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Host specificity and establishment of *Aphthona flava* Guill., (Chrysomelidae), a biological control agent for leafy spurge (*Euphorbia esula* L.) in the United States

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Abstract:

The potential host plant range of the European flea beetle *Aphthona flava*, a candidate biological control agent for leafy spurge, *E. esula*, was evaluated. Fewer than 19 (none of which are rare or legally protected) of the 113 *Euphorbia* species native to the U.S. appear to be potential host plants for *A. flava*. Releases of *A. flava* were made in Montana (1985-1987), North Dakota (1985) and Idaho (1986). Establishment occurred in four of the eight Montana sites, and at the North Dakota site. *Aphthona flava*, which increased to 31 beetles/m^2 at one Montana site in 1988, is part of a complex of insects being introduced in an attempt to control leafy spurge, a serious weed of Great Plains rangelands.

Keywords:

Biological control of weeds, flea beetle, Great Plains, rangeland, weed.

Leafy spurge (*Euphorbia esula* L.) is a deep-rooted perennial herb native to Europe and Asia, which has become one of the most serious weeds of rangelands in the Great Plains region of North America (Lacey et al. 1985, Watson 1985). Cattle, one of the primary products of the Great Plains, will neither eat the plant nor much of the palatable forage growing near it (Messersmith and Lym 1983). Chemical control is usually not economical on the low value land that leafy spurge infests. For this reason, and since leafy spurge was not known to be a problem in its native Eurasian range, a biological control program was begun in the early 1960s by Agriculture Canada (Harris 1984).

The USDA's Agricultural Research Service joined the effort to discover, test and introduce insects of spurge in the mid 1970s (Pemberton 1985). These programs have resulted in the introduction of the following complex of European *Euphorbia* feeding insects to the United States: a foliage and flower feeding moth (*Hyles euphorbiae* L., Sphingidae), a root feeding moth (*Chamaesphecia tenthrediniformis* (Den. and Schif.), *Aegeriidae*), a stem boring beetle (*Oberea erythrocephala* Schrank), Cerambycidae), a shoot-tip gall midge *Spurgia capitigena* Gagné, Cecidomyidae) and four root feeding flea beetles *Aphthona flava* Guill., *A. cyparissiae* (Koch), *A. czwalinae* Weise and *A. nigriscutis* Foudras (Chrysomelidae) (Pemberton 1985, Rees et al.1986, Pemberton and Rees, unpublished data).

Aphthona flava is one of a complex of 40 *Aphthona* spp. recorded to feed on *Euphorbia* spp. in Europe (Harris et al. 1985) and Asia (Pemberton and Wang 1989). Like other *Aphthona* species that feed on *Euphorbia* species, the adults of *A. flava* feed on leaves and flower bracts, and the larvae feed upon the root hairs and roots. *A. flava* has one generation per year. The adults usually emerge in June, feed and lay eggs for several months before dying. The mature larvae overwinter and pupate in late spring or early summer. This flea beetle is native to Europe, from northern Italy, east and north through Yugoslavia, Hungary, Czechoslovakia, Bulgaria, Rumania and Russia (Sommer and Maw 1982). It has been recorded from *Euphorbia cyparissias* L., *E. esula* L., *E. seguieriana* Necker and *E. pannonica* Host. (Kuntze 1930, Sommer and Maw 1982, Harris et al. 1985).

Aphthona flava was evaluated as a candidate biological control agent for leafy spurge by Sommer and Maw (1982), who found that the beetle's potential host range would be limited to species of *Euphorbia*. Based on these data, *A.flava* was introduced to Alberta and Saskatchewan, Canada (McClay and Harris 1984). Before *A. flava* could be introduced into the United States, additional host specificity testing was needed to better define the beetle's potential host range within the genus *Euphorbia*.

Host specificity testing

The United States has 113 native species of *Euphorbia* (sensu lato), including two rare species (*E. garberi* Engelm. ex Chapm. and *E. deltoidea* Engelm. ex. Chapm.) that are legally protected and nine other rare species that are under review for protected status (U.S. Dept. Agric. 1982, U.S. Dept. Inter. 1980 and 1983, Pemberton 1985). It is not possible to predict from the European host plant records which of these North American *Euphorbia* species could become host plants of *A. flava*, because most American *Euphorbia* species belong to subgenera (*Agaloma* and *Chamaesyce*) that are not represented in the European flora. *Aphthona flava*, from *E. esula* near Pisa, Italy, was tested against ten North American *Euphorbia* species in the USDA-ARS quarantine in Albany, California, during 1984 and 1985 (Pemberton, unpublished data). The *Euphorbia* species used in the testing included representatives of the subgenera that occur in North America[1] and species that are rare, weedy, ornamental, or sympatric with leafy spurge.

[1] No species of the small subgenus *Poinsettia* (3 U.S. species) were used, since the two species tested by Sommer and Maw (1982) did not support development.

Host plant suitability was studied by placing adult beetles with test plant bouquets or potted plants to measure adult feeding and longevity; and by transferring eggs or first instar larvae to potted test plants to see which plants could support full larval development (to the third instar).

Table 1 summarizes the results of these studies. None of the tested members of the subgenera *Chamaesyce* (3 of the 57 U.S. species) or *Agaloma* (2 of the 26 U.S. species) were suitable hosts by any of the criteria measured. All six tested species of the subgenus *Esula* (21 U.S. species) were accepted as adult food. Three of these (*E. incisa* Engelm., *E. robusta* (Engelm.) Small and *E. palmeri* Engelm.) supported adult longevity for more than two months. These three species and *E. spatulata* Lam. supported full larval development. Significantly, neither *E. purpurea* (Raf.) Fernald or *E. telephiodes* Chapm., both rare subgenus *Esula* species under review for protected status, appeared to be suitable hosts, since no larval development took place on these plants.

Table 1. Summary of *Aphthona flava* host plant specificity testing on native North American *Euphorbia* species[a].

Test Plant Species	Subgenus	% of Plants Accepted for Adult Feeding	% of Adults Living 2 Months or Longer	% or Plants Supporting Larval 3rd Instar
Euphoria esula	*Esula*	100 (10/10)	86 (19/20)	90 (27/30)
Euphorbia incisa	*Esula*	100 (10/10)	63 (10/16)	90 (9/10)
Euphorbia palmeri	*Esula*	80 (8/10)	53 (8/15)	88 (7/8)
Euphorbia robusta	*Esula*	80 (8/10)	63 (10/16)	80 (8/10)
Euphorbia spatulata	*Esula*	–	5 (1/20)	20 (2/10)[d]
Euphorbia purpurea[b]	*Esula*	30 (3/10)	0 (0/16)	0 (0/10)
Euphorbia telephiodes[b]	*Esula*	60 (6/10)	0 (0/16)	0 (0/10)
Euphorbia maculata	*Chamaesyce*	0 (0/10)	0 (0/16)	0 (0/10)
Euphorbia supina	*Chamaesyce*	0 (0/10)	0 (0/16)	0 (0/10)
Euphorbia serpyllifolia	*Chamaesyce*	0 (0/10)	0 (0/16)	0 (0/10)
Euphorbia corollata	*Agaloma*	10 (10/10)	0 (0/16)	0
Euphorbia marginata[c]	*Agaloma*	0	0	0
Euphorbia heterophylla[c]	*Poinsettia*	0	0	0

[a]From Pemberton unpublished data 1984-85.
[b]Rare species.
[c]Tested by Sommer and Maw 1982.
[d]Many small plants were in each pot, single plants arc probably too small to support larval development.

From these data, we predict that some portion of the remaining 19 subgenus *Esula* species could be potential host plants for *A. flava*, if the beetles were to spread through the United States. If *A. flava* becomes established throughout the North American range of leafy spurge, eight subgenus *Esula* species, which are roughly sympatric with leafy spurge, might become host plants for the beetle. The most sympatric of these is *E. robusta*, a Rocky Mountain species (U.S. Dept. Agric. 1982), which was an acceptable laboratory host plant in the testing. *Euphorbia incisa* and *E. palmeri*, which were also acceptable laboratory hosts, are southwestern species (U.S. Dept. Agric. 1982) that may have some contact with leafy spurge in Nevada or northern Arizona. The other acceptable laboratory host plant, *E. spatulata*, is a small annual that ranges throughout much of the United States (U.S. Dept Agric. 1982). Larval development of *A. flava* occurred in 20%

of the pots densely planted with *E. spatulata*; single plants may be too small to support complete larval development. The other sympatric species are: *E. brachycera* Engelm., a Southwestern perennial, and three annuals: *E. commutata* Engelm. from the east and south central U.S., *E. lurida* Engelm. from the northeast, and *E. crenulata* Engelm. of the Pacific states.

Since relatively few of the 113 Euphorbia species native to the U.S. appeared to be potential hosts of *A. flava*, a petition (Pemberton unpubl. report) for its release was made to the Federal Working Group of Biological Control of Weeds. Approval for release was received in 1985 and releases began the same year.

Release and establishment

All *A. flava* beetles intended for release were collected from leafy spurge populations in the Pisa area of northern Italy by M. Stazi and M. Cristofaro (U.S. Dept. Agric.-ARS Biological Control Laboratory, Rome). Each collection was sent to the U.S. Dept. Agric.-ARS Biological Control of Weeds Quarantine in Albany, California. In the quarantine, a small number (usually ca. 5%) of the beetles were killed and sent to Consulting Diagnostic Service (Berkeley, Calif.) to check for internal pathogens. None were found. A small number of specimens were also sent to R. White (U.S. Dept. Agric.-ARS U.S. National Museum, Washington) to confirm their identity. The remaining beetles were paired and placed on bouquets of leafy spurge to observe feeding and record oviposition. Beetles that fed and laid eggs normally were sent to the field for release.

There was a very high mortality (80-95%) experienced by overwintering larvae in laboratory cultures, which significantly reduced the number of beetles for field colonization. Consequently foreign field collected beetles, instead of laboratory reared material, were released. Since no parasites or pathogens had been found in Italian *A. flava* populations (although many are known from other areas (Sommer and Maw 1982)), release of field collected material from this area appeared to have few risks, and seemed justified to try to establish the beetle in the U.S. Direct release of foreign collected material in the U.S., as a normal mode of operation, is unwise, since pathogens and parasites, which could negate successful biological control programs, could easily be introduced. In 1988, after the releases of *A. flava* from Italy reported here were completed, a pathogenic microsporidian, *Nosemna* sp., and a lethal parasitic mite, *Trombidium susteri* Feider, were found to be associated with *Aphthona* spp. collections, originating from Austria, that were intended for release in the U.S. (G. Johnson, El Cerrito, Calif., pers. comm.).

Aphthona flava was released in Montana from 1985 to 1987, and in North Dakota and Idaho in 1986 (Table 2). The seven Montana releases, cast of the Continental Divide, were made by the authors (primarily NER) assisted by N. Poritz. The Glacier Park release was made by D. Lang (National Park Service, West Glacier). All of the Montana sites had dense infestations of leafy spurge, estimated to constitute more than 50% of the above ground dry weight annual plant production.

Table2. Releases and Establishment of *Aphthona flava.*

Site	Number Released	Date	Number of Adults Recovered	Date
Montana[a]				
North Bozeman (Gallatin Co.)	59	16 July 1985	no recovery (site sprayed 1986)	
Reed Point (Stillwater Co.)	50	31 July 1985	2	9 June 1987
			2	10 June 1988
Columbus Island (Sweetgrass Co.)	57	31 July 1985	1	9 June 1987
Glacier National Park (Flathead Co.)	150	2 Aug 1985	no recovery to date	
Gallatin River (Gallatin Co.)	46	4 Aug 1985	no recovery to date	
Lyman Creek-Shade (Gallatin Co.)	106	25 June 1986	× 31/m^2	4 Aug 1988
Clyde Park (Park Co.)	240	10 July 1986	no recovery to date	
Lyman Creek-Sun (Gallatin Co.)	2077 in 6 releases	9 July-6 Aug 1987	51/278 sweeps	22 July 1988
Idaho[b]				
Featherville (Elmore Co.)	200	8 July 1986	no recovery to date	
Rathdrum (Kootenai Co.)	210	24 July 1986	no recovery to date	
North Dakota[c]				
Bald Hill Dam (Barnes Co.)	260 in 2 releases	11-23 July 1986	× 7.5/m^2	July-Aug 1987
			× 14/m^2	July-Aug 1988

[a]Montana releases made primarily be N. Rees; and R. Pemberton.
[b]Idaho releases made by J. McCaffrey, University of Idaho at Moscow.
[c]North Dakota release made by R. Carlson, North Dakota State University at Fargo.

Brief descriptions of the Montana sites are as follows: The North Bozeman site (altitude ca. 1600 m) is 3.2 km northeast of Bozeman and south of the Bridger Mountains in Gallatin County. It consists of an open, south-facing slope cut by a shallow valley, which in addition to dense leafy spurge, had *Rosa* sp., and mixed annual grasses. This site had a history of herbicide spraying (Tordon and 2,4-D ester) for leafy spurge control and was, unfortunately, sprayed in 1986, the year following the release.

The Reed Point site (altitude ca. 1200 m) is 9.3 km cast of Reed Point in Stillwater County. The spurge infestation is on the south bank of the Yellowstone River, between the river and highway I-90. The site is a level terrace that has been used as a cattle pasture. The vegetation, except for *Salix* along the river, was weedy, including *Iva xanthifolia* Pursh. and *Asclepias speciosa* Torr., in addition to the leafy spurge. Part of the site was plowed in 1986, the year after the release.

The Columbus Island Site (altitude ca. 1100 m) is a rock and sand island, of ca. 2 hectares, in the Yellowstone River adjacent to the town of Columbus in Sweetgrass County. The dominant plants are *Populus deltoides* Marsh, *Salix* and *Rosa* spp. The leafy spurge

density was 48 stems/m^2 in 1983. Goats have been used extensively at this site in an attempt to control leafy spurge.

The Gallatin River site (altitude ca. 1600 m) is 9.6 km east of Bozeman in Gallatin County. The site lies on the east side of the Gallatin River and is dominated by *Populus angustifolia* James, leafy spurge and the exotic tansy (*Tanacetum vulgare* L.). Leafy spurge had a density of 129 stems/m^2 in 1987. The site has had periodic grazing.

The Glacier Park site (altitude ca. 980 m) is located at Big Prairie on the east bank of the Flathead River in the western sector of the Park. In addition to large growths of spurge, this natural prairie has a mixture of small herbs and grasses with patches of introduced *Linaria vulgaris* L. The site had been plowed historically, but has been free of agriculture for many years. The Park Service has used mowing, burning, and a limited amount of plowing to try to control the leafy spurge at this site.

The Lyman Creek Shade site (altitude ca. 1600 m) is located on the northern bank of Lyman Creek on the southern slopes of the Bridger Mountains ca. 8 km north of Bozeman in Gallatin County. Leafy spurge grows in a 50 m^2 opening, surrounded by Douglas fir (*Pseudotsuga menziesii* (Mirbel Franco), Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) and *Prunus virginiana* L. Both Lyman Creek sites are on the City of Bozeman Water Company land and have had no grazing or chemical use for many years.

The Clyde Park (altitude ca. 1600 m) is 5.6 km northeast of Clyde Park and south of the Crazy Mountains in Park County. The site consists of a level pasture, with *Artemisia* spp., *Lupinus* sp. and some grass, and a 30 m long 45 degrees slope running from the pasture to a *Populus trichocarpa* T. & G. dominated riparian community. The beetles were released on the slope, which was densely covered by leafy spurge. The site, particularly the level portion, has been grazed and treated with herbicides to try to control leafy spurge.

The Lyman Creek Sun site is an open, south-facing hillside located ca. 200 m down stream from the Lyman Creek Shade site. The open infested hillside (ca. 1400 m^2) is surrounded by Douglas fir and aspen (*Populus tremuloides* Michx.). On the hillside are *Geranium viscosissimum* Fish. & Mey. and species *of Equisetum, Balsamorhiza, Artemisia, Rosa* and *Symphoricarpos*. In 1988, leafy spurge accounted for 77.5% (SD ± 21.8) of the above ground dry weight plant biomass on the hillside. The $\bar{x}$ leafy spurge density was 216.5 g/m^2 (SD ± 99.42).

The North Dakota release was made by R. Carlson assisted by D. Mundal, North Dakota State University at Fargo. The release site is at Bald Hill Dam in Barnes County. The site is adjacent to the reservoir and has zones of prairie and woodland consisting of planted shelterbelt. The leafy spurge density was 133.4 stems/m^2 in 1986.

The Idaho releases were made by J. McCaffrey of the University of Idaho at Moscow. The Rathdrum site (altitude ca. 760 m) is located in Kootenai County in northern Idaho. Leafy spurge accounted for more than 50% of the annual production at this site, which in addition to spurge, had mixed annual grasses.

The Featherville site (altitude ca. 1500 m) is in Elmore County in southern Idaho. The site is a disturbed sagebrush-grass community with an estimated spurge density of 50 stems/m^2 in about a one hectare infestation.

The Montana releases at North Bozeman, Reed Point, Columbus and Lyman Creek Shade were made in 3 m × 3 m plastic screen cages to concentrate the beetles and possibly aid their establishment. The remaining Montana releases were made in the open. The Idaho releases were made within one m^2 cages and in the open near the cages at both sites. The North Dakota release was made in four 3.3 m^2 cages. The number of *A. flava* released ranged from 50 to 260 beetles per site, except at the 1987 Lyman Creek Sun site release, where a major collection effort resulted in 6 releases totaling 2077 beetles. This "mass" collection and release was done to learn if releasing large numbers could promote better establishment and rapid numerical increase in *A. flava* populations after establishment.

Aphthona flava established at four of the eight Montana sites and at the single North Dakota site. No recoveries have been made to date at the Idaho sites. The best Montana establishment was at the Lyman Creek Shade site where a mark and recapture study (following unpublished techniques used by A. McClay, Vegreville, Alberta) estimated an *A. flava* population of 31/m^2 adults. A visual search and count of *A. flava* adults at the North Dakota site yielded 14/m^2 in 1988 (R. Carlson, pers. comm.) Beetles at the Reed Point and the Columbus, Montana sites were not recovered the year following release (1986), but were found in low numbers two years after release (1987). Establishment of *A. flava* was obtained with the release of only 50, 57 and 106 beetles per site. In Montana, releases made in cages resulted in establishment at three of four sites. The cage release at the North Bozeman site may have failed because of the spraying of herbicides at the site the year following release. The mass release at the Lyman Creek Sun site was the only one of four open releases in Montana that produced an establishment. Good establishment was obtained in North Dakota where cages were used but no recovery of *A. flava* has been made in Idaho where both open and cage releases were made.

There is no apparent pattern relating establishment of *A. flava* to known site characteristics or release dates.

Identification and distinguishing features

Aphthona flava is completely orange, has no elytral sculpturing and is large (3-4 mm) for a flea beetle. The only North America flea beetles recorded from *Euphorbia* species are *Glyptina* species. *Glyptina spuria* LeConte has been collected from *E. maculata* L., and *E. blodgettii* Engelm. ex A. Hitchc. from the east and southeastern U.S. (Wheeler 1981). *Glyptina cyanipennis* Crotch is recorded from *E. cyathophora* Murray in Florida (Schwarz 1890) and *G. atriventris* Horn adults have been found on flowers of leafy spurge in North Dakota (Julian 1984). All of these *Glyptina* species are small (≤3 mm), have regular rows of punctures on the elytra and are darkly colored (Arnett 1968). The other *Aphthona* species that have been introduced against leafy spurge are smaller (2-3 mm) and black (*A. czwalinae* Weise) or brown (*A. cyparissiae* (Koch) and *A. nigriscutis* Foudras).

Conclusion

The ability of *A. flava* to control leafy spurge has not yet been established. The beetle has not had time to increase its populations to the point where they may begin to stress the plants. We think that the utility of *A. flava* will be as part of a complex of natural enemies, stressing different parts of the plant and in different areas of the weed's range, that may eventually control leafy spurge.

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