07 ± 0.01 (S.E.) to 0.03 ± 0.01 (S.E.) on the CS. Sheep in a single species grazing environment provided a greater control of leafy spurge than companion grazing after the first two years of a ten-year study. Companion grazing improved the performance of the steers; however, it had no negative or positive impact on sheep performance compared to single species grazing. In these three years, this improvement in steer performance was seen by having a less negative impact on performance versus the reduction in performance as seen on the CO between years.

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Removing the constraints of sheep as an alternative integrated pest management tool

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The history of grazing sheep on leafy spurge infested rangeland goes back to the late 1930's. In 1936 A.K. Bakke stated that sheep will eat leafy spurge if there is an absence of other desirable forbs. Two years later F.W. Christensen and his colleagues reported that sheep will consume leafy spurge and were effective in controlling leafy spurge in southeastern North Dakota. A year later E.A. Helgeson and E.J. Thompson also reported that sheep could be an effective tool in the control of leafy spurge. At this time Helgeson and Thompson suggested that one answer to the invasion of North Dakota grasslands by this noxious weed was to include sheep in a grazing management plan. In 1942 Helgeson and E. J. Longwell quantified that sheep will consume leafy spurge and were effective in controlling leafy spurge in southeastern North Dakota. As late as the 1980's an aerial flight over the Hurdsfield hills area of North Dakota during the height of the leafy spurge flowering season was clear evidence of the impact of sheep on those acreage that had some history of grazing sheep, as opposed to those which did not (Faller 1994). Since the early discovery that sheep are effective in controlling leafy spurge, there have been many disagreements in literature concerning the use of leafy spurge by sheep (Landgraf et al. 1984), due to one or more chemicals found in leafy spurge that elicit an aversive response when cattle and sheep consume leafy spurge (Kronberg and Walker 1993).

In the past 15 years grazing sheep as a biological control for leafy spurge has become more acceptable. Dahl et al. (1999) showed a trend that the use of sheep in a multi-species grazing approach on leafy spurge infested rangeland will be effective in controlling leafy spurge. Lajeunesse et al. (1995) also have stated that grazing animals can help control leafy spurge by increasing the competitiveness of desirable plants through time of grazing and selective removal of the foliage. Nelson et al. (1991) stated ecological benefit of multi-species grazing, besides natural weed control, would be that some natural resources used for plant growth could be diverted from the less desirable species to the more desirable plants. The principle of multi-species grazing is better utilization of rangeland and to improve livestock production. Therefore the grazing habits of cattle and sheep complement one another and offer economical and ecological benefits (Esmail 1991 in Johnson et al. 1999). There still are low use rates due to the lack of knowledge on the proper equipment (fences, water, shelters), competition for the same forage as cattle, expertise/knowledge to work with sheep, predation losses, and sheep are too time consum-

ing (Sell et al. 1998). The Hettinger Research Extension Center has been working the last 6 years to address some of the constraints with a systematic management approach.

According to Sell et al. (1998) 72% of the individuals questioned lack the proper equipment such as fencing, watering facilities, and shelter. Sheep can be retained in five to six strand barb wire fences and woven wire is not needed. By using barb wire we have cut the fencing cost in half and there is no extra work involved except adding two to three more strands of wire to an existing fence. The same watering facilities used by cattle can be used by sheep. Adding fill to one side of the stock tank allows the sheep to water. A stock dam with a firm slope can be used; however, if the dam has a soft slope drinking area, gravel should be applied to allow sheep to reach the watering area easily.

The next constraint in using sheep as a control method for leafy spurge was the competition for the same forage as cattle (Sell et al. 1998). The dietary overlap of sheep and cattle can be high on native and leafy spurge infested rangeland. Our hypothesis is, once the sheep have acquired the taste for leafy spurge, the dietary overlap is small. However, there are still a lot of unknowns that haven't been answered. Such as, does the breed of sheep have an influence on the use of leafy spurge or does the plant community and the level of aversive chemicals found in leafy spurge in a certain geographical area have an effect on consumption, and does the age of the sheep grazing leafy spurge infested rangelands have an effect on leafy spurge use?

The concern of predation has grown since the bounty on coyotes and other predators has been reduced or eliminated. Predation can be reduced by using adult ewes and implementing them into a multi-species grazing practice. We have found that by mixing cattle and sheep together the livestock species tend to bond and usually graze and bed down together in the same area. Predation has been reduced to I to 2% per year in the last five years using this type of management approach.

Lack of expertise/knowledge and sheep are too labor consuming to use are constraints that have been unanswered currently. The Hettinger Research Extension Center, however, is working on these constraints by developing sheep schools to educate producers in the basics of handling and raising sheep. The constraint that sheep are too labor consuming is presently being worked on to remove the additional burden from the cattle producer. TEAM Leafy Spurge, the Hettinger Research Extension Center, and the Department of Agricultural Economics of North Dakota State University are looking into a sheep co-op program, which will eliminate the expertise/knowledge and time consumption involved in raising sheep for the cattle rancher who is interested in using sheep as an alternative method of controlling leafy spurge.

Additional research that is currently in the process is a 4-year study on alternative management systems of sheep production that will enhance the economics of and utilization of sheep grazing as a control method for leafy spurge. This research is concentrating on designing a fall lambing system and an easy sheep system. The easy sheep management scheme is based on reducing lambing facilities and reducing the work load by letting the ewes lamb out on the prairie. This research should bring forth some new questions and answer some older ones.

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Leafy spurge management with sheep and flea beetles

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Abstract:

Leafy spurge (*Euphorbia esula*) is an aggressive, perennial rangeland weed that displaces native vegetation and causes millions of dollars to be lost annually in the agricultural and nonagricultural sectors. Many cultural, chemical, and biological control methods have been evaluated, but herbicides are used primarily. Leafy spurge infests a wide array of habitats and is considered difficult to impossible to control in sensitive shelterbelts and riparian areas where herbicides are very difficult to use. An experiment was initiated in 1993 (1) to determine an optimum sheep stocking rate and grazing duration that is compatible with flea beetle herbivory, and (2) to determine the impact of sheep grazing alone and sheep grazing plus flea beetles on the entire plant community within a defined leafy spurge infested habitat.

The experiment was conducted in a riparian area 25 miles east of Denver, CO. The site is characterized by low organic matter, sandy, gravely soil, with primarily a leafy spurge-western wheatgrass (*Agropyron smithii* Rydb.)-Kentucky bluegrass (*Poa pratensis* L.) understory and a semi-open plains cottonwood (*Populus sargentii* Dode) overstory. A factorial design arranged as a split-plot was used. Main plots were four stocking rates (two, four, six, or eight sheep/A) by three grazing durations (10, 20, or 30 days). Each plot was 1 acre in size. In 1993, all main plots were split; 500 flea beetles (*Aphthona flava*) were randomized and released onto a single point into one half of each main plot. There were 12 treatments and one control plot per block. Each treatment was replicated twice and all data were subjected to regression analysis.

Data collected in June, 1998 reflect the results of treatments invoked in 1995, 1996, and 1997. These data show that 4 or 6 sheep grazing alone for 10 or 20 days were exerting biological control of leafy spurge. Leafy spurge density within these treatments was decreased 57 to 64% while

smooth brome cover increased 4- to 7-fold and Kentucky bluegrass cover increased 2- to 3-fold. The June data show that all stocking rates of sheep grazing for 30 days stimulated leafy spurge growth and 30 days of grazing was too long regardless of stocking rate. There was about 1.6 times more leafy spurge cover within all 30 day treatments compared to non-grazed plots. The greatest smooth brome cover in June 1998 occurred where 8 sheep grazed for 10 or 20 days, but Kentucky bluegrass cover was suppressed within these treatments. Data collected in fall 1998 also show that sheep were behaving as biocontrol agents when 4 or 6 sheep grazed per acre for 10 or 20 days. Leafy spurge was effectively suppressed while the cool season grasses all displayed a positive response within these treatments.

There were no functional leafy spurge equations produced from data collected on flea beetle transects in June 1998. However, fall 1998 data indicate that a synergism was apparent between grazing sheep and flea beetles relative to decreasing leafy spurge populations and increasing grass populations. Where 6 sheep grazed for 10 days concurrently with flea beetles, leafy spurge density was decreased 50% while smooth brome, western wheatgrass, and Kentucky bluegrass cover increased 36-, 26-, and 5-fold, respectively.

LS=**54.1**-**7.9**(# sheep)-**2.6**(#days)+**0.8**(# sheep)^2+**0.1**(# days)^2

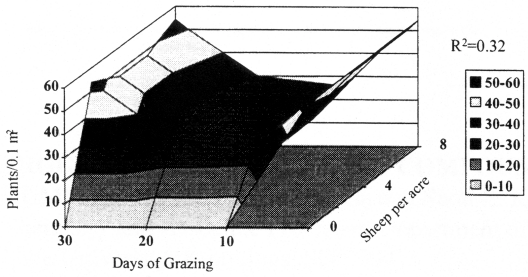

Figure 1. Leafy spurge density along flea beetle control transects June 1998

SB=1-**13.3**(# sheep)+**5.1**(# days)+**1.5**(# sheep)^2-**0.14**(# days$^{)2}$

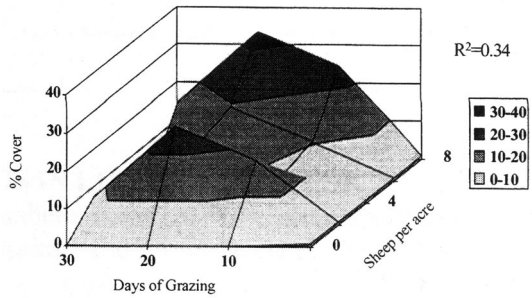

Figure 2. Smooth brome cover along flea beetle control transects June 1998

LS=**1.7**-0.02(# sheep)-**0.08**(# days)-**0.02**(# sheep)^2+**0.01**[(# sheep)(# days)]+**0.002** (# days)^2

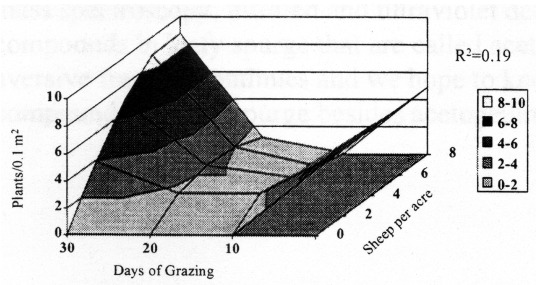

Figure 3. Leafy spurge density along flea beetle release transects Sept. 1998

SB=1.9-**8.2**(# sheep)+**4.5**(# days)+**2.1**(# sheep)^2-**0.4**[(# sheep)(# days)]-**0.01**(# days)^2

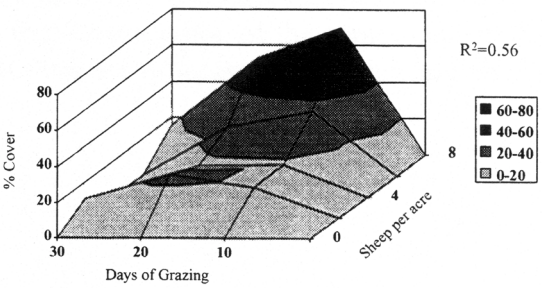

Figure 4. Smooth brome cover along flea beetle release transects Sept. 1998

WWG=0.5-0.47(# sheep)+**0.08**(# days) +**0.03**(# sheep)^2+0.005[(# sheep) (#days)]

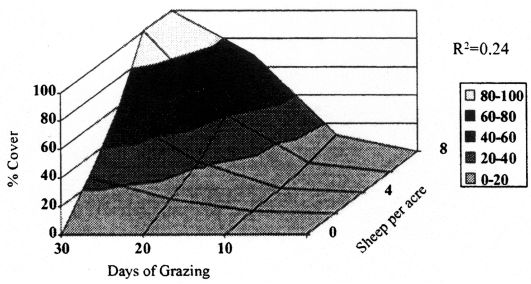

Figure 5. Western wheatgrass cover along flea beetle release transects Sept. 1998.

KBG=2.0+**9.6**(# sheep)-**1.8**(# days)-**1.2**(# sheep)^2+**0.18**[(# sheep)(# days)]+**0.03**(# days)^2

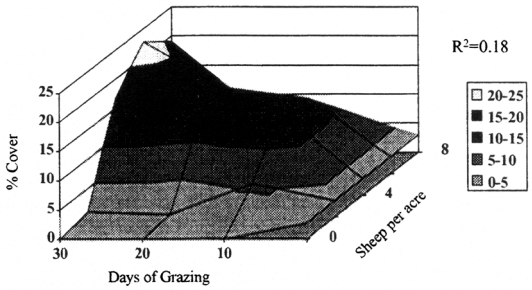

Figure 6. Kentucky bluegrass cover along flea beetle release transects Sept. 1998.

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Progress update on toxic compounds in leafy spurge for ruminants

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Abstract:

The reluctance of cattle to graze leafy spurge is a major reason why this introduced and toxic plant is considered a noxious weed in North America. The toxic and aversive chemicals in this plant are probably toxic to sheep as well as cattle. Although sheep appear to be much less susceptible to the toxic chemicals in leafy spurge, at higher levels of leafy spurge intake these toxins likely affect them also and consequently limit the capacity of sheep to graze and help control leafy spurge. During the last several years, we have been conducting a bioassay-guided chemical investigation of leafy spurge in order to identify compounds in leafy spurge that are toxic and aversive to ruminants. Our bioassays have been food aversion trials with rats and cattle and cytotoxicity tests. Our work is currently focused on identifying toxic compounds within a fraction that elicits feeding aversions in rats and cattle. This fraction contains about 40 compounds. Using high-performance liquid chromatography coupled with high resolution nuclear magnetic resonance, mass spectroscopy, infrared and ultraviolet detection, we have identified a series of cytotoxic compounds in leafy spurge that are called acetogenins. Our investigation of the compounds in the aversive fraction continues and we hope to know soon if there are other types of toxic and aversive compounds in leafy spurge besides acetogenins.

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Impacts of leafy spurge on local and landscape patterns of plant species diversity in Theodore Roosevelt National Park

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Abstract:

This study was conducted in the South Unit of Theodore Roosevelt National Park, North Dakota. Five grassland, ten shrubland, and six woodland community types were identified and evaluated in 1997 using the Field Methods for Vegetation Mapping and National Vegetation Classification System documents prepared by The Nature Conservancy (TNC) for the National Vegetation Mapping Program. Seven of the identified communities were found to be currently infested with leafy spurge and were evaluated using TNC procedures. Information on local patterns of diversity were evaluated from Trammell and Butler (1985, J. Wildl. Manage. 59(4):808-816). Because the invasion of leafy spurge into the Park is a relatively recent phenomenon, historical species richness for the seven communities was estimated from autecological and phytosociological studies conducted prior to 1985. A similarity matrix using species presence was calculated among 1997 sampled communities for both infested and non-infested communities and pre-1985 sampled communities. Percent foliar cover was used to calculate Shannon Diversity Indices for infested and non-infested communities sampled in 1997.

Table. Patterns of local and landscape levels of mean species richness and mean Shannon's Diversity Index in response to heavy infestations of leafy spurge in Theodore Roosevelt National Park. Effects of infestation on mean diversity and richness within each community type were compared using a 2-sample *t*-test (* = P < 0.05)

	Local Patterns				Landscape Patterns			
	Species Richness		Shannon's Diversity		Species Richness		Shannon's Diversity	
Community Type	Infested	Non-infested	Infested	Non-infested	Infested	Non-infested	Infested	Non-infested
Cottonwood	na[1]	na	na	na	15	22*	2.26	2.94*
Silver Sagebrush	13	15	1.96	1.89	8	29*	1.43	2.21*
Green Ash	26	31*	2.68	2.59	14	31*	1.86	3.09*
Juniper Slope	19	24*	2.24	2.18	15	26*	2.08	2.80
Buckbrush	na	na	na	na	6	13*	1.13	1.39
Needle & Thread	12	13	1.64	1.68	10	21*	1.83	2.78*
Western Wheatgrass	na	na	na	na	6	18*	1.08	2.28*

Similarity values averaged 74% (range = 68% to 90%) between 1997 and pre-1985 sampled communities at the landscape level. This suggest that the TNC protocol used in evaluating infested and non-infested communities was adequate for detecting the majority of the species present in each community type. Mean species richness was significantly lower for the two woodland communities evaluated at the local level. However, no difference in mean Shannon diversity values between infested and non-infested communities was observed. These results indicate that species not recorded on infested sites were probably minor constituents of the community type and had little effect on the diversity index. In contrast, mean Shannon diversity values were significantly reduced by heavy infestations of leafy spurge for all seven communities evaluated at the landscape level. The loss of species on infested sites at this level is also reflected in reduced mean diversity values. Further, similarity values among 1997 sampled non-infested communities, pre-1985 sampled communities, and heavily infested communities was reduced to an average of 49%. Consequently, communities infested with leafy spurge are now compositionally less rich compared to their current non-infested counterparts and their historic (pre-1985) non-infested counterparts. Decreases in similarity and diversity values likely reflect a combination of the local extinction of infrequent species and a reduction in frequency and cover for the common species. Several species, identified as consistent components of several non-infested communities, were conspicuously absent from infested communities. Depending on the redundancy of species across the landscape, such a trend strongly suggests that some species may be reduced by heavy infestations of leafy spurge to the point of local extinction in the Park.

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Seedbank study of a leafy spurge infestation

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Abstract:

Approximately 15 to 20% of the Sheyenne National Grassland in southeastern North Dakota is infested with leafy spurge (*Euphorbia esula* L.). The purpose of this research was to determine seedbank composition, which may play a role in future site revegetation during leafy spurge control efforts. Herbicide efficacy trial plots were established to determine herbicide rates to be used in controlling leafy spurge in areas that also contain the western prairie fringed orchid (*Platanthera praeclara* Sheviak and Bowles). These plots were also used to determine seedbank composition. Three herbicides at two rates each were applied in the fall of 1997, glyphosate plus 2,4-D (0. 5 and 1 lb/A), AC 263,222 (0.0625 and 0.125 lb/A) plus Sunit (0.25 lb/A) plus 28% N (0.25 lb/A) and quinclorac (0.8 and 1 lb/A) plus Sunit (0.25 lb/A). Soil cores 2.5 cm deep were taken in May 1998 and were washed through a 4 min sieve and a 0.2 min sieve to remove coarse and fine materials. Samples were then spread 3 to 5 mm deep on a layer of sterile sand (approximately 1 cm), which prevented contact between sample and potting soil. Seed from a total of 56 composited (4 blocks, 7 herbicide treatments, 2 subsamples) soil cores were grown in the greenhouse. Seedlings were counted and removed after identification. Unidentified seedlings were transplanted until identification was possible. Removal of seedlings was necessary due to high seedling density. Identification continued until no further germination was noted approximately eight weeks after planting. Seedlings were identified by species and placed in categories of leafy spurge, forb, grass, grasslike and other species for statistical analyses. No statistical significance ($p<0.05$) was determined between the treatments using Tukey's mean separation test. Leafy spurge comprised 40% of all germinated seedlings, with grasses 25%, forbs 22%, grasslike 10% and other species 3%. Thirteen grass species were identified, four were desirable native warm season species [big bluestem (*Andropogon gerardii* Vitman), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), little bluestem (*Schizachyrium scoparium* (Michx) Nash)

and sand dropseed (*Sporobolus cryptandrus* (Torr.) Gray)] and three were desirable native cool season species [prairie junegrass (*Koelaria pyramidata* (Lam.) Beauv.), needle and thread (*Stipa comata* Trin. and Rupr.) and green needlegrass (*Stipa viridula* Trin.)]. Eighty-five percent of all grass seedlings that germinated were *Poa* spp. and would be considered undesirable at that level of presence. Twenty-eight forb species were identified of which 86% were considered undesirable (23 species) while 14% (5 species) were considered desirable natives [white prairie aster (*Aster ericoides* L.), wild strawberry (*Fragaria virginiana* Duchense), wood sorrel (*Oxalis* spp.), common evening primrose (*Oenothera biennis* L.) and black-eyed susan (*Rudbeckia hirta* L.)]. The competitive nature of leafy spurge and its high representation in the seedbank will present continuing control problems for revegetation efforts.

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Effects of prescribed burning and herbicide treatments on leafy spurge (*Euphorbia esula*)

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Abstract:

A 3-year experiment to evaluate herbicide treatments with prescribed burning to improve long-term leafy spurge (*Euphorbia esula* L.) control compared to herbicide alone was established on the Gilbert C. Grafton South Military Reservation in North Dakota. Six treatments were evaluated including an untreated control, prescribing fall burning with no herbicide, spring applied picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) plus 2,4-D [(2,4-dichlorophenoxy) acetic acid] applied at 0.28 plus 1.1 kg ha^{-1} (normal) and unburned, spring applied picloram plus 2,4-D applied at 0.56 plus 1.1 kg ha^{-1} (heavy) and unburned, spring applied picloram plus 2,4-D applied at 0.28 plus 1.1 kg ha^{-1} following a fall burn, and spring applied picloram plus 2,4-D applied at 0.56 plus 1.1 kg ha^{-1} following a fall burn. A prescribed burn was conducted on the predetermined treatment plots in mid October of 1994 with herbicides applied in 1995 and 1996. Study objective was to evaluate burned and unburned treatments in conjunction with differing rates of herbicide on leafy spurge control. All herbicide treatments, regardless of burning, reduced ($P<0.05$) the density of leafy spurge compared to the control. No differences ($P>0.05$) were noted between the burned and unburned plots after 12 months and 24 months on any treatment. Burning alone did not affect leafy spurge stem densities as new spring growth grew uniformly and with vigorous sprouting occurring following the fall prescribed burn. Leafy spurge stems were reduced ($P<0.05$) 69% and 95% on the normal and heavy herbicide rates of picloram plus 2,4-D on the burn treatment, respectively, compared to the control after 12 months of herbicide treatment. After 24 months of herbicide treatment on the burn plot, leafy spurge stems were reduced to 88% on the normal herbicide rate of picloram plus 2,4-D which was a reduction ($P<0.05$) of 19% compared to 12 months following treatment. No change ($P>0.05$) in leafy spurge stems was noted on the heavy rate of picloram plus 2,4-D between the 12 months and 24 months herbicide application on the burned treatments. Leafy spurge stems were reduced

($P<0.05$) 62% and 82% on the normal and heavy herbicide rates of picloram plus 2,4-D on the unburned treatments, respectively, compared to the control after 12 months of herbicide application. No change ($P>0.05$) in leafy spurge stems was noted on either the normal or heavy rates of picloram plus 2,4-D between the 12 months and 24 months following herbicide application on the unburned treatments. A fall prescribed burning program alone did not affect leafy spurge stem densities or improve herbicide control when compared to unburned treatments. However, fall prescribed burning did enhance leafy spurge control using picloram plus 2,4-D applied at 0.28 plus 1.1 kg ha^{-1} under a 2-year spraying program compared to unburned treatment results.

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Site characteristics of established flea beetle colonies in western North Dakota

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Abstract:

A total of 59 USDA-APHIS flea beetle release sites were located and evaluated in 1998 on the Little Missouri Grasslands near Medora, North Dakota. Five hundred flea beetles were released at each site during 1993, 1994, or 1995. Five flea beetle species were released: *Aphthona cyparissiae, A. czwaline* / *lacertosa, A. flava*, and *A. nigriscutis*. Physical characteristics of release sites measured were aspect, soil texture, landscape position and site micro-topography. Biological information recorded was control area, leafy spurge density and cover, and cover of co-dominant plant species in the control area. No pre-release site data was available. The data set was subjected to principal component analysis which reduced the dimensionality and eliminated random background variation. The number of significant PC's was determined using Fisher's Proportionality Test. No PC's were significant for any data set. However, area of leafy spurge control appeared to be the parameter with the greatest influence in graphically separating sample units (release sites). Nine sites having the greatest leafy spurge control (avg. 5,000 m^2) separated when plotted on an XY-graph. A stepwise comparison was then made on these nine sites to determine the magnitude of importance of each physical parameter. The physical site variables ranked from most to least importance are as follows: (1) aspect, (2) micro-topography, (3) landscape position, and (4) soil texture. The nine sites had aspects ranging from 90° to 270°, a micro-topography of level to convex, were located on the upper portion of the landscape (upland or summit), and had sandy to silty loam soil textures. These physical characteristics would all contribute to the nine successful release sites having warm and dry habitats for the larvae to live in.

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The response of glutathione reductase and glutathione-S-transferase to environmentally- and chemically-induced stress; amelioration by polyamines in leafy spurge (*Euphorbia esula* L.)

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Abstract:

Research is underway to establish key processes in the growth and development of leafy spurge that may be amenable to new and innovative methods for controlling this invasive weed that will be effective, cheaper and more environmentally friendly than present methods. These methods could be applied in the event that future circumstances render present methods ineffective. Basic physiology, biochemistry and genetics are areas of active research within our unit. Control of enzyme systems involved in the plant's response to stress (imposed by biotic or abiotic means) are possible candidates. Glutathione (GSH), a major constituent of all plant cells, consists of three amino acids linked together (a tri-peptide) that aids in controlling the plant's response to foreign chemicals and other stress, and behaves in many instances as an antioxidant. Glutathione reductase (GR) and glutathione S-transferase (GST) are key enzymes that regulate the action of GSH. The objective of our research is to characterize GR and GST in leafy spurge, determine their responses after induced stress of various kinds and establish ways to regulate them to the disadvantage of leafy spurge. In this report we also show that diclofop-methyl (DM) can be applied to leafy spurge to induce symptoms very similar to natural senescence. GR activity from leaves of untreated leafy spurge plants are consistently higher and somewhat more variable than GST activity (using 2,4dichloronitrobenzene as a substrate). Activities ranged from approximately 120 to 170 nmol of product/min/mg protein for GR and approxi-

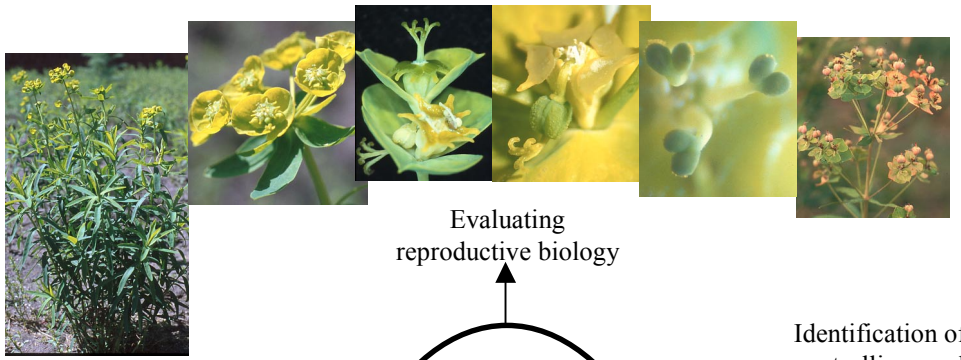
mately 50 to 120 nmol of product/min/mg protein for GST. Daily activities were more linear for GST than for GR. The activity of GR and GST from plants sprayed with 5 mM of the senescence-inducing compound DM increased within a few hours to nearly maximum levels by 26 h, and leveled off by 42 h. Activities of GR and GST from leafy spurge leaves treated 42 hrs with 5mM DM ranged from 250 to 320 nmol of product/min/mg protein and 175 to 2 10 nmol of product/min/mg protein, respectively. Polyamines are also natural constituents of plants that have many functions, most of which are still speculative, but are actively being investigated worldwide. Leafy spurge plants pre-treated 0.5 to 1 h with 20 mM polyamines (putrescine, spermidine or spermine) showed less visual damage when sprayed with 5 mM DM compared to plants sprayed with 5 mM DM alone. GR and GST activities were at essentially control levels in plants pre-treated with any one of the three polyamines, and less severe visual damage occurred to the leaves of the polyamine-treated plants than to plants sprayed only with DM. The increases in GR and GST activities induced by DM are similar to those of leafy spurge plants stressed by drought or iron deficiency. The ability of these polyamines to counteract the DM-induced activity of GR and GST suggest that they may play an important role in amelioration of the effects of biotic and abiotic stressors. Research is currently underway to attempt to establish whether these polyamines are functioning as anti-senescent agents; perhaps as antioxidants. We are still in the early stages of learning how to control the action of GSH, polyamines and their related constituents. This research should lead us forward in efforts to eventually control growth and development of leafy spurge and other perennial weeds.

“Know Thine Enemy”-Understanding Weed Management through Biological Research

Plant Science Research, Fargo ND: James V. Anderson, David Davis, Mike Foley, and David Horvath.

Problem

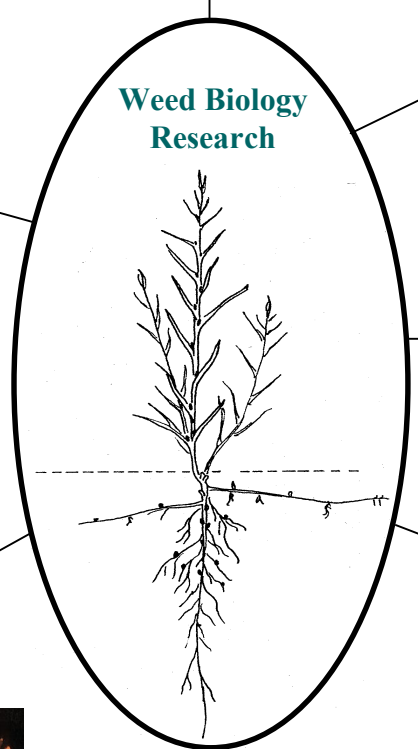
Weeds reproduce by both seeds and vegetative buds. Variation in the control and growth of different reproductive organs (seeds and buds) allows weeds to avoid conventional control measures. Variation in environmental factors also influence biocontrol agents and growth and development



Evaluating reproductive biology

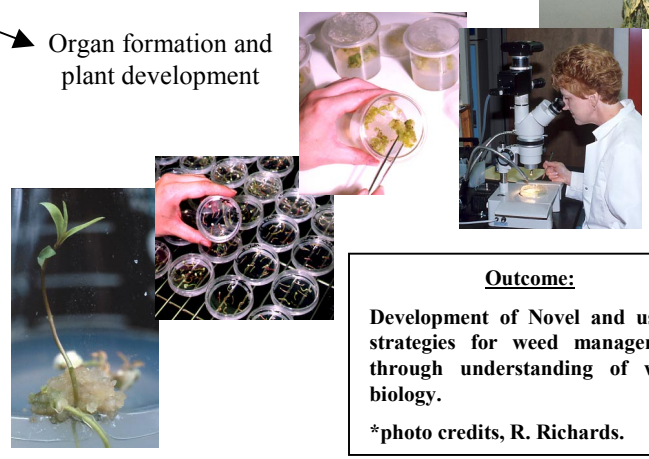
Identification of genes controlling seed dormancy and germination

Understanding whole plant physiology and biochemistry



Evaluating the genetics of resistance to biocontrol agents

Organ formation and plant development



Identification of genes controlling growth of vegetative buds

Outcome:

Development of Novel and useful strategies for weed management through understanding of weed biology.

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