Revisiting Leafy Spurge Biocontrol: A Case Study

Cost free management for 16 years!

By Ankush Joshi and Denise L. Olson

There are two sites in North Dakota where millions of workers have worked to control leafy spurge for free—for 16 years! These "workers," called *Aphthona* flea beetles, were imported as biological control agents to the United States from Eurasia to manage leafy spurge (*Euphorbia esula* L.) infestations. If released in suitable habitats, *Aphthona* populations rapidly increase to cover the entire populations of leafy spurge. Once established, *Aphthona* beetles provide economic and sustainable control of leafy spurge. This reduces labor, cost, frequency of herbicide application, and their undesirable effects on other plants and animals.

Biocontrol uses one organism to reduce the population of target species considered noxious to tolerable levels. This works well for exotic pests introduced into non-native areas. Insects feeding on such a weed in its native range are explored, identified, tested for their host specificity, and then released in the United States for the control of their host.

Why Control Leafy Spurge?

Leafy spurge is an aggressive weed that quickly spreads across a variety of habitats including rangeland, pasture, and woodlands. Toxic substances released by leafy spurge roots suppress growth of other vegetation[1] with the milky, sticky latex of leafy spurge causing dermatitis in humans and other animals. Eating fresh leafy spurge can cause livestock death[2,3] though cattle and wildlife typically avoid grazing in leafy spurge infested areas. As a result, leafy spurge reduces rangeland carrying capacity and vegetation diversity[4] with some infestations expanding their range exponentially and doubling every 10 years.

Leafy spurge infestation now covers more than 491,000 acres (198,000 ha) in North Dakota and more than 2.7 million acres (1.1 million ha) in the Northern Great Plains. Economic losses are estimated to be US$130 million annually in the Northern Great Plains and $86 million in North Dakota alone.[5,6] In some states, noxious weed laws require that landowners control leafy spurge on their property. Management of leafy spurge using herbicides requires persistent efforts that can be expensive, while biocontrol offers a safe, economic, and practical alternative for many areas.

History of Biocontrol Introductions

Biological control efforts were expanded in North Dakota in the mid-1980s[7] (Table 1). The stem-boring beetle (*Oberea erythrocephala*), the hawk moth (*Hyles euphorbiae*), and the gall midge (*Spurgia esulae*) are established at low population levels throughout the state.[8] In addition, four *Aphthona* species are also established in North Dakota. *Aphthona flava* is established but shows a slow population increase.[7] *A. nigriscutis* was originally the most successful biocontrol agent;[9] however, a mixed population of black beetles, *A. czwalinae* and *A. lacertosa*, reproduced and expanded rapidly in the mid-1990s and became the most successful *Aphthona* species in reducing the leafy spurge.[9,10]

Successful establishment of *Aphthona* is variable along with its effectiveness in controlling leafy spurge across variable habitats in North Dakota.[7,9,11] Temperature, moisture, soil type, ground cover, slope, and/or associated vegetation at release sites affects flea beetle survival and establishment[10,12] with different *Aphthona* species exhibiting differing preferences to these factors.[13] Post-establishment monitoring is an important aspect of classical biological control. However, limited quantitative post-establishment data are available, especially, for *Aphthona* spp.

Success Story of the Flea Beetles

Biological control agents for leafy spurge management have been released at several locations in North Dakota; however, the earliest records of successful introduction of flea beetles were reported from two sites in southeastern North Dakota where leafy spurge infestations were >200 stems per 1.1 square yard (stems/m^2) in 1989.[10] *Aphthona* beetles of different types, in the range of 80–1,000 individuals, were released on these two sites, Katie Olson Wildlife Management Area and private rangeland near Valley City, North Dakota.[10,14] Within 8 years following their introduction there was a 40-fold reduction in leafy spurge stands that

Table 1. Insect species used for the biocontrol of leafy spurge in the northern Great Plains of North America with release date and impact on leafy spurge

Common name	Scientific name	Release year	Impact on leafy spurge
Flea beetles	*Aphthona flava*	1986	Larvae of the beetle feed on roots, adults feed on leaves of the leafy spurge. *A. cyparassiae* and *A. abdominalis* have not recovered in North Dakota.
	A. cyparassiae	1986	
	A. lacertosa	1988	
	A. czwalinae	1988	
	A. nigriscutis	1989	
	A. abdominalis	1993	
Hawk moth	*Hyles euphorbia*	1965	Larvae feed on leaves and flowers. Very low establishment in the region.
Gall midge	*Spurgia esuale*	1986	Larvae feeds on terminal leaves and flower buds causing galls. Defoliation doesn't stop vegetative growth of leafy spurge.
Stem- and root-boring beetle	*Oberea erythrocephala*	1988	Larvae tunnels down the stem in to roots; adults feed on leaves and flowers. It has low reproductive potential.

co-occurred with an impressive growth in the *Aphthona* populations at these sites.[10] Over 32 million *Aphthona* beetles were harvested from these sites and were distributed to other regions in the United States and Canada.[9] Eight years after the successful reduction of their host plant, these two release sites in southeastern North Dakota are providing an excellent opportunity to evaluate long-term biological control of leafy spurge and population dynamics of the *Aphthona*.

A Case Study: How Long is Leafy Spurge Biocontrol Effective?

We designed a study to determine whether leafy spurge biocontrol by *Aphthona* beetle remains effective 16 years later. We monitored the Katie Olson Wildlife Management Area and the private rangeland where *Aphthona* were released during the 1980s in 2002–2004. This region is a part of the Sheyenne River drainage system within the northern mixed prairie that has a sub-humid continental climate. Long-term average precipitation at Valley City, the town nearest the study sites, was 18.9 inches, and approximately 75% was received from April to September.

Aphthona and leafy spurge populations were monitored in four habitats: high-prairie, mid-prairie, tree, and wetland. High-prairie habitats are convex hilltops where uppermost slopes lose most of their precipitation as runoff.[15] The mid-prairie includes mid-slopes where the water loss and gain to runoff are similar. A wetland is a combination of low prairie, marshes, and wetland, with sluggish drainage that retains gravitational water through out the summer period.[15] *Aphthona* beetles were monitored in order to determine their population level and their habitat preferences 16 years after their release. At both locations the level of leafy spurge control was evaluated using 21.9-square-yard (20-m^2) transects replicated five times in each habitat (Table 2).

Associated Vegetation

At both study sites, Kentucky bluegrass was typically present in all habitats. More vegetation diversity was observed in the mid-prairie habitat. Buckbrush, snowberry (*Symphoricarpos occidentalis*), wild raspberry (*Rubus idaeus*), milkweed (*Asclepias viridiflora*), Canada thistle (*Cirsium arvense*), poison ivy (*Rhus radicans*), curlycup gumweed (*Grindelia squarrosa*), needle-and-thread (*Hesperostipa comata*), and needlegrass (*Stipa viridula*) were common in mid-prairie habitats. Perennial woody plants such as cottonwood (*Populus deltoides*), green ash (*Fraxinus pennsylvanica*), bur oak (*Quercus macrocarpa*), and boxelder (*Acer negundo*) were observed in tree habitats. Cattail (*Typha* spp.), prairie cordgrass (*Spartina pectinata*), rushes (*Juncus* spp.), and sedges (*Carex* spp.) were observed in wetland habitats.[16]

Findings: 16 Years and Counting

Aphthona beetles had been released at the Wildlife Management Area and the private rangeland sites during the mid-1980s. Greater than 95% leafy spurge control was achieved by these biological control agents in 1994 and continued 10 years later.

Over the 3-year study period, leafy spurge infestations and flea beetle populations were sustained at low levels (<1 stem per 1.1 square yard, and <1 beetle/soil core, respectively) with no change among the years. During each

Table 2. Methods used to determine the effectiveness of *Aphthona* beetles as a biocontrol of leafy spurge 16 years after their introduction

Data collection	Data were collected for leafy spurge and *Aphthona* flea beetles in each plot for three years
Aphthona	• During mid-May, when flea beetles are in their pupal stage, three soil cores were taken randomly over leafy spurge cane (the previous year's leafy spurge) from each treatment plot (21.9 square yards) using a golf-cup cutter (4-inch diameter x 6-inch depth). • Soil cores were inserted into individual paper containers and taken to the laboratory. An inverted funnel with a collection trap attached to its spout was placed over individual cylinders. The laboratory was maintained at 71.6 ± 1.8°F (22 ± 1°C) and 24:0 hours L:D photoperiod. • Emergence traps were monitored daily and number of flea beetles collected were recorded and removed. • A standard insect sweep net was used to randomly sweep a 1.1-square-yard area for flea beetles in each experimental plot beginning in early June and continuing weekly until mid-August.[16]
Leafy spurge	• Leafy spurge stem counts in five randomly selected quadrats (1.1 square yard) were taken during late May. • As an indicator of *Aphthona* larval activity and leafy-spurge root reserve, root dry weights were measured. • Three soil cores, as previously described, were randomly taken over the leafy spurge stems in mid- to late October of each year to record root dry weight after 30 days of drying at room temperature.
Data analyses	• Very low densities of the flea beetles and leafy spurge in experimental plots, and lack of distribution normality of the subject population, required use of non-parametric Kruskal-Wallis test for data analysis. • Treatment means were compared using Fisher's protected least significant difference procedure at $P \leq 0.05$.

study year, emergence of *Aphthona* beetles from soil cores and sweep counts were low and occurred mainly in the high prairie and the middle prairie (Table 3). Populations at both sites were generally lower than observed by Jordan in 1998.[14] Stem and root data for leafy spurge were greater in high-prairie and mid-prairie habitats. Leafy spurge was hardly seen in tree and wetland habitats (Table 4). This reduced level of leafy spurge stems to <5 per 1.1 square yard should favor increased forage production sustaining cattle and wildlife populations.

Near absence of leafy spurge in tree and wetland habitats explains absence of *Aphthona* beetles in those habitats. Gradients of temperature, moisture, light, and soil nutrients associated with different habitat types may be important factors that determine density and spread of leafy spurge infestations. Shade and competition from trees in tree habitat, competition of brush and grasses in the mid-prairie habitat, and high moisture in wetland habitat may be limiting factors as well. Analysis showed soil concentrations of potassium and magnesium in tree and wetland habitats. Studying association of leafy spurge with level of soil nutrients may provide further clues to its management.[17]

Original success of *A. nigriscuti*[9] and later increase in the *A. czwalinae* population in North Dakota[9,10] was surpassed by *A. lacertosa* populations in the study region,[14] and observation supported by our study in which more than 90% of the beetle populations were *A. lacertosa*. *A. lacertosa* is tolerant to a range of soil textures and moistures and has a broader ecological range.[17] Habitat conditions at the Wildlife Management Area and private rangeland may not be suitable for all *Aphthona* species or *A. lacertosa* may have competitively excluded other *Aphthona* species. *A. flava*, *A. cyparissiae,* or *A. abdominalis* were not recovered at the study sites.

Although the long-horned stem beetle, the root-boring beetle, and the leafy spurge hawk moth were released in southeastern North Dakota, these two species were not observed at the study sites. The leafy spurge gall midge was also released in the region but was rarely seen thereafter.

Competition and toxic effects of leafy spurge on associated plant species are a concern, for reasons that include a reduction in plant diversity.[1] However, competition from cool season grasses (i.e., Kentucky bluegrass) and the *Aphthona* beetles should keep leafy spurge infestations at low levels at these sites.[10] More vegetation diversity was observed in mid-prairie and high-prairie habitats at the Wildlife Management Area and range pasture. Leafy spurge was reduced to acceptable levels, allowing greater plant diversity and forage production in these habitats.

Summary

The rate of *Aphthona* beetle establishment and their impact on leafy spurge are variable across habitat types. During the 3-year study period at the Wildlife Management Area,

Table 3. Number of *Aphthona* spp. individuals in four habitats at study sites in southeastern North Dakota, 16 years after their introduction

Habitat	2002		2003		2004	
	Soil core	Sweep counts per 1.1 square yard	Soil core	Sweep counts per 1.1 square yard	Soil core	Sweep counts per square yard
Wildlife Management Area						
High-prairie	0.6	0.4	0.5	1.4	0.8	2.4
Mid-prairie	0.3	0.1	0.5	1.3	1.0	1.0
Tree	0.0	0.1	0.0	0.1	0.0	0.0
Wetland	0.0	0.1	0.3	0.3	0.0	0.1
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS
Private rangeland						
High-prairie	0.4	0.3b	0.0	2.9ab	0.3	2.2b
Mid-prairie	0.3	5.0a	0.5	7.1a	1.3	8.6a
Tree	0.2	0.0b	0.3	0.0b	0.0	0.0b
Wetland	0.9	0.4b	0.1	1.4b	0.0	1.8b
$LSD_{(0.05)}$	NS	1.1	NS	2.3	NS	1.5

Aphthona lacertosa constituted >90% of flea beetle populations.
Means within a column followed by different letters are significantly different at $P \leq 0.05$. LSD indicates least significant difference; NS, not significant.

Table 4. Change in leafy spurge stem and root counts in four habitats at study sites in southeastern North Dakota, 16 years after their introduction

Habitat	2002		2003		2004	
	Stem count per 1.1 square yard	Root dry wt (g)	Stem count per 1.1 square yard	Root dry wt (g)	Stem count per 1.1 square yard	Root dry wt (g)
Wildlife Management Area						
High-prairie	0.8	1.3	1.1a	0.8a	1.4a	0.8a
Mid-prairie	1.2	0.6	1.0a	0.7ab	0.7ab	0.5ab
Tree	0.1	0.1	0.0b	0.0c	0.0b	0.0b
Wetland	0.1	0.0	0.3ab	0.0c	0.0b	0.0b
$LSD_{(0.05)}$	NS	NS	0.5	0.3	0.6	0.2
Private rangeland						
High-prairie	1.1b	0.3	1.4b	0.8	5.4ab	0.3
Mid-prairie	9.3a	0.4	5.3a	0.9	8.8a	0.5
Tree	0.0b	0.0	0.0b	0.0	0.0b	0.0
Wetland	0.7b	1.1	0.0b	1.0	1.2b	1.2
$LSD_{(0.05)}$	2.4	NS	1.1	NS	3.0	NS

Means within a column followed by different letters are significantly different at $P \leq 0.05$. LSD indicates least significant difference; NS, not significant.

Aphthona beetle populations were almost non-existent in the tree and wetland habitats, with <1 beetle/soil core in high-prairie and mid-prairie habitats. Similarly, leafy spurge stem counts were <1 stem per 1.1 square yard at the Wildlife Management Area, and there was a similar result on the other introduction site. *Aphthona lacertosa* constituted >90% of flea beetle populations across the study habitats at both study sites. Monitoring *Aphthona* beetle and the leafy spurge infestations during 2002 to 2004 in southeastern North Dakota reveals continued success of biological control 16 years after the initial release of these biological control agents.

Implications

Selecting the right biological control agent and introducing them to suitable habitats is the key to leafy spurge management. *Aphthona* beetles combined with competition from other vegetation is controlling leafy spurge populations at these sites in North Dakota. *Aphthona* beetles biocontrol reduces the need for costly and labor intensive herbicide applications. It may also help to restore vegetation diversity and forage production of the rangeland.[17]

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