Impact

CASE Study

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Beetles arrest the leafy spurge scourge in North America

Summary

Leafy spurge (*Euphorbia esula* L.) is an aggressive, deep-rooted perennial of Eurasian origin. First reported in the United States (US) in 1827, by 1933 it had spread through 19 states and was considered a threat to the rangelands in the northern Great Plains. By 1997, it was estimated to infest 2 million hectares (ha) across 35 states. The invasive pest has a number of adverse economic and ecological effects. In rangeland, leafy spurge reduces livestock carrying capacity – decreasing earnings of livestock producers and increasing expenses related to control. In wildland, the weed reduces native species richness and cover, wildlife habitat productivity, and soil and water conservation benefits. Controlling the species poses a number of challenges and neither repeated chemical control nor programmes using sheep and goat grazing have sustained long-term success.

CABI's work on leafy spurge started in 1961 with a number of surveys on biological control agents in western Europe. As a result of this work, 12 agents were screened and released in the US between 1970 and 1988. The biocontrol agents included five species of *Aphthona* flea beetles; of these, *A. nigriscutis* Foudras, and mixed populations of *A. czwalinai* (Weise) and *A. lacertosa* Rosenhauer proved to be the most successful. At the sites where flea beetles thrive and persist, leafy spurge is maintained at low densities.

Key highlights

- *Aphthona* flea beetles have significantly contributed to the effective control of leafy spurge in the north-western US
- Of the five species of flea beetles released, *A. nigriscutis*, and mixed populations of *A. czwalinai* and *A. lacertosa* proved the most effective
- In contrast to other management practices, stable coexistence between the *Aphthona* beetles and the target weed leads to long-term, sustained control
- Greatest effectiveness in control was observed where different control methods were integrated, for example beetles with herbicides or with sheep or goat grazing
- The total direct economic benefit from biological control was estimated at US$19.08 million for 1997
- A benefit–cost analysis conducted for the period 2000–2050 showed that the benefits of using biological control far outweigh the costs of the research and development of the agents – with the benefit ranging from 8.6–56 times the cost of the work

Context

Euphorbia esula, or leafy spurge, is a deep rooted perennial herb of Eurasian origin, found primarily in untilled land. This includes untilled agricultural land such as pasture, rangeland, hayland and idle cropland – and other untilled land such as ditches, shelterbelts, wildlife areas, parks, and around lakes and rivers. The plant's sticky, white latex is toxic to cattle, who rarely eat it and will avoid leafy spurge-infested pastures even if they contain palatable grasses. Reproducing by seed and vegetative root-buds, leafy spurge aggressively outcompetes rangeland grasses and other herbaceous plants.

Leafy spurge was first reported in the US in the state of Massachusetts in 1827. By 1933, the plant had spread to 19 states and several Canadian provinces, and was considered a threat to the rangelands in the northern Great Plains of the US. By 1949, the weed had dispersed to all Canadian provinces except Newfoundland and by 1979 it was present in 30 US states. In 1997, the invasive weed was estimated to infest 2 million ha across 35 US states. The most widely-infested areas include the western and central US and the prairie provinces of Canada.

Leafy spurge has a number of adverse economic and ecological effects. In rangeland, this invasive species reduces livestock carrying capacity with subsequent economic effects on livestock producers and their expenditures. In wildland, leafy spurge reduces native species richness and cover, use of infested areas by ungulates, and wildlife habitat productivity with subsequent effects on outdoor recreation activities and changes in soil and water conservation benefits.

Controlling this noxious weed poses a number of challenges. Chemical control reduces top growth and the underground root system, but does not achieve sustained long-term control. In addition, herbicides cannot be used in sensitive environments and their use is usually not economically viable on range and untilled land. Weed control programmes using grazing by sheep and goats have reported success, but once the animals are removed, leafy spurge regrows to original densities.

What we did

From 1961, CABI in Switzerland undertook surveys, upon request of the Canadian Department of Agriculture, on natural enemies of leafy spurge. Since leafy spurge originates in Eurasia, these surveys started in western Europe and were extended to central and south-eastern Europe in 1973. Based on this work CABI, with additional help from US collaborators, determined the environmental safety of 12 biological control agents, which were subsequently released for leafy spurge control in the US and Canada between 1970 and 1988.

The 12 biological agents included five species of flea beetles: *A. czwalinai*, *A. lacertosa*, *A. nigriscutis*, *A. flava* Guillebeau and *A. cyparissiae* (Koch). Of the five species, A. nigriscutis, and mixed populations of A. czwalinai and A. lacertosa reached the highest population densities and proved to be the most successful biocontrol agents. Flea beetle adults feed on leafy spurge foliage and flowers and may completely defoliate shoots, though this damage has little or no impact on the weed. It is mostly the larval mining on the roots that contributes to plant mortality by disrupting water and nutrient transport, and providing entry points for soil-born fungal pathogens.

Following the release of the agents, a massive re-distribution programme was facilitated by an area-wide pest management programme, TEAM Leafy spurge. Financed by the Agricultural Research Service of the United States Department of Agriculture, over 85 million beetles (from mixed populations) were released from North Dakota to various other states and Canada. Overall success of the control can be attributed to the scale of the massive redistribution programme and to the rapid rate at which flea beetle populations increase to cover infested areas.

One North Dakota study reported that leafy spurge density was reduced by over 95% within four years of release. Similar reductions were found six years after release. In a study conducted in Montana and South Dakota, mean foliar cover and density of leafy spurge were 83–90% and 73–78% less than pre-release values, respectively, six years later. At eight release sites in Fremont County, Wyoming, A. nigriscutis reduced mean cover of leafy spurge from 59% to less than 20% from five years after release onwards; and to less than 10% from 15 years after release onwards. Similarly, at several locations in Montana, A. nigriscutis reduced leafy spurge densities to 5–30% of pre-release densities within three to five years.

However, control of leafy spurge varies between sites, potentially influenced by local characteristics such as soil texture, spring warming, density of the weed and presence of soil-borne pathogens. Beetles appear to be less effective at very sandy sites and in very dense leafy spurge stands. In stark contrast to other control measures, including herbicides, which need to be regularly repeated, the beetles are able to persist at sites with low remaining levels of leafy spurge, maintaining control over many years. Stable coexistence between the biocontrol agent and the target plant at low densities is the optimal case scenario in weed biocontrol, leading to long-term, sustained control. According to some studies, the most effective way to control leafy spurge is achieved through an integration of different control methods. For instance, incorporation of flea beetles with herbicides or combining them with sheep or goat grazing can result in faster and more complete control of leafy spurge than insects alone.

What impact was achieved?

For North Dakota, a 57% reduction in infested area was estimated as a result of a combination of biocontrol, herbicide applications and grazing from the mid- to late-1990s to 2014. Biocontrol alone worked very well in about one-third of all infested areas and to a lesser degree in another third.

In sites where biocontrol has been successful, the plant remains present at low levels but without resulting in a negative economic impact. To achieve 50% forage utilisation by cattle, the level of leafy spurge canopy cover must be less than 10% and this level has been reported by numerous studies three to six years after release of the flea beetles, demonstrating the programme's success. In addition, in many areas where leafy spurge is still present, plants are unbranched, mostly less than 20 cm tall and non-flowering, while before the implementation of biocontrol, plants were typically 25–50 cm tall, heavily branched and flowering.

A 1999 analysis by Bangsund *et al* assessed the economic benefits of using flea beetles to control leafy spurge in the northern Great Plains of the US. In rangeland, where the principal land-use is beef cattle production, control of leafy spurge was assumed to lead to increased grazing output, and a subsequent increase in cow-calf production which, in turn, would lead to increased net income and decreased producer expenses related to control. In wildland, the economic benefits of biological control were based on assumed increases in wildlife habitat productivity, and soil and water conservation values. These include increases in wildlife-associated recreationist expenditures that increase earnings of local suppliers of related goods and services; and reductions in user expenditures to mitigate damages from water runoff and soil erosion.

To estimate the annual total direct economic benefit from biological control of leafy spurge, a number of projections were made based on the views of more than 25 scientists involved in research on leafy spurge and biocontrol technologies, as well as individuals involved in implementing and tracking biocontrol activities. Leafy spurge infestations in the four-state region were estimated at 760,000 ha by the year 2000. Future leafy spurge infestations that would eventually be controlled with biological agents by the year 2025 were projected at 522,000 ha (337,000 ha on rangeland and 185,000 ha on wildland). Control was defined as reducing the infestation density below economic thresholds. Benefits that would accrue as a result of the control were projected as follows:

- On rangeland, a recovered grazing capacity valued at US$4.98 million (in 1997); this would support an increased 39,400 cattle, leading to additional production expenditures to the region's input suppliers of about US$11.47 million. Together, the grazing capacity and increased earnings would add up to US$16.45 million (based on 1997 dollars).
- On wildland, increased annual expenditures for wildlife associated recreation of about US$1.8 million and a US$785,000 annual increase in soil and water conservation benefits were estimated, generating a total US$2.6 million (based on 1997 dollars).

The total direct economic benefits from biological control were thus estimated at US$19.08 million annually. CABI used this annual figure and took Bangsund *et al*.'s work a step further by projecting benefit:cost ratios for the period 2000–2050 (it was expected that the control effects from *Aphthona* beetles would continue at least that long). The total cost of CABI work on *Aphthona* beetles was estimated at Can$1.5 million. A number of benefit–cost analyses were calculated using direct benefits and control costs. In all scenarios, it was evident that the benefits of using biological control far outweighed the costs of the research and development of the agents.

For example:

- The minimum benefit calculated, using a 5% discount rate, was 8.6 times the cost of the work, achieved after five years of maximum control (i.e. in 2030)
- The maximum benefit calculated, using a 15% discount rate, was 56 times the cost of the work, achieved after 25 years of maximum control (i.e. in 2050)

A number of US states and Canadian provinces in which leafy spurge was successfully controlled were not included in the above assessment, so benefits were rather underestimated. Secondary benefits such as subsequent spending within the economy made possible by the direct benefits – estimated at US$39.3 million (1997 dollars) – were also excluded from the analysis. Overall, actual control achieved compared well with projections in existing literature and our calculated benefit:cost ratios are rather conservative.

Way forward

The successful biological control of leaf spurge has triggered increasing interest in this management method, especially for invasive weeds in extensively managed rangelands in the north-western US and the western provinces of Canada. Further work at CABI Switzerland in developing weed-specific biocontrol led to the release of several agents for the control of Dalmatian toadflax, diffuse and spotted knapweed, Russian knapweed, Musk thistle and houndstongue (only in Canada), all of which, at least locally, have been successful. Biological control agents were also successfully released for the control of environmental weeds such as purple loosestrife and more recently dog strangling vine (only in Canada).

In the US, an increasingly risk-averse attitude has led to a continuous decrease in the number of weed biological control agents released. Since 2000, only 22 weed biocontrol agents have been released in the US – a 39% reduction compared to the two previous decades – and since February 2011 not a single agent has been approved. Currently, ten petitions for field release are awaiting legislative action. Meanwhile invasive weeds continue to have detrimental economic and environmental impacts, and the issue lacks sustainable solutions. We believe that the US may miss opportunities for sustainable and environmentally benign management of invasive weeds using biological control if the regulatory framework only considers the *risks* of agents and not their potential *benefits*, which can be considerable as demonstrated in our case study.

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