# Leafy Spurge *News*

Agricultural Experiment Station
NDSU Extension Service
North Dakota State University, Fargo, ND 58105

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## From the Editor's Desk

Well, faithful readers, this is the last hurrah for **The Leafy Spurge** *News*, as this is the last issue!! We have come a long way since its inception at the Bismarck, N.D., meeting in summer 1979. I think that you will agree that it has been a very successful program, one based on good interaction among the research community, the Extension people and our user groups. It reached its zenith under the Team Leafy Spurge Program. Even though most research and demonstration funding has dried up and the emphasis has shifted to other more pressing programs, such as saltcedar, I was able to locate sufficient contributors to provide you with an interesting issue.

Included are three short articles from the ARS research facility in Fargo, a longer one on how cold soil temperature affects the winter survival of *Aphthona* spp., and one on assessing the economic impact of leafy spurge, both from NDSU and from one of our users, the Theodore Roosevelt National Park. Two articles, one from BASF and one from Dow, give us the chemical perspective. We also have an interesting article from the North Dakota Weed Control Association and the important part it plays in this whole effort. Finally there is a letter to the editor, providing a historical perspective from Roald Lund, who was one of the prime movers, way back in 1979, in getting the whole program off the ground.

I have been your editor for 11 years now, following the footsteps of Russ Lorenz, and also was involved in the fateful 1979 meeting. I was fortunate to be with such a successful program since its beginning. My heartfelt thanks to all of you who sent me information for the **Leafy Spurge** *News* through the years.

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## North Dakota Weed Control Association: **How Does it Fit In**

The North Dakota Weed Control Association (NDWCA) has evolved over time like every other agency that deals with noxious weeds. Officially established in 1981, it was composed of weed board members appointed by county commissioners and weed officers hired by weed boards. Membership has expanded to include other private individuals, educators, industry representatives, and tribal, federal and state agencies. Cooperative ties are being formed with horticultural associations and the organic farming community. Common cause has been recognized in noxious weed control.

In the beginning, weed board members took the initiative on the board of directors. As weed officers became familiar with their duties, their experience proved useful to the board. Weed officers now dominate the board membership. Nearly every major project in recent years — biocontrol, mapping, educational projects, grant development, etc. — has had an involved weed officer at the center of it. Weed officer job descriptions have grown from chemical applicator to include biocontrol technician, public education specialist, grant writer, native plant expert and other ever-expanding titles.

Weed control funding has been problematic. The county commissioners were given authority to levy up to 4 mills, with 1 of those mills dedicated to leafy spurge control. These monies were a start but insufficient to cover weed control expenses in all counties. The North Dakota Department of Agriculture was authorized to subsidize cost-share payments; again, there was a shortfall. Fund-

**Weed Control Association** continued on page 2

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**Weed Control Association** continued from page 1

ing went up and down with each legislative session. The NDWCA helped draft an equitable cost-share disbursement formula for the funds we did have.

A real breakthrough came in 1991, when the Environment and Rangeland Protection Fund was established. These monies come from annual chemical registration fees paid to the state of North Dakota. A portion is dedicated to noxious weed control. Steady funding has dramatically improved weed control programs. EARP funds have subsidized many long- and short-term projects — the Landowner Assistance Program, biocontrol research, IPM projects, GPS mapping and a professional weed management manual, just to name a few.

Change and adaptation have ever been factors. Communications have come from carbon-copied letters and land-line phones to fax machines, e-mail, Web sites, cell phones and beyond. In the near future, videoconferencing and teleconferencing will be part of the NDWCA.

New noxious weeds are appearing. Knapweeds, purple loosestrife and saltcedar are some of the latest. Movement of tourists, hunters, harvesters, construction equipment, river waters, highways and railroads across state lines brings in seed and plant parts. The CRP program inadvertently brought in yellow starthistle with imported grass seed. A switch to row crops from cereal grains has challenged the ability to control broadleaf weeds. Hay inspection, interstate and interagency cooperation and improved chemical tools are counters to these threats. Evolution of both problems and solutions is the only constant in noxious weed control. The NDWCA will continue to look forward, evolve and adapt to meet new challenges.

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## Seed Dormancy in Leafy Spurge

Leafy spurge reproduces asexually via crown and root buds and sexually by seeds. Our unit largely has focused on dormancy in buds and vegetative reproduction. However, dormant seeds in the soil play a key role in the persistence of weeds. For example, leafy spurge seeds can remain dormant and viable in the soil from three to eight years. I designed an experiment to answer two questions: What type of dormancy occurs in leafy spurge seeds, and what environmental conditions shift the seeds from a dormant to nondormant state?

Two main types of seed dormancy occur: embryo-imposed and seed covering-imposed. Our investigations revealed that removal of the hard seed coat surrounding the endosperm and embryo caused rapid germination. Removal of the soft nutrient-containing endosperm tissue from around the embryo did not increase the rate of germination. Therefore, leafy spurge displays covering-imposed dormancy due to a hard seed coat.

To examine what environmental conditions facilitate after-ripening, that is "breaking dormancy," we exposed seeds to warm-dry, warm-moist, cool-dry and cool-moist conditions for periods of 12 and 24 weeks. Seeds harvested in one year after-ripened best under warm-moist conditions, while seeds harvested in a second year responded nearly the same to both warm- and cool-moist conditions. In addition, 24 weeks of after-ripening, followed by 21 days of incubation in water, was required to break dormancy and achieve nearly complete germination, respectively. The mixed response to temperature under moist conditions, relatively long duration of after-ripening to break dormancy, and protracted incubation to complete germination, suggests we have yet to determine what environmental conditions or factors facilitate germination of hard-seeded leafy spurge.

Follow-up studies should focus on defining environmental factors or conditions that weaken or break the seed coat, and environmental and genetic factors that provide leafy spurge seeds with a hard coat. Unit scientists have been discussing how we might use the genomic tools (i.e., expressed sequence tag database and microarrays) that we are developing in follow-up studies. As with all our research, the goal is to provide new biological insights that will give rise to practical ways to manage weeds.

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# Leafy Spurge Control:
## A Dow AgroSciences Perspective

My first day on the job with the Dow Chemical ag division in Montana (August 1982) was to visit a leafy spurge site that had been treated with 1 gallon per acre of Tordon™ 22K the previous year. The ranch was a large research site for Peter Fay at Montana State University, and the control looked excellent. This was cause for excitement within our newly formed range and pasture division, but we still were in the learning process.

Since then, we have changed our company name multiple times, as well as our leafy spurge recommendations. The next summer, at the 1983 leafy spurge symposium in Sundance, Wyo., Harold Alley and his students demonstrated a root core apparatus that they had developed to better understand what was happening below the ground. Needless to say, it was evident that there was not going to be a silver bullet in control of this weed.

During the next 20 years, Dow, as Dow, DowElanco and now Dow AgroSciences (DAS), supported multiple research projects with universities and private researchers to try to understand the optimum leafy spurge management system. The early work was started in the late '70s and early '80s with the University of Wyoming, Montana State University and North Dakota State University. In the late '80s and '90s, the leafy spurge effort expanded to Colorado State University, South Dakota State University, the University of Nebraska and the University of Minnesota.

The first studies focused on multiple-year treatments at lower rates. Recommendations were developed for retreatment programs for broadcast situations (lower rates), and the maximum rate was decreased to 2 quarts per acre for spot treatment on the Tordon 22K label. Any time a new herbicide was available, it was evaluated with high hopes. Internally in the DAS greenhouses, Rod Lym and his staff taught us how to grow leafy spurge so we could include it in our routine evaluations of all our discovery compounds. DAS has supported integrated weed management approaches with Tordon 22K and insects, grazing and grass interseeding, and many excellent integrated pest management recommendations have developed.

Since the late '70s, Dow has had range and pasture specialists in the leafy spurge states who have worked with landowners to provide the best recommendations available for their unique situations. The "Mapping and Planning Guidelines Workbook" was developed to help land mangers map and develop a prioritized leafy spurge management plan before spending resources, and ultimately improve success.

In 2005, we continue to evaluate the potential to mix Tordon with other herbicides. The newest tank mix to evaluate is Overdrive™+Tordon 22K. One thing we have learned through the years is not to make a judgment on any new treatment until the results are evaluated from multiple trials across a wide geographic area. Based on the information we have reviewed from field trials, differences across locations and data are not conclusive about the advantages and/or disadvantages of adding Overdrive to Tordon 22K for leafy spurge control. Dow AgroSciences continues to support research with this mix to determine the feasibility and long-term efficacy of using it for broadcast treatments. For spot treatments, however, Tordon 22K at 2 quarts per acre continues to be the best option.

We at Dow AgroSciences understand that Tordon 22K is not the total answer to leafy spurge control, but when you look at the last 20-plus years, it has been and continues to be an integral part of many successful leafy spurge management programs.

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# A History of Exotic Plant Management
## in Theodore Roosevelt National Park

Theodore Roosevelt National Park (THRO), located in southwestern North Dakota, has been battling exotic plants for more than 40 years. The park has 82 known exotic plants, including leafy spurge, Canada thistle, Russian knapweed, absinth wormwood and field bindweed. Exotic plant control efforts in THRO primarily target leafy spurge and Canada thistle. Russian knapweed and absinth wormwood have been found more frequently and are being treated as a higher priority. Other exotic species treated include common burdock, black henbane, Russian and spotted knapweed and perennial sowthistle.

The majority of exotic plant infestations occur in the riparian and disturbed areas of the park and along roadways. High-priority targets include areas around campsites, along the Little Missouri River, along popular hiking trails and a 300-meter-wide buffer on the east, north and west boundaries of the park's South Unit. Secondary priority targets include areas that are difficult to reach on foot or horseback. The park has to control weeds in all areas of the park but earmark the primary targets for more intensive control.

The park has been using an integrated approach to confront exotic plants. Sensitive areas are controlled by hand or using shovels. Biological control agents are used for leafy spurge in the wilderness area and where soil properties allow establishment. Chemical control methods include backpack sprayers, truck-mounted pressure sprayers, ATV-mounted Boombuster sprayers and helicopter application. Prescribed fires also are being used to manage some exotic grass species, primarily smooth brome and crested wheatgrass. Vegetation monitoring is being conducted to determine the effectiveness of treatments and seek out new infestations as soon as possible.

### Leafy Spurge

Leafy spurge is the park's No. 1 exotic plant management concern, currently infesting between 2,000 and 4,000 acres. Almost 30 acres first were treated in the park in 1969, using Tordon 212 with a hand sprayer. Biological control agents first were used in 1986, but weren't as successful as anticipated. Other chemical treatments and biocontrol releases were used sporadically prior to the 1990s, when park staff began a full-blown attack. In 1993, 200 acres of leafy spurge were treated for the first time, using a helicopter equipped with a microfoil boom. Since this initial aerial treatment, at least 300 additional acres have been treated each year with an exception of 0 acres in 2000. To date, more than 4,783 acres have been treated chemically. Biocontrol agents were established successfully in 1995 and have prospered. Since then, more than 19 million biocontrol agents have been released to 3,500 sites.

### Canada Thistle

Canada thistle has increased in abundance and density during the last few years and has quickly become a high priority for the park. In 2004, 330 acres were treated aerially in the South Unit. Two other aerial applications are scheduled for fall 2005, one in the South Unit and one in the North Unit. More than 823 total acres of Canada thistle have been treated with herbicides since 1993.

Backpack spraying leafy spurge at the North Unit.

ATV application at
Theodore Roosevelt National Park.

## Other Exotic Species

The main focus of exotic plant management at THRO has been directed at leafy spurge and Canada thistle. New invasives continue to be found and are treated as needed. The Little Missouri River area and other drainages are surveyed annually for saltcedar, which recently was discovered in the North Unit of the park. Other species treated include bull thistle, black henbane, common burdock, perennial sowthistle, Russian knapweed, spotted knapweed, Russian knapweed and Russian olive.

Surveying for salt cedar along the Little Missouri River.

## Northern Great Plains Exotic Plant Management Team

The Northern Great Plains Exotic Plant Management Team (EPMT) became operational in 2002. The team provides exotic plant management support to 14 national parks in North Dakota, South Dakota, Wyoming and Nebraska, including Theodore Roosevelt National Park. The team has had at least four personnel stationed at THRO the last four field seasons. Ground crews have treated more than 500 acres of exotic species using chemical and manual control methods. The EPMT also has provided funding for helicopter applications in the park.

More than 550 acres of leafy spurge were treated in 2003. In 2004, 660 acres of leafy spurge were treated, and 330 acres of Canada thistle were treated by helicopter. In 2005, leafy spurge and Canada thistle are scheduled once again for treatment. The EPMT has distributed more than 12 million biocontrol agents in the park since 2002. The EPMT also has provided funding to contract with the Montana Conservation Corps (MCC), a group of young adults working with the park to treat leafy spurge. In 2003 and 2004, 300 acres were treated each year with the help of the MCC. Another 300 acres is scheduled for treatment in fall 2005.

Exotic plant management will continue at Theodore Roosevelt National Park as long as exotics continue to invade the area. The park hopes eventually to control major exotic plants, such as leafy spurge and Canada thistle, to a maintenance level while remaining vigilant in its hopes to stop new invaders, such as saltcedar and yellow starthistle, from getting a foothold in the park.

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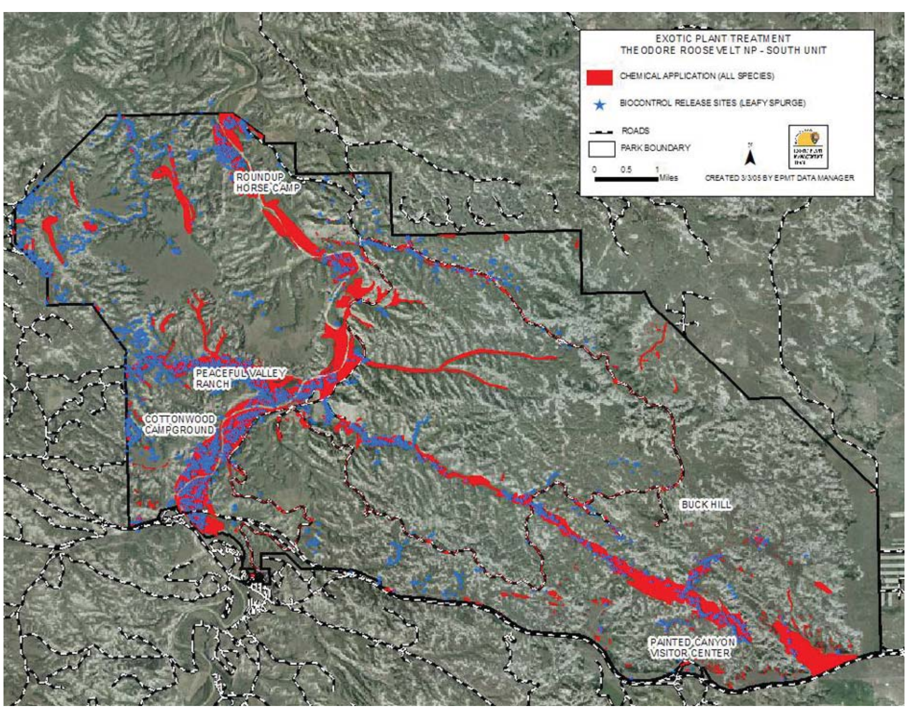


Exotic plant treatment in the South Unit of Theodore Roosevelt National Park.

## Winter ground cover effects on soil temperature and *Aphthona* spp. winter survival

The Aphthona flea beetles continue to have a significant impact on leafy spurge (*Euphorbia esula* L.) in numerous areas throughout the northern Great Plains states. However, in some areas, *Aphthona* spp. do not appear to overwinter successfully (Nelson and Lym 2003).

Maw (1981) reported that the larval stage of the flea beetles requires two to three months of temperatures at 39.2 to 50 F to complete their development successfully. In North Dakota, winter soil temperatures typically dip below these temperatures for longer than 60 to 90 days. How winter soil conditions, such as ground cover, winter soil temperature and duration of the winter soil temperature, affect the overwintering success of *Aphthona* flea beetles is not clear. The importance of the ground covers of snow, debris and snow plus debris were evaluated to determine the effects of subfreezing soil temperature and the duration of subfreezing soil temperature on the overwintering success of *Aphthona* flea beetles.

This study was conducted during a four-year period, 2000 through 2004, in a range pasture infested with leafy spurge and with an established population of *Aphthona* flea beetle spp. Between late October to first emergence of the flea beetles in mid-June, the winter soil temperature (WST), winter days (WD), continuous subfreezing soil temperature (CSFST) and continuous subfreezing winter days (CSFWD) were determined using data loggers placed at 4 inches below the soil surface in each treatment plot.

The WST is the soil temperature during WD. Winter days are the number of days between the first and last day when the soil temperature was below 32 F. The CSFST is the mean soil temperature for the CSFWD. The CSFWD are the number of consecutive days when the soil temperature was below 32 F during the period of WD. During each year, soil cores were taken over leafy spurge in late October to estimate the population level of *Aphthona* spp. entering the overwintering period in each treatment plot. Soil cores were taken again in late May to estimate the overwintering success of the flea beetles.

During all four study years, *Aphthona* emergence in the spring was lower than the population entering the overwintering period (Figure 1). In spring 2001, significantly more beetles emerged from the plots that were protected with snow during the winter months (Table 1). However, in the 2001-02 study year, spring flea beetle emergence was significantly higher from unprotected plots, compared with plots provided with snow cover. During the 2002-03 and 2003-04 experimental years, a ground cover of debris was added to the study.  A debris cover during the winter did not appear to enhance the overwintering survivability of *Aphthona* flea beetles, compared with a snow cover.

The WST and CSFST, at 4 inches below the soil surface, usually were lower when the ground was bare, compared with when a ground cover was provided during the winter period (Table 1). Also, lower temperatures were recorded in soil that had a debris cover only, compared with a snow cover during the winter period. Usually more WD and CSFWD resulted when the ground was left unprotected, compared with when the soil was protected with a winter cover.

Only during the 2000-01 study year did spring flea beetle emergence have a significant relationship to WST, CSFST, WD and CSFWD. As the WST and CSFST decreased, flea beetle survival decreased. As the number of WD and CSFWD, flea beetle survival decreased. The lowest mean temperatures at which the *Aphthona* larvae survived were 23.0 WST and 21.9 C CSFST. The highest number and longest duration of subfreezing temperature days at which *Aphthona* survived was 132 WD and 117.5 CSFWD. In the snow-covered plots, 90 percent of the flea beetle emergence occurred at WST between 27.5 and 30.2 F. For the 2000-01 study year, the total number of WD explained 80 percent of the variation in spring flea beetle emergence.

The 2001-02 winter was warmer than the previous winter. The average maximum air temperature was 32 from Nov. 1, 2001, to March 30, 2002. During this period, the maximum air temperature climbed above 32 F on an average of eight consecutive days. As a result, our research plots had nine fewer WD in the no-snow treatment than the maximum number of WD (132) of subfreezing temperatures at which *Aphthona* flea beetles survived the 2000-01 winter. This may explain why substantially more beetles

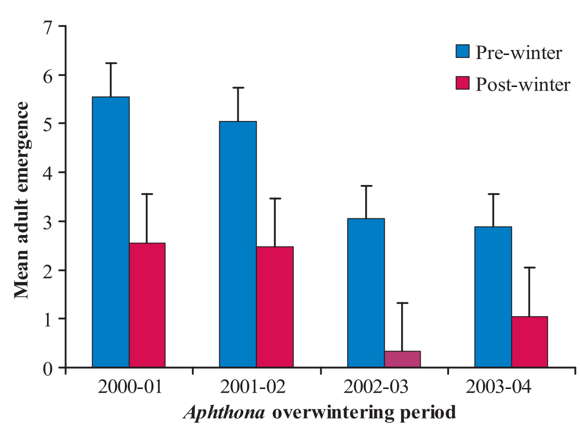


**Figure 1. Mean Aphthona flea beetle population entering and surviving the winter period.**

emerged from the no-snow treatment during spring 2002, compared with spring 2001.

The warm conditions, especially during February and March, also caused the snow to melt in the snow treatment plots during these months. Snow melt may have caused excessive soil moisture, resulting in high *Aphthona* larval mortality in the snow treatment. This may explain why spring *Aphthona* emergence was significantly lower from the snow treatment than the plots with no ground cover.

During winter 2002-03, the average number of WD and CSFWD were approaching the maximum number of WD (132) and CSFWD (117.5) at which *Aphthona* flea beetles appear to survive. The higher number WD and CSFWD among all of the experimental plots during the 2002-03 winter may have been an important mortality factor for Aphthona flea beetles.

In winter 2003-04, again the number of WD and CSFWD were near the maximum number at which *Aphthona* spp. apparently can survive. However, the WST in the snow-covered plots was at least the minimum WST (27 F) at which 90 percent of the flea beetles successfully overwintered during 2000-01. In the debris-only and the no-ground-cover plots, the mean WST did dip below 27 F during the 2003-04 winter and spring flea beetle emergence was lower from these treatments than from plots covered with snow.

Snow does have insulation properties and the soil temperatures can be higher in soil that is protected with a snow cover during the winter period (Nelson and Lym 2003).

During winters 2000-01, 2002-03 and 2003-04, the WST and CSFST, and spring flea emergence, were higher in soil that was protected with snow, compared with bare ground. During winters when the mean WST is between 27 and 30 F in snow-covered ground, we could expect the flea beetle survival rate to be approximately 90 percent.

However, during the 2002-03 winter, the snow cover failed to provide protection against the WST from dipping below 27 F. During this winter, the average daily air temperature and the consecutive number of days of subfreezing air temperature were similar to that in the 2000-01and 2003-04 winters.

Why the snow cover failed to prevent the WST from dipping below 27 F is unclear. When winters are warmer than average, flea beetle mortality may be high due to excessive soil moisture during periods of snow melt. Debris does not appear to provide as much insulation as snow and the WST may dip below 27 F when only debris is available as a winter ground cover.


Maw, E. 1981. Biology of some *Aphthona* spp. (Col: Chrysomelidae) feeding in *Euphorbia* spp. (Euphorbiaceae) with special reference to leafy spurge (*Euphorbia* spp. near *esula.* M.S. Thesis, University of Alberta, Edmonton, Canada.

Nelson, J.A., and R.G. Lym. 2003. Interactive effect of *Aphthona nigriscutis* and picloram plus 2,4-D in leafy spurge *(Euphorbia esula).* Weed Sci. 51:118-124.



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Table 1. Winter ground cover effects on winter soil temperatures and *Aphthona* spp. winter survival in southeastern North Dakota.

| Treatment | WST °F | CSFST °F | WD | CSFWD | *Aphthona* spp. Emergence |
|---|---|---|---|---|---|
| | | | 2000-01 | | |
| Snow | 28.5 a | 28.4 a | 107.7 a | 100.2 a | 5.0 a |
| No snow | 24.1 b | 23.0 b | 130.5 b | 115.7 b | 0.5 b |
| | | | 2001-02 | | |
| Snow | 28.7 | 28.7 | 119.7 | 118.0 | 1.4 a |
| No snow | 28.6 | 28.4 | 122.8 | 121.0 | 3.5 b |
| | | | 2002-03 | | |
| Snow | 24.6 ab | 23.7 ab | 127.0 | 114.5 | 0.0 |
| Debris | 23.7 bc | 22.5 bc | 127.0 | 114.2 | 0.7 |
| Snow + debris | 25.3 a | 24.1 a | 130.7 | 114.3 | 0.2 |
| No snow + no debris | 22.5 a | 21.2 c | 126.3 | 122.3 | 0.4 |
| | | | 2003-04 | | |
| Snow | 27.0 ab | 26.1 a | 129.3 | 113.2 | 1.7 |
| Debris | 26.6 bc | 25.9 a | 126.3 | 113.0 | 0.7 |
| Snow + debris | 27.7 a | 27.0 a | 135.2 | 118.3 | 1.0 |
| No snow + no debris | 25.7 c | 24.6 b | 134.8 | 115.0 | 0.9 |

Means followed by the same letter within a column for each experimental year are not significantly different.
The temperature data for 2001-02, and WD, CSFWD and Aphthona emergence for 2002-03 and 2003-04 are so close together among the experimental treatments that these data cannot be considered different.

# Leafy Spurge — **Unwelcome Pest to a Modern Day Model Plant**

Leafy spurge has been known since at least 1000 A.D., when Eurasian communities designated it as wolf's milk. Unfortunately, as shipyards, the rail system and immigrants unintentionally introduced leafy spurge seeds into North America, the natural control mechanisms indigenous to Eurasia also were not introduced.

Since its introduction and spread into the Midwestern states in the late 1800s, we have burned, cultivated, grazed, infected, mowed, pulled, sprayed, extensively studied, and yes, even cursed it, and yet we can't get rid of it. Heck, leafy spurge has gained such attention in the northern Plains that we have even named festivals after it.

However, starting in the 1990s, the introduction of natural enemies, such as flea beetles, provided a promising new addition to an already extensive integrated pest management (IPM) approach. In fact, the control of leafy spurge by natural enemies is a success story in areas where it has reduced the stand density or kept its spread in check. Unfortunately, natural enemies are not successful in all ecosystems and this resilient pest requires research to develop additional IPM measures.

So, what is it that makes this plant so resilient to everything in the kitchen sink and more? Vegetative reproduction from an abundance of underground adventitious crown and root buds, and dormancy within these vegetative buds and seeds, are the main mechanisms for persistence of this weed. Like most perennial plants, leafy spurge is capable of growing new shoots from vegetative propagules when the above-ground tissues are damaged, killed or removed.

However, very few chemical applications are either practical or effective at killing crown and root buds of leafy spurge. Dormancy within these reproductive organs optimizes the distribution of shoot emergence over time, and therefore is one of the leading factors that allow many weeds to escape current control measures. Current IPM recommendations essentially are designed to reduce the energy-carrying reserves in the root system over time, which ultimately reduces its capacity to compete and survive within the ecosystem.

But, leafy spurge seeds also are capable of remaining dormant within the soil seed bank for up to eight years and re-establishment of seemingly eradicated patches is common. Just as you and I adapt to our environment, so do weeds such as leafy spurge. Survival depends on it!

Interestingly, the same weedy characteristics that make leafy spurge such a nuisance in rangeland and other ecosystems actually make this plant a potential model for advancing our understanding of dormancy, not only in weedy perennials, but for economically important perennial crop plants as well.

In the November/December 2005 issue of the journal Weed Science, research scientists in our unit published a paper entitled "Potential model weeds to study genomics, ecology and physiology in the 21st century." In this article, we make compelling arguments for promoting leafy spurge as a model plant for the study of perennial broadleaf weed species (Canada thistle, field bindweed, etc.) based on its known weedy characteristics, ease of propagation, existing tools, stakeholder support, a scientific community and funding.

Although weedy plants likely never will gain the attention and support lavished on most crop plants, knowledge gained from the study of dormancy in a model perennial such as leafy spurge could be used to enhance production of perennial crops such as alfalfa, berries, grapes, and fruit and poplar trees that have an economic impact on global agriculture. The greatest potential for enhancing our understanding of bud dormancy and vegetative reproduction, and hence discovering new management strategies, is dependent on our unique genomics-based research program for studying global patterns of gene expression in the model noxious perennial weed, leafy spurge.

Important components of genomics-based programs are expressed sequence tag (EST) databases that can be used to identify unique gene sequences for the construction of DNA microarrays. Microarray technologies are standard procedures in modern biotechnology laboratories, which allow scientists to study the global expression of hundreds to thousands of genes in one experiment.

Through various in-house, collaborative and competitively funded programs, we have in excess of 50,000 ESTs in our leafy spurge database. These ESTs represent in excess of 23,000 unique sequences that are in the process of being organized for the construction of DNA microarrays. We already have plans to use the leafy spurge microarrays to identify the signaling pathways involved in regulating dormancy in crown and root buds.

Understanding how these signaling pathways regulate dormancy will enhance our understanding of potential treatments to manipulate dormancy and vegetative reproduction. This new information will be an important addition to the current IPM strategies.

So the next time you are standing on that butte that overlooks the pasture infested with leafy spurge, go ahead and kick the dirt and curse the scourge. But remember, behind-the-scenes fundamental research is quietly being done with this model plant to provide important clues to dormancy and the control of perennial weeds.

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## Carbohydrates affect dormancy and growth in underground buds of leafy spurge

The term “low-carb diet” frequently is mentioned by a health-conscious society interested in reducing carbohydrate intake. What are carbohydrates? In general, carbohydrates either are simple sugars such as glucose, fructose and sucrose (table sugar), or complexes of sugars such as starch. Carbohydrates are manufactured by plants during the process of photosynthesis and are a principal energy source for plants and animals. Since underground buds (crown and root buds) of leafy spurge are the primary means of vegetative reproduction, and reproduction and growth require carbohydrates, we are investigating how carbohydrates such as glucose, sucrose and starch within underground buds affect dormancy and growth.

Our current models suggest that a leaf-derived signal, requiring photosynthesis for its production or transport, is involved in keeping crown and root buds of leafy spurge dormant. Our studies indicate that sugar may be the basis for the leaf-derived inhibitory signal. The growth-regulating hormone gibberellic acid (GA), long known to promote the growth of buds, now also is known to overcome the leaf-derived inhibition of crown and root bud growth. Specifically, we have found that both glucose and sucrose inhibit root bud growth at concentrations as low as 30 millimoles (mM), while GA concentrations at 0.015 mM overcome the inhibitory effect of sugar.

In addition, crown and root buds of intact leafy spurge plants contain sucrose levels near 30 mM, which should be inhibitory to growth induction. The fact that sucrose levels decrease dramatically after removal of all aboveground tissue (decapitation) supports our hypothesis that sugars play an important role associated with dormancy.

Starch is the major energy reserve for plants and would be expected to decrease in crown and root buds after the removal of growth-inhibiting signals. Indeed, our research indicates that starch levels are abundant in root buds of intact plants but decrease nearly eightfold during the first five days after decapitation. This and other research on glucose, fructose and sucrose levels in root buds following decapitation indicate the products of starch breakdown are utilized rapidly for metabolic reactions associated with the early growth of buds.

Our model indicates that sucrose inhibits the GA response pathway or, alternatively, sucrose affects the levels of active GAs by inhibiting GA synthesis. Interactions between sugars and GA also may affect starch metabolism. Sucrose and glucose are known to repress expression of enzymes (alpha-amylases) involved in starch digestion, and GA is known to promote synthesis and activity of these enzymes. Thus, our research suggests that these simple sugars likely interact with GA to regulate the breakdown of starch in crown and root buds of leafy spurge during growth induction.

The knowledge gained from these fundamental studies should enhance our potential to devise new methods for controlling the reproductive capacity of perennial weeds such as leafy spurge.

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ment of the Bureau of Land Management, Forest Service, state and local soil and water conservation districts, and state land and parks division would all have been lost without the cohesive communication force of being able to work together toward a known common good, e.g., the control and management of this weed.

Interestingly, today we use this template of research, evaluation, integration, communication, Extension, and interstate and inter-country cooperation on nearly all the problems facing agriculture in a changing world. As we look ahead to the impact on the producers and consumers of food, feed, fiber and fuel by genetic engineering and biotechnology, we have a ready-made template from our leafy spurge effort upon which to construct and communicate a successful solution to the problems of the future.

There are many ways to express my feelings about this effort. For example, recall the statement “the Eagle has landed” when we put a man on the moon and our collective sense of achievement. The Bible says, “Well done, thou good and faithful servant.” As Arlon Hazen, who was the dean and director for agriculture at that time, would have said today, “May it always be so!”

All the best,

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# Assessing the Economic Impact of Leafy Spurge

By the late 1980s, leafy spurge in the northern Great Plains region had become a major concern to federal, state and local decision makers. Despite widespread treatment with herbicides, the area affected by leafy spurge infestations in North Dakota had been doubling every decade since 1950 (Bangsund, et al., 1999).

The adverse impact of leafy spurge on grazing capacity for beef cattle was widely recognized, but the cost of available herbicide controls was substantial. Further, these treatments served only to control leafy spurge stands temporarily and slow their spread. Biological control of leafy spurge was believed to hold promise, but implementing a biological control program would require a substantial investment.

To assess the economic feasibility of either intensifying the use of available chemical controls or developing a biological control program, everyone needed a better understanding of the economic effects of leafy spurge infestations. In 1988, researchers in North Dakota were engaged to assess the economic impacts of leafy spurge infestations, first in North Dakota, and subsequently in the four-state northern Great Plains region.

Researchers developed a bioeconomic model for estimating the impacts of leafy spurge infestations. The evaluation process estimated the impact of leafy spurge on (1) grazing land, and (2) wildlands. In each case, the analysis involved estimating the effect of changing levels of leafy spurge infestation on land output (e.g., carrying capacity for cattle, wildlife supported). Then, the changes in biophysical outputs were used to estimate direct economic impacts. Changes in livestock carrying capacity were used to estimate effects on livestock producers (reduced income) and local agribusiness firms (reduced sales/receipts). Similarly, changes in wildlife populations and watershed benefits were used to estimate changes in outdoor recreation expenditures and outlays necessary to mitigate damages from runoff and soil erosion.

The secondary economic impacts (i.e., those resulting from the initial or direct effects through the multiplier process) were estimated using input-output analysis. The total (direct plus secondary) economic impacts measure the effects of leafy spurge infestations on the economy of the northern Great Plains region (i.e., reduced incomes of households and receipts of firms in various sectors).

Grazing land was defined as all lands used for grazing of domestic livestock, without reference to land tenure, other land uses, management or treatment practices. The four-state region has approximately 146 million acres of grazing land, of which 1.1 million acres (0.8 percent) were estimated to be infested with leafy spurge, based on a survey of county weed boards. The economic impacts of leafy spurge on ranchers and landowners include reduced income from reductions in grazing capacity and lost livestock sales. These values were derived from the number of lost animal unit months (AUMs) of grazing.

In 1993, the grazing capacity lost to leafy spurge in the four-state area was estimated to be 736,200 AUMs, which would have supported a herd of about 90,000 cows, resulting in about $37.1 million in annual livestock sales, $10.7 million in annual income for ranchers and landowners, and $26.4 million in livestock production expenses (receipts for agribusiness firms) (Figure 1).

The four-state region has about 68 million acres of wildland, of which 500,000 acres (0.8 percent) were estimated to be infested with leafy spurge. These infestations were estimated to reduce wildlife-related recreation expenditures by $2.4 million annually and watershed benefits by $1 million annually (Figure 1).

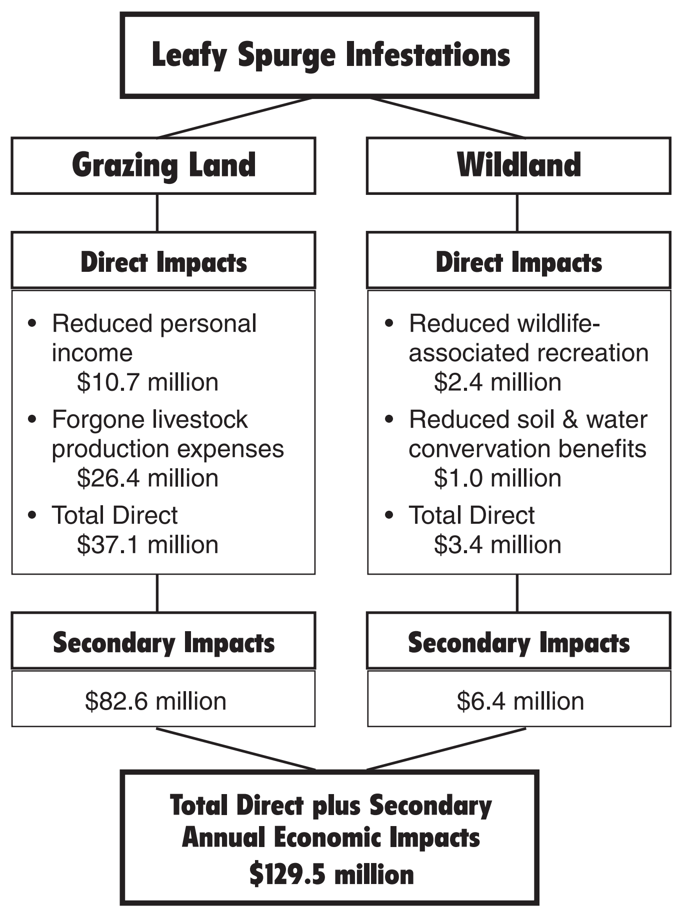


**Figure 1. Annual economic impacts of leafy spurge in Montana, North Dakota, South Dakota and Wyoming, 1993**

Results of the analysis are summarized in Figure 1. The direct economic impacts of leafy spurge on grazing land were estimated to total $37.1 million annually, while the direct impacts of leafy spurge on wildland totaled $3.4 million. Thus, the total direct economic impact of leafy spurge infestations was more than $40 million annually.

The secondary impacts of leafy spurge infestations on grazing land were estimated to be $82.6 million annually, or about $2.23 per dollar of direct impacts. Secondary impacts of wildland infestations were estimated to be $6.4 million annually, or $1.88 per dollar of direct impact. Total impacts (direct plus secondary) for the four-state region were estimated to be $129.5 million annually.

The results of the study were widely disseminated to decision makers at federal, state and local levels. The findings indicated not only the substantial economic losses associated with current levels of leafy spurge infestations, but also the potential for even greater impacts if the spread of leafy spurge continued at past rates.

A recent survey of county weed boards across the four states indicates that leafy spurge expansion has slowed considerably in recent years. In 2002, leafy spurge infestations were estimated to cover about 1.9 million acres, compared with 1.6 million acres in 1993 – an increase of about 19 percent (Hodur, et al., 2004).

The results also clearly indicated that economic losses from leafy spurge infestations were not confined to agricultural producers and landowners. Rather, the secondary economic impacts (which accrue primarily to the trade and service sectors of the regional economy) substantially exceeded the direct impacts.

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## Development of Leafy Spurge Control Products

Without a doubt, developing a herbicide to control leafy spurge has presented a great challenge to herbicide manufacturers. BASF Corporation has developed a number of compounds that are active on leafy spurge going beginning in the 1960's with Banvel (dicamba). Banvel was developed by Velsicol and was acquired by BASF through a series of acquisitions that included Sandoz. Similar to many of the growth regulator herbicides developed in the 1960s, Banvel is a broad-spectrum herbicide active on annual and biennial broadleaf weeds. Banvel applied at 1-2 qts/A will provide good activity during the season of application, but its relatively short residual limits its long-term control.

In the 1980s, herbicide manufacturers developed numerous herbicide active ingredients that ushered in the next generation of weed control products. When compared to those of previous decades, these new products had much more selectivity, lower use rates and lower toxicity to non-target species. While the majority of these products were developed for crop uses, a few of had pasture and rangeland opportunities. Imidazolinone herbicides discovered by American Cyanamid (acquired by BASF in 2000) began showing promise on leafy spurge. In the early 1990's work conducted by Robert Masters, formerly with the USDA-ARS, indicated that Arsenal had activity on leafy spurge, but its broad-spectrum characteristics limited its applicability to rangeland. This began a wider screening of imidazolinone herbicides and resulted in the development and labeling of Plateau for leafy spurge control. Plateau first received a section 18 for leafy spurge control on rangeland in 1999 and received its full grazing label in 2001 In addition to its excellent activity on leafy spurge, Plateau has many unique characteristics such as lower use rates, limited activity on trees, and safety on many native forbs and wildflowers.

Most recently, BASF has been developing diflufenzopyr, an active ingredient that enhances the activity of auxin herbicides such as dicamba and picloram. In 2003, Overdrive, which is a combination of dicamba and diflufenzopyr, was registered for pasture and rangeland usage. Research conducted by BASF and Dr. Rod Lym has indicated that the diflufenzopyr component of Overdrive increases the activity of Tordon (picloram) on leafy spurge and can allow for lower rates of picloram. BASF considers this an important development in the continuing battle against leafy spurge. By developing products that require lower use rates and less impact on desirable species, BASF's aim is to continue providing solutions to land managers who are winning the war against this invasive weed.

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# *Letters* To The Editor

**Dear Leafy Spurge News:**

Your editor asked that I provide some thoughts in a capstone statement in this, the last issue of the Leafy Spurge News. The leafy spurge story is one for the books! Can you imagine a group of ranchers sitting on hay bales on the site that would become the Central Grasslands Research Extension Center and speculating on "howcum" that this "scourge of the prairies" was not a problem in Europe, its suspected center of origin.

One of these ranchers had visited USDA-ARS stations in Europe and reported that natural diseases and insects in the "scourge's" native land kept it under control. "Let's introduce these elements since they didn't come with the original seed." Easier said than done. Other ranchers reported that sheep and goats would graze on spurge. Also, the scientists chimed in and said we have some wonderful new herbicides. The botanists said, "Are we dealing with the euphorbia esula that grows in Europe?"

As luck would have it, all of the people were discussing these views within range of an active North Dakota Agricultural Experiment Station administration, which had a history of maintaining a fully integrated relationship with the USDA-ARS on the NDSU campus. Also, the AES, with its federal Hatch Act research funding, would be able to work easily with surrounding states and Canada, in which spurge was a problem.

The stage was set! What I think is most remarkable, but not totally unexpected, was the willingness of the working farmer and rancher to embrace "biological control" as a feasible means to control "the scourge of the prairies." Recall that this "greatest generation" of ag producers had seen firsthand the impact of 2-4-D, genetic resistance to rust, and breeding of high-quality crops of sunflowers, barley, hard red spring wheat and durum, and its impact on their professions of farming and ranching.

The saga of the pursuit, roping and branding of the prairie scourge is well documented in the pages of the Leafy Spurge News. We all owe a great debt to the communicators who put together the first leafy spurge symposium in 1979 in Bismarck. And volunteers who went on to assemble a newsletter that spans the entire period of this effort, 27 volumes! The work on species clarification, herbicide use, insect identification, introduction and culture, along with the many sheep and goat grazing trials all over the state, the positive and cooperative involve-

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