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Published by: Westview Press, Boulder, CO.

Biological control of leafy spurge – Noxious range weeds: Chapter 17

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Abstract:

Leafy spurge (*Euphorbia esula*) is an aggressive, perennial weed of the northern United States and southern Canada which reproduces by seeds and vegetative root buds. Dense stands of leafy spurge replace grasses and forbs and restrict cattle grazing on rangeland. Eight Eurasian insect species which attack leafy spurge are currently approved for release and have become established in the United States. Eight additional insect species are in various stages of United States clearance procedures. A total of twelve insect species have been approved for release in Canada and many are established there. In 1990, a large scale five-state research project was started to determine methods for establishment, population increase and assessment of impact of the flea beetle, *Aphthona nigriscutis* (Coleoptera: Chrysomelidae) on leafy spurge.

Introduction

Leafy spurge is an aggressive, persistent, deep-rooted perennial plant of Eurasian origin that has become dominant on rangelands and pastures, displacing useful forage plants in North America. First reported in the United States in 1827, leafy spurge now extends throughout much of southern Canada and the northern United States (1-3). Leafy spurge produces a milky latex that is poisonous to some animals and can cause blisters and irritation on contacted skin, and similar results to the digestive tract when ingested by man and some animals. In cattle, it causes scours and weakness, and in larger ingested amounts, can cause death (4,5). Cattle usually refuse leafy spurge as food unless it is given to them in weedy hay or when better forage is not available.

Leafy spurge reproduces both by vegetative regrowth and the production of large quantities of seeds which are often distributed by birds, wildlife, man, water, etc. (6,7). Leafy spurge plants are able to maintain high root reserves through an extensive root system, ranging from a massive network of small roots near the soil surface to deep penetrating tap roots. This ability to maintain high root reserves permits the plant to recover quickly from physical and most chemical damage (8,9).

A conservative estimate of loss in the United States, in terms of expenditures for controlling leafy spurge and loss of productivity, was given by Noble *et al*. in 1979 as $10.5

million annually (10). Derscheid and Wrage report that the problem is most severe on undisturbed lands, but on cultivated cropland areas, it can reduce crop yields from 10-100% (11). Thompson *et al*. recently concluded that in North Dakota, 405 thousand hectares of leafy spurge had depreciated land values by $137 million and had a total economic impact of $105 million in that state for 1989 (12).

In Europe, there are 105 native *Euphorbia* species which belong to the subgenus *Esula*, the group to which the target leafy spurge belongs. An additional four species belong to the subgenus *Chamaesyce*. In North America, 21 native species belong to the subgenus *Esula*, 26 species belong to the subgenus *Agaloma*, 3 species to *Poinsettia* and 57 species to *Chamaesyce*. Two species (*E. garberi* and *E. deltoides*), belonging to the subgenus *Chamaesyce*, currently have federal protection under the endangered or threatened species act[1] (13-16).

The taxonomic status of the introduced North American leafy spurge complex is in a state of confusion. Whereas Ratcliffe-Smith lists 79 different species, crosses, and hybrids in Europe (17), some believe that the leafy spurge complex in the United States is one species (18). It is difficult to believe that only one spurge species was introduced into the United States from Eurasia. Either way, more perplexity is added when one considers that this weed may have been introduced from multiple sources throughout Eurasia (19,20). These conditions must all be considered, therefore, when biocontrol agents are being selected for introduction into North America (21).

Established biocontrol agents

Since leafy spurge reproduces by both seed and vegetative regrowth, and can maintain high root reserves, eventual management programs against leafy spurge must utilize an assortment of biotic agents which are able to concentrate their action at various, distinct locations on the plant, (e.g. root hairs, roots, crown, stems, leaves, flowers, and seeds).

Variations in environment, plant communities, soil conditions and structure, ground aspect, host biotypes, etc. can influence the suitability of a biocontrol agent at specific locations. For example, a root-attacking insect that is adapted to dry, sandy soils in open sunlight would do well at one location, while one that is adapted to wet, loamy soils in the shade would do well in another.

Eight insect species, which are host specific to leafy spurge, are currently approved for release in the United States by U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine (USDA/APHIS/PPQ), and are established in the United States. These include a moth that defoliates the plant, a beetle that burrows in the stems and roots, a fly that galls the growing tips of leafy spurge, a clear wing moth whose larvae attack spurge roots, and four species of flea beetles that attack both the foliage of the plant and its roots.

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[1] Pemberton R.W. Petition by Rees, Pemberton, *et al*. to clear *Dasineura* sp. nr. *capsulae* submitted to T.A.G. 1989. (This species has not yet been named.)

Leafy spurge hawk moth, *Hyles euphorbiae* (Lepidoptera:Sphingidae)

Larvae of the leafy spurge hawk moth are defoliators of leafy spurge. There are generally two generations per year, with pupae overwintering in the soil. Adults rest during most of the day but will fly, mate, and lay eggs in the daylight and twilight hours. Eggs are generally deposited on the underside of leafy spurge leaves and resultant dark, hungry larvae hatch and devour the leaves and flower parts. Each instar is somewhat different in color beginning with a dark grey caterpillar and ending in the last larval instar with one which is brightly colored. The bright coloring serves to identify the larvae as being toxic to predators through its sequestering of leafy spurge toxins (22,23).

The hawk moth was first collected in Europe on *E. sequieriana* and cypress spurge (*E. cyparissias*) and was maintained in Canada by Peter Harris in both laboratory and field colonies (24). Insect releases in the United States between 1966 and 1974 were obtained from these colonies. Although initial establishment was documented on leafy spurge near Bozeman, Montana, after a 1966 release, moths from numerous releases at other sites from Canadian stock of the hawk moth were never recovered.

Batra collected third and fourth instar larvae at Braeside, Ontario, Canada, and released them at Chestertown (Warren Co.), New York, on cypress spurge in 1977. The insect established on cypress spurge and one of the hybrids of leafy spurge. The population increased from the original 180 larvae to an estimated 1 million insects within 5 years with total defoliation of spurge in some areas (25).

Hawk moths were collected in 1974 near Debrecen, Hungary, from *E. esula* and *E. virgata*. As a result of the release of the Hungarian insects, four field colonies were established. Moths from these colonies have dispersed over large areas in Montana. Redistribution of insects from the Bozeman and New York field colonies to other states and other locations within Montana was conducted in 1985 under the direction of Robert Nowierski (Montana State University) with the assistance of Steven Hight (presently with the USDA/ARS).

Two factors have reduced the potential of the leafy spurge hawk moth as a biocontrol agent for leafy spurge. First, it is a defoliator of leafy spurge. Defoliation has little impact as sheep and goats defoliate leafy spurge with little reduction in the reproduction of leafy spurge. Second, several colonies of the hawk moth are known to contain a nuclear polyhedrosis virus which was either introduced with it or subsequently infected from other lepidoptera in the United States. Under proper conditions, the virus is an important mortality factor.

Red headed beetle, *Oberea erythrocephala* (Coleoptera:Cerambycidae)

Adults of the red headed longhorn beetle girdle and make hollows in the stems of leafy spurge into which they deposit eggs. Larvae feed first in the stems and then migrate into the crown and roots. Feeding causes major damage to the root reserves of the plant.

There is only one insect generation per year with larvae overwintering in the roots near the crown. Adults are generally first located in the field about the first of July (26).

Releases of the red headed longhorn beetle began in 1982 from material collected near Debrecen, Hungary. Establishment first occurred near Bozeman, Montana, and later at three other locations in the state (27). It also became established in North Dakota at two or three sites (Robert Carlson, personal communication). Although of great importance in countries such as Yugoslavia, populations in Montana have never increased to large numbers. Therefore, adults have not been relocated to new sites in the United States.

Gall midge, *Spurgia esulae* (Diptera:Cecidomyiidae)

Larvae of this gall midge, a delicate small fly, cause terminal leaves of leafy spurge to grow together, forming a gall. The leaf gall becomes a protective niche in which the immature stages of the insect develop. Inner leaves of the gall, which are the apical tip of the stem, eventually die, thus reducing the plant's ability to produce flowers and seeds.

The gall midge has multiple generations per year. Adults generally hide in shaded areas during the day. There they will mate and lay eggs on the terminal spurge leaves. An adult gall midge may live for only 24 to 36 hours. Mass adult emergence is often associated with storm systems which last for four to five days. Mature larvae of the autumn generation overwinter in the soil.

The gall midge was originally thought to be *Bayeria capitigena* when it was screened and much of the life history information on *B. capitigena* from the literature was applied to it. Some differences in the supposed life cycle were detected, requiring new life history studies in Montana. This midge was first released in Montana in 1985 and one site was established in North Dakota by Robert Carlson of NDSU. Three of six Montana releases were established by 1987, but the insect population declined until galls were found only at the original release site in 1989. The size and density at this release site, however, has been increasing each year and is the focus of life history and habit studies. Releases in North Dakota have also been successful (Robert Carlson, personal communication).

Chamaesphecia empiformis (Lepidoptera:Aegeriidae)

Larvae of this clear wing moth attack the roots of leafy spurge. The moth was cleared for introduction into the United States in 1977 to assist in the control of cypress spurge. Although there have been several attempts to establish this species in the western part of the United States, especially in California, Oregon, and Washington, no records of recoveries are known. A second, closely related species, *C. tenthrediniformis*, may have been introduced accidentally, but also is thought not to have established. Although there are numerous species in this genus, each species is extremely narrow in its host range. The host range of *C. empiformis* is restricted to cypress spurge, and *C. tenthrediniformis* is restricted to leafy spurge. A permit was issued to Robert Pemberton (USDA/ARS) in

1985 to work on *C. tenthrediniformis* in quarantine, but none survived on the spurge offered (Jack Coulson, personal comumunication).

Flea beetles, *Aphthona* spp. (Coleoptera:Chrysomelidae)

Flea beetles: black spurge flea beetle, black dot spurge flea beetle, brown dot spurge flea beetle and copper spurge flea beetle.

Adult flea beetles, *Aphthona* spp., feed on leafy spurge leaves and bracts, while the larvae feed on the root hairs and yearling roots. Larval feeding damages the roots and reduces the plant's ability to take up nutrients and moisture. Moderately attacked plants show retarded flowering periods. Canadian releases in the early 1980s have shown that continued pressure by the flea beetles first reduces the average plant height and then, as the insect population increases further, plant density drops to acceptable levels and native vegetation returns (28).

Most *Aphthona* flea beetle species have one generation per year on leafy spurge; adults are present between late June and early September when eggs are laid in the soil near leafy spurge roots. Larvae hatch and immediately begin to feed on leafy spurge roots. As they grow, they move to larger roots where they feed both externally and internally. A portion of the leafy spurge control that has already been documented from flea beetle release sites may be due to the secondary invasion of plant pathogens since they are present in all soils. Mature larvae overwinter in the soil and pupate in late spring or early summer.

Although these four species of flea beetles are similar in action, there are some characteristics which tend to separate them. The black spurge flea beetle (*A. czwalinae*) is totally black in color and resides in areas of higher moisture and relative humidity than are acceptable by the other three species. The copper spurge flea beetle (*A. flava*) is amber colored, while the brown dot spurge flea beetle (*A. cyparissiae*) and the black dot spurge flea beetle (*A. nigriscutis*) are brown and can be separated by a black dot between the forward section of the two elytra on the latter species (29). From work by Peter Harris in Canada, it appears that the black dot flea beetle prefers sandy soils with low humus content, while the brown dot flea beetle does better in higher humus and moisture content soils (Peter Harris, personal communication).

The black spurge flea beetle has not been recovered in Montana from a 1987 release, although several establishments occurred from releases by Robert Carlson (NDSU) and Robert Richard with the USDA/APHIS (Robert Carlson and Robert Richard, personal communications). The copper flea beetle was first released near Bozeman in 1985 and in North Dakota and Idaho in 1986. It established at four of the eight Montana sites and at a single North Dakota site. The brown dot flea beetle was first released in Montana in 1987 and established at two sites. Most 1989 releases of the black dot flea beetle appear to have established in 1990 in Idaho, Montana, Nebraska, and North Dakota.

Additional Canadian releases

Canada has approved 12 insect species for the biological control of leafy spurge. In addition to the agents cleared and released in the United States, Canada has released a clear wing moth (*C. empiformis*), a second clear wing moth (*C. tenthrediniformis*), a leaf tying tortricid moth (*Lobesia euphorbia na*), a geometrid moth (*Minou murinata*), and two gall flies (*Pegomya curticornis* and *P. euphorbiae*).

Biocontrol agents presently being screened in the U.S.

The flea beetle *A. abdominalis* is multivoltine (more than one generation a year). The head and most of the body is reddish-yellow, with the elytra and legs a light, bright yellow. Adults feed on the leaves of leafy spurge as do all the other introduced flea beetles. However, the larvae feed on stem buds of adventitious roots instead of directly on the roots as do the other *Aphthona* species. The USDA/ARS laboratory in Rome, Italy, conducted host specificity testing of this species, and the target date for its release into the United States is the summer of 1991.

Aphthona chinchihi is a flea beetle which was collected in China and is being screened by the USDA/ARS Rome laboratory. It is hoped that testing of this species can also be done at the biological quarantine facility at Bozeman. Target date to complete screening of this species is probably three years away.

A third flea beetle, *A. seriata*, was also collected in China and is under testing at the USDA/ARS Rome laboratory. Once the relationship of *A. seriata* to leafy spurge is established at the overseas lab, and if the data show clear host specificity, a request will be made to import the species into the biological quarantine facility at Bozeman for final testing. Target date to complete screening of this species is probably 1993.

Chamaesphecia crassicornis is a clear winged moth similar to *C. empiformis* and *C. tenthrediniformis*. Research already completed by ARS at their Rome laboratory indicates that this species appears to be restricted to *E. virgata* type leafy spurge. It has one generation a year with emergence occurring from May through July and oviposition thereafter. Eggs are deposited on leafy spurge stems. Hatching larvae migrate down the plant to the crown where they penetrate the plant to feed in the roots. Mature larvae bore upwards to the stem where pupation occurs. Final testing will be conducted at Bozeman with a target release date of summer 1992.

Dasineura sp. nr. *capsulae* is another species of gall fly similar to *S. esula*, except that the gall is an encapsulate gall and the species has only one generation per year. This species is still awaiting a proper name. The petition to introduce this species into the United States was approved last September by the Technical Advisory Group (TAG) of Plant Pest & Quarantine (PPQ), but issuance of permits is awaiting approval of the Environmental Assessment.

Eurytoma euphorbiana is a small wasp that attacks the seeds of leafy spurge. Testing of this species is just beginning and will be conducted at both the Rome and Bozeman quarantine facilities from specimens obtained in the USSR.

Oxicesta geographica is a multivoltine noctuid moth whose larvae defoliate leafy spurge. The early instars are gregarious, with the last two being solitary. Most of the host specificity testing was conducted in Europe and will be concluded in Bozeman this year.

Simyra dentinosa is a univoltine moth whose larvae feed in silk webs on the apex of leafy spurge. There are six instars requiring a total of 30 days, with all instars being hairy. The first instar is yellow and black, the second black, the third to sixth are dark brown with light brown banding. The first four instars are gregarious, while the last two are solitary. Most of the host specificity testing has been done in Europe, but should be concluded in Bozeman this year.

Additional Canadian screening

Aphthona lacertosa is a black flea beetle species, with a light to dark brown hind femur, which separates it from *A. czwalinae* with a black hind femur. Each female can deposit two to three hundred eggs in small groupings under the soil surface near the stem of their hosts, leafy and cypress spurge. Mature larvae overwinter in the roots. In Hungary, this species occurs on a range of mesic-dry to moist sites (28).

Large scale testing of the flea beetle, *Aphthona nigriscutis*

A large scale experiment was begun in 1990 to observe the various conditions which affect the efficiency of the black dot flea beetle to suppress leafy spurge. Whenever possible, seven treatments with nearly matching soil, plant, physical and environmental conditions were established at six sites in five states. Each treatment/check area measured ca 500 m × 100 m, with a 100 m dia. treatment at one end and its equal check at the other. This experiment has the following objectives:

1. To study the efficacy of various numbers and patterns of releases of *Aphthona nigriscutis* as to its effects on populations of the leafy spurge plant, flowering periods, growth patterns, and spurge density.
2. To study the effects and interactions of different associated plant communities on the efficacy of the beetle in suppressing populations of leafy spurge.
3. To study the effects of different leafy spurge densities on the efficacy of the beetle.
4. To study the direct and indirect effects of different soil types and composition on the efficacy of *A. nigriscutis.*
5. To determine factors that affect how fast *A. nigriscutis* populations can increase and expand.
6. To monitor the changes in plant community constituents, density, and biomass production as leafy spurge competition is reduced.

7. To determine the optimum size of release for *A. nigriscutis*. From this information, protocols for the sizes of future release for various *Aphthona* species may be established.
8. To determine the optimum period for releasing adults.
9. To locate detrimental factors for *A. nigriscutis* establishment and population dynamics and to investigate how best to avoid or manipulate such factors.
10. To compare efficiency of sweep sampling of the flea beetle on leafy spurge with D-VAC sampling.
11. To determine effectiveness of the beetle in relation to weather conditions, elevation, site conditions, etc.
12. To investigate the effect of host-plant genetics (biotype) on the efficacy of *A. nigriscutis* against leafy spurge.

This research is being conducted by the USDA/ARS in cooperation with Bureau of Land Management (BLM), U.S. Forest Service (USFS), USDA/APHIS, Resource Conservation and Development (RC&D), Agriculture Canada, and Montana State University (MSU). Six sites were selected in five states, Colorado, Idaho, Montana, Nebraska, and North Dakota.

From three to seven treatments and duplicate checks were randomly assigned at each site, such that topography, vegetation, soil conditions, etc. were similar throughout the study area, and particularly between each treatment and its check. Where possible, a minimum of one kilometer exists between treatments, and 200 to 300 meters separates a treatment and its check. Transects radiate outward from the center in each of eight directions: north, northeast, east, southeast, south, southwest, west, and northwest. Along each transect, marked wooden stakes identify sampling loci along the transect. The stakes begin 8 m from the center spike (the point of insect release in the treatment), and continue outward every 4 m for a total of 40 m. Outer ends and the center are demarcated with railroad spikes imprinted with the treatment/check number and direction of the transect.

Plant composition, canopy cover, spurge plant height, spurge density and number of flowering stems are to be sampled and recorded from each of the 0.1 m^2 north, east, west, and south test loci. The four remaining transects are to be used for clipping samples at each 0.1 m^2 locus. Plant clippings are taken each year by advancing the sample site outward the width of the Daubenmire frame for each previous year sampled, with this year's sample being clipped on the opposite of the line from that of the last.

Conclusion

Since leafy spurge is not considered a problem in its native lands, there is a very strong likelihood that in time, with the proper understanding and the correct combination of biocontrol agents, we can recreate that balance of nature in North America that endures in Eurasia, and ultimately force leafy spurge to take a role as simply a member of the North American plant community rather than as a noxious weed.

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