

TEAM leafy spurge: An areawide pest management program

C.W. Prosser¹, G.L. Anderson¹, L.E. Wendel², R.D. Richard³ & B.R. Redlin⁴

¹USDA, Agricultural Research Service, Northern Plains Agricultural Research Laboratory (NPARL), Sidney, MT 59270, U.S.A.

²USDA, APHIS, Plant Protection and Quarantine, Moore Air Force Base, Mission, TX 78572, U.S.A.

³USDA, APHIS, Plant Protection and Quarantine, FSL, MSU, Bozeman, MT 59717-0278, U.S.A.

⁴USDA, Agricultural Research Service, NPARL, Sidney, MT, U.S.A.

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Abstract

The Ecological Areawide Management (TEAM) Leafy Spurge project is a United States Department of Agriculture and Agricultural Research Service (USDA–ARS) regional, Integrated Pest Management (IPM) program focused on the Little Missouri River drainage in the states of North and South Dakota, Montana, and Wyoming, U.S.A. TEAM Leafy Spurge project represents the first large-scale, systematic study and demonstration of weed management alternatives under USDA–ARS's Areawide Pest Management Program. The other three projects previously approved under the program targeted insect pests. TEAM Leafy Spurge's primary goal has been to demonstrate the use of ecologically based IPM strategies to achieve effective, affordable leafy spurge control. TEAM Leafy Spurge is co-chaired and overseen by the USDA–ARS in cooperation with the USDA–Animal and Plant Health Inspection Service. Both agencies have many years of experience in research and implementation of leafy spurge control tactics as well as valuable contacts and resources. Together those federal partners make a powerful team to address the leafy spurge problem on a multi-state basis. Additional federal agencies participating in TEAM Leafy Spurge include: Bureau of Land Management, U.S. Forest Service, National Park Service, Bureau of Indian Affairs, Bureau of Reclamation, and U.S. Geological Service. State partners include: state departments of agriculture and other state agencies, Cooperative Extension Services, land grant universities, and county weed managers, while private sector representatives include landowners and ranchers. A non-partisan *ad hoc* committee consisting of state and federal researchers, land managers, representatives from local, state, and federal entities, and private landowners/ranchers provides guidance and helps to ensure the quality and applicability of the program. The extensive partnerships are of particular importance because they help to ensure continued dissemination of information past the limited life span of TEAM Leafy Spurge, which is set to expire in 2003.

The five components of TEAM Leafy Spurge research and demonstration project are: (1) Program management; (2) Operations; (3) Assessment; (4) Supporting research, and (5) Technology transfer. As of this writing, the bulk of the research work has been completed and now TEAM Leafy Spurge is focusing its energies on assessment and technology transfer projects. Where available, brief outlines of research results are included here in addition to discussion of the program's key components, overall structure and general operation.

Introduction

The Ecological Areawide Management (TEAM) Leafy Spurge, an Areawide Integrated Pest Management (IPM) research and demonstration project, is based on the premise that IPM, offers landowners and land managers the flexibility needed to control agricultural

plant and insect pests across broad regions. Using IPM techniques, landowners and managers can apply different management strategies according to varying ecological habitats. To demonstrate the effectiveness of the IPM approach for controlling the noxious weed leafy spurge across a wide and varied expanse, TEAM Leafy Spurge chose the Little Missouri River drainage

as its primary study area because of its complex variety of ecological conditions including upland, midland and lowland plant communities, and riparian, woodland, and abandoned cropland areas, all impacted by leafy spurge. To accomplish its task, TEAM Leafy Spurge stresses teamwork and has assembled an experienced group of researchers and land managers into a focused, goal-oriented team shown in Figure 1. TEAM Leafy Spurge organizational structure and the duties assigned to each unit are shown in Figure 2. Over its 6-year life span, the program’s collaborative emphasis has enabled participants to share resources and expertise, aptly demonstrating how teamwork/partnerships can be used to implement IPM strategies and achieve successful leafy spurge control over broad regions. In particular, the effort has helped demonstrate how *Aphthona* spp. flea beetles can provide affordable and sustainable biocontrol of leafy spurge in much of the study area, with further containment accomplished through judicious herbicide applications and multi-species grazing.

and managed cooperatively with USDA–Animal and Plant Health Inspection Service (APHIS). Since its inception, TEAM Leafy Spurge has invested a significant proportion of its funding in research and demonstration studies conducted by TEAM members. Each year, potential program partners submitted leafy spurge research and demonstration proposals to the *ad hoc* committee, which would then discuss them and offer suggestions or recommendations before deciding where to allocate funding. Special consideration was given to projects that built on existing data and/or explored innovative methods of integrating control strategies. Altogether, about 80% of TEAM Leafy Spurge’s annual funding has been distributed to research and demonstration efforts being conducted by partners at land grant universities and by local, state, and federal researchers. For their part, research program participants often supplemented their awards with additional funds from their own organizations totalling hundreds of thousands of dollars each year.

An additional funding priority has been given to technology transfer projects, ranging from press releases, to ‘how-to’ manuals, to interactive CD-ROMs and web sites, all designed to ensure that new information and technologies developed under the program would reach the intended users quickly and continue to be available once the program ends. As part of its

How It Works

The Ecological Areawide Management Leafy Spurge is funded by the United States Department of Agriculture and Agricultural Research Service (USDA–ARS)

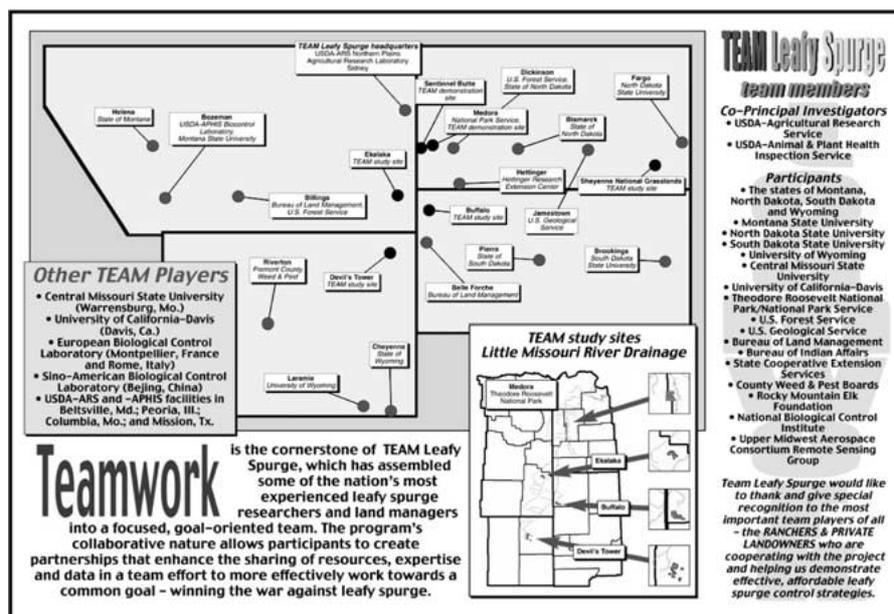


Figure 1. TEAM Leafy Spurge partners.

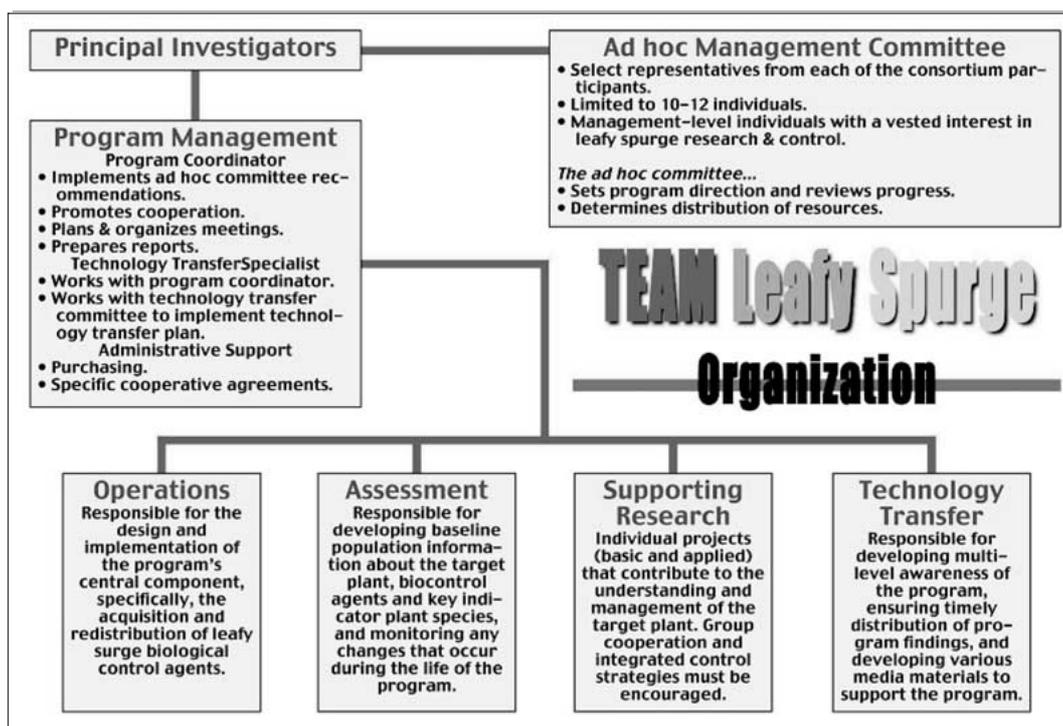


Figure 2. TEAM Leafy Spurge organizational chart.

technology transfer efforts, TEAM Leafy Spurge staff also worked hard to provide competent, timely, and personalized service to its customers and stakeholders. It was not an easy task. While TEAM Leafy Spurge is a large, regional weed management program, its regular paid staff is small, totalling no more than two to three full-time individuals at any one time. Despite that limitation, TEAM leaders still travelled more than 250,000 miles, hosted and/or attended more than 100 field days, seminars, trade expositions, weed and scientific meetings, and biocontrol agent distributions, as well as providing one-on-one technical guidance to hundreds of customers and stakeholders.

Program Background

Leafy spurge (*Euphorbia esula* L.) is a herbaceous, deep-rooted, perennial weed found in 35 states (USDA-NRCS 1999) and six Canadian provinces (Dunn 1979). Initially identified in Massachusetts in 1827 (Britton 1921), the plant was probably introduced as seed in ballast soil from ships sailing from Europe. It was not reported again in the literature until 1848, when it was listed in Gray's Manual of Botany and described as 'likely to become a troublesome weed'

(Hanson & Rudd 1933). For several decades, leafy spurge remained an incidental component of the north-eastern flora. Although reported in New York in 1875 and in Michigan in 1881 (Dunn 1979), leafy spurge remained uncommon across this initial new world range. Yet, by the 1900s, leafy spurge had spread by seed and vegetative fragments to many areas of the western United States. By the end of the century, the annual economic impact of leafy spurge infestations for North and South Dakota, Montana, and Wyoming was estimated at \$130 million annually (Leitch *et al.* 1994).

In its native Eurasian habitat, leafy spurge is controlled by natural enemies (Messersmith *et al.* 1985). In North America, however, leafy spurge has readily adapted to a wide range of habitats with little evidence of control by natural enemies (Photo 1). Without aggressive management it can dominate landscapes ranging from open prairie and hillsides to riparian areas and lowlands. Because it can repeatedly rejuvenate itself from extensive root reserves and soil seed banks, it is difficult to control. Cost-effective control of leafy spurge on rangeland (public and private), wildlands, and other public lands (roadways, historic sites) requires a combination of chemical, biological, and cultural control techniques in a biologically based IPM system (Lym 1998).



Photo 1. Leafy spurge infested rangeland.

The USDA–ARS already recognized IPM as a valuable tool for managing difficult agricultural pests. In 1993, ARS, in concert with USDA’s IPM Working Group, developed a partnership framework for collaborative activities on an areawide pest management approach that would include federal, state, and private sectors (Faust & Chandler 1998). In 1994, USDA commenced its IPM Initiative (USDA 1993, 1994). This initiative redirected and recombined resources of the USDA and land grant university programs into a single coordinated and cooperative effort with farmers, private consultants, and industry charged with achieving the national goal of IPM on 75% of U.S. crop acres by the year 2000 (Faust & Chandler 1998). Under its own areawide program, ARS actually expanded the emphasis to include IPM strategies on all lands, not just crop acreages. The first two projects approved under the new areawide program focused on insect pests, the codling moth, and corn rootworms. Then in October 1996, a second request for areawide pest management project preproposals was distributed to ARS scientists and state IPM coordinators. Twelve reviewers provided evaluation and recommendations regarding the qualifying criteria, including the quality and scope of the science and the relevance of the preproposals to the areawide pest management concept (Faust & Chandler 2000). Out of the 16 preproposals offered in 1996, TEAM Leafy Spurge and the stored grain project in Kansas and

Oklahoma were selected for funding (Chandler & Faust 1998), making TEAM Leafy Spurge the first areawide project involving not only an important weed pest, but also one that primarily impacted rangeland.

The Ecological Areawide Management Leafy Spurge was officially instituted in 1997 as a major biologically based IPM research and demonstration project charged with developing and integrating sustainable leafy spurge management methods across the diverse habitats found in the Little Missouri River drainage. Later TEAM Leafy Spurge would expand its successful IPM work into the Sheyenne National Grassland in southeastern North Dakota, as well as areas into the Grand River, Powder River, and Heart River drainages in South Dakota, Wyoming, and North Dakota, respectively. This combination of land types, uses and ownership (private, state, and federal) gave TEAM Leafy Spurge members an opportunity to research and demonstrate IPM strategies in a variety of situations. It also allowed the program to create and capitalize on partnerships between private and public entities. Initial project objectives of TEAM Leafy Spurge were: (1) to develop and integrate sustainable leafy spurge management methods in an areawide broad demonstration project with national implications and applicability; (2) to form long-term partnerships among federal, state, and private land managers, and (3) to transfer economically and ecologically proven

management technologies to land managers that fit specific requirements dictated by habitat and social needs. The latter two objectives were particularly important because they would ensure continuation of the IPM control effort once funding for the original areawide program ended.

The Challenge

Although research already indicated that IPM with a strong biological control component was the key to long-term management of leafy spurge (Quimby & Wendel 1997), practical, comprehensive IPM information regarding leafy spurge management had not yet been compiled for land managers across a range of habitats. That, then, became the goal of TEAM Leafy Spurge. To meet that goal, however, TEAM Leafy Spurge had to address several problems surrounding the use of biological control in a wider IPM program, problems first identified two decades earlier.

In 1978, a USDA Office of Environmental Quality Activities study team issued the report *Biological Agents for Pest Control: Status and Prospects* (Quimby & Wendel 1997). The study's major findings included the following: (1) information on pesticide alternatives are not easily available; (2) more research is needed to improve a priori predictions of success (to develop production, storage, and application techniques) and to assess the impacts of use; (3) users need better technical assistance, and (4) mechanisms are necessary to coordinate federal, state agencies, and private weed management efforts. Most of this report's major conclusions are as true today as they were then, and remain applicable to integrated weed management strategies in general.

However, in 1999, renewed emphasis was given to the battle against leafy spurge and other non-native plant and animal pests when U.S. President Clinton issued Executive Order 13112 on Invasive Species. That order specifically mandated development of programs to: (1) prevent the introduction of invasive species; (2) detect and respond rapidly to and control populations of such species in a cost-effective and environmentally sound manner; (3) monitor invasive species populations accurately and reliably; (4) provide for restoration of native species and habitat conditions in ecosystems that have been invaded; (5) conduct research on invasive species and develop technologies to prevent their introduction, and provide for environmentally sound controls, and (6) promote

public education on invasive species and the means to address them.

All are goals shared by TEAM Leafy Spurge and its public and private partners. Highly motivated to manage the weed, public and private landowners in the TLS study area had, in some cases, already organized community grazing or biological control programs of their own. But it fell to TEAM Leafy Spurge to generate widespread support for these alternative tools by demonstrating that a biologically based IPM approach was 'doable' and sustainable across a wide spectrum of land types, uses, and ownership structures.

The Approach

The Ecological Areawide Management Leafy Spurge research and demonstration projects have all been designed to build on existing data and explore promising new areas of leafy spurge research. These projects have covered a range of topics including biological control using *Aphthona* flea beetles, multi-species grazing, herbicides, range management techniques, cultural controls, and the combination and integration of those various control tools.

Under the program, research has been conducted by weed specialists, range scientists, ecologists, and entomologists to gain a better understanding of how and why biological control agents work, how biological control interacts with other management tools, and how different tools can be used alone and in combination to improve leafy spurge control. Research has also been conducted overseas at the USDA-ARS European Biological Control Laboratory in Rome Italy, where entomologists and plant pathologists continue to search for new biological control agents. Other research efforts explored the economic and environmental damage caused by leafy spurge.

Grassroots Collaboration

In addition to the research effort, demonstration sites have been established in varied habitats along the Little Missouri River drainage (Figure 1), offering a unique opportunity to implement integrated technologies developed by universities and federal researchers on both public and private lands. Land managers such as the U.S. Forest Service, Bureau of Land Management, and the National Park Service have actively participated in the process and provided access to professional staff capable of gathering the data needed

for this type of project. For their part, private landowners have welcomed the opportunity to work beside public land managers to control leafy spurge, while university researchers have welcomed the opportunity to apply their knowledge to a large-scale project.

A coordinated effort to communicate and educate land managers about the outcomes of the project has also been mounted by TEAM Leafy Spurge staff and partners using a variety of techniques including print and electronic media along with face-to-face meetings at field day events, trade shows and expositions held repeatedly throughout the four-state region. The majority of individuals reached in this manner have shown a great deal of interest in and enthusiasm for controlling leafy spurge through a coordinated and large-scale effort.

Key Concepts

The Ecological Areawide Management Leafy Spurge was built on three main, interrelated concepts. First, it relies on a regional approach. As a USDA–ARS areawide program, TEAM Leafy Spurge evaluates the leafy spurge problem on a regional rather than a local basis to ensure that any management techniques developed will be applicable across a large area rather than a single place.

Second, TEAM Leafy Spurge relies on IPM, or the coordinated use of multiple tools and tactics, to improve leafy spurge control while assuring stable ecosystem function. Because of its emphasis on multiple tools over a single management technique, the IPM approach provides the flexibility needed to manage leafy spurge across wide regions that incorporate a range of ecological, social, and economic situations. Also, by reducing reliance on any one method of pest management (i.e., chemical, fire, mechanical, or biological), the IPM approach focuses on finding lasting solutions to pest problems considering all ecologically sound and sustainable alternatives. Ongoing development of new technologies also provides additional IPM tools to improve efficacy of pest management systems such as TEAM Leafy Spurge research testing for new herbicides and their effectiveness with biological control agents.

And finally, the third major concept of TEAM Leafy Spurge is teamwork, pulling together federal, state, and local entities as well as private individuals to more successfully battle leafy spurge, both on the ground and in the laboratory. To that end, TEAM Leafy Spurge

has assembled an experienced group of researchers and land managers into a focused, goal-oriented team. The program's collaborative emphasis has also enabled participants to share resources and expertise to more effectively work toward common goals.

Key Components

The Ecological Areawide Management Leafy Spurge program consists of five major components. They include: program management, operations, assessment, supporting research and demonstration, and technology transfer. Information on each is provided below.

Program management

Program management consists of a full-time program coordinator to promote cooperation among affiliates and to facilitate the project. The coordinator organizes regular meetings for the administrative and operational components as well as project participants, serves as liaison between TEAM Leafy Spurge and other entities, and provides guidance and technical advice to USDA and federally funded personnel under specific cooperative agreements or research support agreements with this project.

The Ecological Areawide Management Leafy Spurge project has drawn together the resources of state, federal, and local partners to demonstrate an integrated approach to manage leafy spurge (Figures 1 and 2). Frequent, effective communication has been vital to the success of this geographically dispersed project, which throughout has encouraged its cooperators to participate in multi-jurisdictional, large-scale efforts that offer everyone a better opportunity to assess the cost, ecological impacts, and efficiency of various leafy spurge management strategies. However, that large-scale approach has required considerable coordination to ensure effective communication among the participating agencies, organizations, and individuals.

Operations

The operations component is headed by USDA–APHIS and is responsible for coordinating and expanding the collection and redistribution of biological control agents within the specific study area and throughout adjacent states and Canadian provinces. Operations personnel work closely with the program coordinator

and other USDA–APHIS field staff to provide technical support for evaluation teams, insect collections and releases, technology transfer activities, and ground truthing of digital imagery data collected by aerial mapping. Operations personnel have also integrated research efforts across a wide range of agencies and institutions, creating a series of demonstration sites where landowners could see firsthand both the application and the benefits of a variety of control technologies. Operations has aggressively promoted the redistribution of flea beetles across leafy spurge infested rangeland, met with landowners in dozens of counties and provided a model for similar projects in other regions. In 1999 alone, operations personnel were responsible for the redistribution of over 20 million *Aphthona* spp. flea beetles to locations in 50 counties in seven states. Altogether more than 48 million insects have been distributed in 12 states and three Canadian provinces during the life of the program. Given the thoroughness of the insect redistribution program, establishment of the insects and the effectiveness of the IPM approach integrating grazing/herbicides, grazing/biological control, herbicides/biological control (see assessment section), it is reasonable to assume that leafy spurge will become a manageable part of the ecosystem in the near future.

Assessment

Under TEAM Leafy Spurge, three assessment teams were developed to assess the integrated leafy spurge management demonstration efforts at four major sites (North Dakota, South Dakota, Montana, and Wyoming) served by TEAM Leafy Spurge. In particular, assessment teams have quantified the plant community before and after weed management strategies were implemented and are currently examining the role selected site characteristics (slope, aspect, soil texture, soil moisture regime, topographic position) have played in the establishment and persistence of two species of flea beetles (*Aphthona nigriscutis* and *A. lacertosa*) released at the sites. To date, research findings from assessment teams across the 4-state region indicate site establishment rates for biological control agents of 85% or more and an average rate of control of approximately 0.65 ha/release/year when 3000 *A. lacertosa/czwalinae* and 3000 *A. nigriscutis* were released at each site.

“Of the 101 insect biocontrol sites established in the Little Missouri River drainage of western North

Dakota, nearly 100% have good leafy spurge control (>400 m²) demonstrated at each site after 3 years. Leafy spurge canopy cover at release sites has decreased nearly 100-fold from 40% to 5% in only three growing seasons. Results indicate that control has been similar across aspect, soil type, range site, topographic position and slope, which is contrary to previous reports.” – *Don Kirby 2001*

“The impact of the 1998 *Aphthona* releases on leafy spurge has been very significant. Leafy spurge canopy cover has declined from an average greater than 50% to approximately 6% in the plot centers. Areas of *Aphthona* impact, although highly variable, were as great as 43,000 m² in 2001. Moreover, the *Aphthona* releases were successful in all vegetation and topographic types, including wooded, riparian areas that historically had been resilient to *Aphthona* attack.” – *Dave Kazmer 2001*

The rate of leafy spurge control using flea beetles is, of course, not constant. As flea beetle populations increase exponentially, so will their impact in most sites (Photos 2 and 3). One researcher in Montana reported a 7-fold increase in flea beetles between 1998 and 2000 (Butler 2000).

Supporting research and demonstration

The Ecological Areawide Management Leafy Spurge research efforts were designed to better understand the biology of leafy spurge and the ecological implications of infestations; to evaluate existing management strategies and develop new IPM approaches, and to refine inventory methods to more accurately and economically monitor leafy spurge. Research funded under the program focused on five areas:

1. *Ecological barriers.* The habitat associations of seven flea beetle species are being characterized for leafy spurge infestations occurring in dry to very moist sites in the U.S. Because leafy spurge is able to infest dry, moist, and wet sites across the U.S. the question is often posed: How much of the U.S.A. is susceptible to attack by leafy spurge? The answer to such a question is of critical importance for predicting the potential ecological and economic damage of leafy spurge. In order to address this question, the relative abundance of leafy spurge is being correlated with chemical and physical properties of the soil, aspect of the site, elevation, average moisture levels, levels of plant productivity, and other factors to determine which factors are most



Photo 2. Olson Waterfowl Production Area (Marshall County, S.D.), 1999.



Photo 3. Olson Waterfowl Production Area (Marshall County, S.D.), 2000. Mixtures of *A. czwalinae/lacertosa* were released here in 1994–1996; their impact on heavy leafy spurge infestations between 1998 and 2000 was dramatic. Nearly 8 million flea beetles were collected at the site in 1999 and 2000.

strongly correlated with the presence of leafy spurge. These habitat associations were characterized with regard to levels of plant productivity, physical properties of the soil, and micro- and macro-nutrients in the

soil, micro- and macro-nutrients in the spurge foliage and roots. This information will help guide the future release of flea beetle species in appropriate types of habitats, thus improving chances of establishment as

well as optimum insect impact on leafy spurge. Leafy spurge has high genetic, chemical, and morphological variability, and as a consequence, there is considerable confusion regarding its taxonomy. Furthermore, it has long been suspected that this high degree of variability may be responsible for the lack of flea beetle establishment or population increase at some leafy spurge release sites. To date, Nowierski *et al.* (2002) has found that *A. czwalinae* and *A. lacertosa* were associated with sites containing higher levels of clay and plant productivity and higher levels of Mn in the roots of leafy spurge, while *A. nigriscutis* was associated with sites with intermediate levels of sand, clay, and plant productivity and higher levels of Ca, K, and N in the roots of leafy spurge (Nowierski *et al.* 2002). Both flea beetle species have proven effective in controlling leafy spurge, but it is *A. lacertosa* that has had the greatest impact. The more demanding habitat requirements of *nigriscutis* and the fact that it has been shown to harbor the Wolbachia virus favoring the proliferation of females may account for its more limited success in establishing at certain locations.

2. *Grazing.* Grazing is a valuable component of many integrated management plans for leafy spurge (Lym *et al.* 1997). Under TEAM Leafy Spurge, North Dakota State University and Montana State University researchers are looking at the long-term effects of grazing combinations of cattle and sheep on leafy spurge-infested land (Dahl *et al.* 2002). The economics of this strategy are being quantified, along with its impact

on plant communities and its integration into traditional cattle ranching operations. TEAM participants are also evaluating the impact of grazing treatments on other biocontrol agents, i.e., flea beetles (*Aphthona* spp.), and on the native plant community. In addition, researchers are assessing biomass, leafy spurge density, plant community composition and productivity, flea beetle abundance, and grazing animal performance relative to levels of herbivory treatment. This data will be combined with similar research being conducted at Colorado State University and used to help synthesize the results into practical guidelines for integrating grazing management as part of a comprehensive leafy spurge management plan. Results to date show rapid reductions in leafy spurge densities when insect biological control agents were used in combination with cattle and sheep. Research on one section of land containing approximately 40–50% leafy spurge with stem counts approaching 200 stems/m², demonstrated a 63–78% reduction in leafy spurge stem densities in 3 years (Samuel 2002) (Photos 4 and 5). Questions remaining to be answered concern the most effective seasonal timing for grazing and the degree of utilization of leafy spurge that effectively harms the plant without negatively affecting the remaining plant community or performance of other grazing animals.

3. *Inventory methods.* Weed species such as leafy spurge are difficult to assess because the area infested is large, the types of ecological systems impacted are diverse, and the population expansion



Photo 4. In 1998, a multi-species grazing and biological control project was implemented near Sentinel Butte, North Dakota.



Photo 5. The difference just 3 years later (in 2001) after implementation of an IPM program using multi-species grazing with biological control agents.

is rapid. Therefore, a careful evaluation of potential inventory/assessment resources is necessary to ensure that relevant and timely information is obtained at a minimum investment. The inventory program is designed to examine satellite imagery, aerial photography, and aerial videography as data sources for leafy spurge inventory and assessment. The development of effective and coordinated noxious weed management strategies at the national, regional, or local level depends upon accurate information concerning the extent, distribution, and dynamics of the problem species. In this project, USDA–ARS, National Park Service, and United States Geological Survey researchers used aerial photographic mapping developed at Theodore Roosevelt National Park in Medora, ND (Anderson *et al.* 1996) to inventory leafy spurge populations across two 6500-ha intensive study sites located in Wyoming and North Dakota. This landscape-scale mapping effort developed an inventory baseline that will be used to assess change over the life of the project. The objectives were to map the extent of leafy spurge within each study area, evaluate the robustness of the procedure between different regions, and determine the adequacy of the inventory/assessment resources for monitoring change and evaluating the effectiveness of various leafy spurge control efforts. Regional-scale mapping was also conducted as part of the research component of this project. GIS/GPS technology will be used to demonstrate the importance of spatial data in developing an optimized integrated weed management program.

4. *Life history of leafy spurge.* The objective of this study is to gather the life history information necessary

to develop a computerized decision-making management tool for leafy spurge. Understanding the biology and ecology of leafy spurge is central to its management. Decision-making tools must be based on our understanding of how weed populations change over time and how each management option alters that change. Thus, knowledge of the life history of leafy spurge is critical to developing a management decision-making tool that is based on ecology, science and technology, and economics. For example, Sheley & Larson (1994) studied the life history of yellow starthistle, and Maxwell & Sheley (1997) developed an educational model to help students and managers understand integrated yellow starthistle management. This model is adaptable to leafy spurge and is being used as a basis for the decision-making tool; however, information about the life history of leafy spurge is needed. To fill these data voids, information being collected includes: leafy spurge population dynamics, the number of seeds in the seed bank, the number of seeds that germinate, the number of germinations that become juvenile plants, the number of juveniles that mature and produce seeds, the number of seeds produced, and the number of viable seeds that fall to the ground.

A significant amount of information regarding the management of leafy spurge exists (TEAM Leafy Spurge 2001). However, the information is scattered throughout the scientific literature in a form that is very difficult to interpret and apply toward management. A major goal of this project has been the compilation of this information into a user-friendly, interactive, decision-making tool integrating our understanding of leafy spurge ecology, science and technology, and

economics. New information will be incorporated into the model as it becomes available. Currently, work on the project is expected to extend beyond the end of the TEAM Leafy Spurge program.

5. *Socio-economic investigations.* Three studies of economics and sociology related to leafy spurge are being conducted.

A. A study to assess the economic impact of leafy spurge reduction and range restoration. Gains in the regional economy associated with leafy spurge reductions will reflect alternative assumptions regarding the rate at which control technologies are adopted, and the rate at which rangeland grazing capacity recovers after control has been achieved. These scenarios will illustrate the potential payoffs from programs to speed adoption of various control technologies and restoration of grazing capacity.

B. A study to evaluate costs and benefits of biological control strategies including grazing, combinations of biological and chemical control strategies, and to develop an economic decision model. Costs and benefits will be evaluated under various environmental situations and will include grazing land and wildlands. Analyses of specific control strategies and combinations will serve as the basis for a decision model that will evaluate the least-cost and/or most economical long-term control strategies. The user-friendly model will be designed to run on a wide range of IBM-compatible computers. It will be similar to the Microcomputer Economic-Demographic Assessment Model (Leistriz *et al.* 1994).

C. A study to evaluate managerial, institutional, and social factors that inhibit implementation of various control strategies and, if appropriate, to develop approaches to counteract those factors. This study will also assess the impact of the demonstration program on attitudes and perceptions of landowners, land managers, and other local decision makers. Data was collected through periodic interviews, surveys, and focus-group meetings. The data was collected at the beginning and end of the project. A survey of 459 ranchers, 56 local decision makers, and 50 public land managers was conducted. This initial study focused on a five-county region in Montana, North Dakota, South Dakota, and Wyoming (Sell *et al.* 1999). The questionnaire focused on weed management in general and specifically on the perceptions and attitudes of ranchers, land managers, and local decision makers who have directly or indirectly affected by leafy spurge. In addition to the survey, separate focus-group meetings were held with local decision makers and ranchers from

the study area (Sell *et al.* 2000). The local decision makers' focus-groups were generally composed of county weed board members, local legislators, and county commissioners. The purpose of the focus group meetings and personal interviews was to discuss issues not addressed in the mail questionnaire. In all studies, leafy spurge was recognized as the most important weed problem for ranchers, local decision makers, and public land managers in the 5-county area (Sell *et al.* 1998).

A follow-up study surveyed the same ranchers, local decision makers, and public land managers that were contacted in the first study. This study was designed to evaluate changes in the perception of leafy spurge and determine the effects of the demonstration project on the adoption of various leafy spurge control technologies (Bangsund 2002). In addition to the follow-up survey by Bangsund (2002), a separate survey is being conducted on private landowners, local weed control officials, and public land managers throughout the four-state region of North and South Dakota, Montana, and Wyoming. The purpose of this project is to determine the extent to which biological control strategies are being adopted and assess the potential long-term consequences of widespread biological control use on the level of current and future leafy spurge infestations. The final follow-up surveys evaluating the perceptions of leafy spurge are in their final stages of completion (Bangsund 2002). In addition to the perceptions of leafy spurge, an additional survey is being conducted to evaluate the use of biological control and its associated impact with ranchers and public land managers. The ultimate success of this project will depend on the extent to which control strategies are adopted by private landowners and public land managers. This aspect of the project will develop recommendations to improve the acceptability of selected control strategies among this population.

Technology transfer

The primary goal of the technology transfer team is to take information developed through the research and demonstration projects, collate it into an easily useable format and distribute user-friendly information to ranchers, landowners, and land managers. A secondary, but equally important, goal is stimulating increased public awareness of and interest in IPM. The technology transfer team is using a variety of tools to achieve the project goals, including newsletters, news releases, pamphlets and brochures, multi-media presentations,

CD-ROMs, web sites, open houses, field days and tours of demonstration sites, documentary-style videos, and displays at various events.

Managers recognize that education, outreach, and technology transfer are major components of any integrated weed management plan being implemented across a large region. Awareness of the seriousness of leafy spurge and knowledge of various IPM techniques used to combat it are central to the development and implementation of a successful management plan. Together, TEAM Leafy Spurge researchers and technology transfer staff are working to ensure the most economically viable and ecologically sound integrated weed management strategies are adopted by land managers for leafy spurge control and they are using a variety of tools to do it.

Information products for end users

The Ecological Areawide Management Leafy Spurge has developed and continues to add to a four-part IPM Information Series focusing on how to use the most effective weed control techniques currently available. IPM techniques featured include biological control, multi-species grazing, herbicides, and IPM. Information on each is provided through an in-depth, 'how-to' manual paired with an interactive CD-ROM that incorporates additional informational materials and is designed for use with groups. The series' first 'matched set' focuses on the 'Biological Control of Leafy Spurge.' The how-to guide was originally published in April of 2000 and is now in its third printing with more than 40,000 copies distributed in 27 states and four Canadian provinces. Its companion CD-ROM is in its second printing, with approximately 5,000 CD-ROMs distributed to date, and provides a variety of other useful items on biological control, including a fully automated, 20-min, 'how-to' PowerPoint presentation. TEAM Leafy Spurge biological control experts developed the presentation, which includes a voice-over that actually puts the expertise of these experts into the hands of the end user. Additional information products available on the CD, include: a photo gallery, posters, publications, and an extensive bibliography.

Each new addition to the IPM information series will follow the same format, combining how-to manuals and interactive CD-ROMs for a one-two punch. Already completed is the 'how-to' handbook on multi-species grazing, with 10,000 manuals already distributed, and another 10,000 on order. This product will be followed by another on herbicide use.

The supplemental CD-ROMs on multi-species grazing and herbicides are also in various stages of production. In every case, the information presented will be built around the premise of bringing the expert to the end user.

Due in part to the extension of the program from 5 to 6 years, TEAM Leafy Spurge tech transfer representatives will continue to produce products for several more years. To help coordinate their distribution, the program has developed the 'TEAM Leafy Spurge Information Resource Center,' a comprehensive leafy spurge resource package using three-ring binders with pocket pages that can be easily updated as new materials are completed. These materials – containing the latest information on identifying, mapping, and controlling leafy spurge – were developed by TEAM Leafy Spurge personnel and partners and distributed to every Extension agent and weed supervisor in the states of North Dakota, South Dakota, Wyoming, Montana, Nebraska, Idaho, Washington, Manitoba, and Saskatchewan, Canada. In addition, the Information Centers were also distributed by request to the Bureau of Land Management, Bureau of Indian Affairs, Forest Service, APHIS, National Park Service, North Dakota Fish and Wildlife Service, North Dakota State Lands, Minnesota Department of Transportation, Minnesota County Ag Inspectors, Minnesota Department of Natural Resources, and Minnesota Natural Resources Conservation Service.

In addition to their other projects, TEAM Leafy Spurge tech transfer personnel have also substantially updated the 'Purge Spurge: Leafy Spurge Database,' winner of a federal technology transfer award in the mid 1990s. This updated CD-ROM features more than 900 research reports, abstracts, bulletins, conference proceedings and other articles, photos, maps, and illustrations on leafy spurge and its management. Information on the CD is easily accessed through an Adobe Acrobat interface and is PC and Mac compatible to reach the broadest possible audience.

In addition to the technical products, TEAM Leafy Spurge has also provided ranchers, landowners and land managers with a first-hand look at the results produced by various IPM strategies (Photo 6) in special tours of its demonstration sites. Tours and events such as Spurgefest '99 (Photo 7) were held repeatedly to provide updates about new and improved management strategies, as well as to distribute free biocontrol agents to interested participants.

The combination of free insects, pertinent information and impressive results made these events very



Photo 6. Workshops on the use of biological control agents to combat leafy spurge are popular Field Day events.



Photo 7. Bob Richard, director of the USDA–APHIS Biological Control of Weeds Laboratory, Bozeman, Montana U.S.A., tells Spurgefest tour participants about biological control.

popular. Attendance at the two Spurgefest events numbered 200 plus in 1999 and more than 300 participants in 2001 despite being held in late June early July, a busy time for most people involved in the area's agriculture. Attendees came from across the United States and Canada. Spurgefest I attracted participants from 18 states and 3 Canadian Provinces and Spurgefest II

attracted participants from 11 states and 2 Canadian Provinces.

Spurgefest-99 and Spurgefest II (2001) were 3-day events where each day targeted a different audience. The first day focused on sharing scientific and technical information. The second day consisted of demonstration site tours where land managers could see firsthand

the effectiveness of using biologically based, IPM to control leafy spurge. The tours also provided an opportunity for landowners and land managers to interact with leading experts in controlling the pest. Day three provided the opportunity for all participants to collect their own biological control agents. Individuals worked with personnel experienced in collecting leafy spurge flea beetles to refine techniques and to see the entire process from collection to distribution. A special emphasis was also placed on bringing federal and state policy makers to these events to help educate them about the invasive weed problem and to give them an opportunity to share existing and upcoming legislation and programs. Participants in 1999 and 2001 included the Agriculture Commissioners from North Dakota and South Dakota (Roger Johnson and Larry Gabriel), the Science Advisor to the Secretary of the Interior (Bill Brown), the Invasive Alien Species Coordinator for the Department of Interior (Gordon Brown), USDA Invasive Species Liaison (Rebecca Besch), National Park Service Assistant Regional Director (Ron Hiebert), the agricultural representative for Idaho Governor Kempthorne (Brenda Waters), and the Executive Director of the National Invasive Species Council (Lori Williams). In her address, Ms. Williams praised TEAM effort as an excellent example of bringing federal, state and local interests together in a united effort to battle invasive weeds, adding, 'This program is serving as a model and showing how coordination can help reduce the impact of invasive species.' The program was also featured in the Council's final management plan entitled, 'Meeting the Invasive Species Challenge' (National Invasive Species Council 2001).

Conclusion

The Ecological Areawide Management Leafy Spurge has assembled many of the most experienced leafy spurge researchers in the U.S.A. and abroad and has focused their attention of development of a variety of management tools including grazing, biological control, herbicides, and reseeding for ecologically sound and sustainable leafy spurge control. The expertise found among TEAM participants has enable a unique sharing of information and exchange of ideas to combat this noxious weed in various habitats and situations. However, the primary question that must be answered remains: What has been the impact of the USDA-ARS, Areawide Pest Management Program on leafy spurge to date? One example of the success of the program has

been the overwhelming demand for technology transfer 'how-to' items. In 2000, TEAM Leafy Spurge produced its first easy-to-read manual on how to use biological control as an effective leafy spurge management tool. The first 10,000 manuals were gone in 2 weeks. Today, the manual is in its third printing with over 40,000 copies sent to 27 states and many federal agencies. Interest in the manual has been further fueled by the 48 million *Aphthona* flea beetles distributed free to private producers in more than 82 counties and 12 states and the success shown with them. National, and even international, awareness has been fostered by media coverage of TEAM Leafy Spurge activities, including contributions to the British Broadcasting Companies 'Earth Report' which reaches more than 167 million people in 200 countries and a segment of the Public Broadcasting System's 'Living on Earth' series. TEAM Leafy Spurge web site (<http://www.team.ars.usda.gov>) also provides an excellent venue for new materials as well as an archive accentuating the progress of the program. It will also ensure that the information developed will continue to be available long after the program has ended. These, as well as other educational IPM materials, continue to be developed and provided to federal, state, and private landowners, and the general public. Efforts to increase public awareness and provide land managers with cost-effective and ecologically sound control practices have been the most successful aspects of TEAM Leafy Spurge program to date. Leafy spurge is a formidable opponent that cannot be controlled or eliminated by any single entity or management practice – a collaborative, integrated, and areawide approach is essential to solving this costly problem. Programs such as TEAM Leafy Spurge are using just such an approach to reach large segments of the population and are working with them in developing ecologically based IPM strategies that can be used to achieve effective, affordable, and sustainable leafy spurge control.

The following comments attest to the success of the program and the IPM approach:

North Dakota

"In the last 3–4 years I have collected and redistributed approximately 6 million flea beetles over 15 sections of rangeland. These 6 million flea beetles are located on approximately 2,000 different sites. I have had more success with the flea beetles than we ever did spraying for the past 40–50 years. USDA, TEAM Leafy Spurge just delivered an additional 3 million insects to me last week. I tell my neighbors

that within 3–4 years leafy spurge on this ranch will be reduced 70–75%. Where we are standing right now the insects are working and while I am out haying tomorrow the insects will still be working. Biological control for leafy spurge is definitely the way to go”. Roger Myers – June 1999.

“My ranch was overrun with leafy spurge and I had to reduce my cattle numbers to the point where I was nearly forced to sell the ranch and move to town. Then biocontrol and TEAM Leafy Spurge came along. I currently combat leafy spurge with both sheep and flea beetles. Without TEAM Leafy Spurge and biocontrol, I would have been forced to sell the ranch but today my sons have something to live for. In 2–3 years I will not have any leafy spurge on this ranch”. Dale Maus – June 2000.

South Dakota

“The ranchers are feeling better about the options they now have against leafy spurge. TEAM Leafy Spurge has been a big plus for area producers. As of 3–4 years ago we knew nothing about biocontrol. We didn’t know what to do, let alone how to get massive numbers of flea beetles working on the ground. Along with TEAM Leafy Spurge and the Moreau Weed Management Area, we now have more options. TEAM Leafy Spurge has done a remarkable job in getting the word out about those options. People in this area have now contained the spread of leafy spurge and are now seeing the benefits of a biologically-based IPM approach”. Larry Nelson – November 2000.

Montana

“We had sprayed for many years attempting to control leafy spurge with very limited success. Then Neal Spencer brought us some of the brown flea beetles. The flea beetles have reduced the amount of leafy spurge we once had. Since then TEAM Leafy Spurge has given us some of the black flea beetles that appear to be doing very well. There is no doubt the flea beetles are our only chance at getting rid of leafy spurge”. Glen Rugg – June 1999.

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