Proc. VI Int. Symp. Biol. Contr. Weeds, 19–25 August 1984, Vancouver, Canada. Delfosse, E.S. (ed.). Agric. Can., pp. 837–42 (1985)

Status of Biological Weed Control in Montana

Jim M. Story

Montana State University, Agricultural Experiment Station, Western Agricultural Research Center, 531 NE Quast Lane, Corvallis, MT 59828, U.S.A.

Abstract

A total of 22 insect species have been introduced in Montana as biological control agents against nine target weeds since 1948. An additional weed-feeding insect, the tephritid fly, *Urophora quadrifasciata*, introduced in British Columbia, Canada, against *Centaurea maculosa* and *C. diffusa* (spotted and diffuse knapweed) in 1972, has migrated into Montana. Of these 23 insects, five species are well-established, four appear to be established in small numbers, and nine failed to establish. The status of five newly released species has not been determined. Of the established insects, the tephritid fly, *Urophora affinis*, released on *C. maculosa* and the seed-head weevil, *Rhinocyllus conicus*, released on *Carduus nutans* (musk thistle), have shown the fastest increase and dispersal.

État de la Lutte Biologique Contre les Plantes Nuisibles au Montana

Depuis 1948, 22 espèces d'insectes, au total, ont été introduites au Montana pour assurer la lutte biologique contre neuf plantes nuisibles particulières. Un autre insecte se nourrissant de plantes nuisibles, *Urophora quadrifasciata*, introduit en Columbie-Britannique, au Canada, en 1972, a étendu son aire de dispersion jusqu'au Montana. Sur ces 23 insectes, cinq espèces se sont bien établies, quatre espèces semblent s'être établies en petits nombres et neuf espèces n'ont pas réussi à s'établir. Cinq autres espèces d'insectes ont été libérées récemment, mais on ne sait pas encore si elles s'établiront.

Introduction

Although the concept of biological weed control is fairly new in Montana, the use of natural enemies to control weeds has been in practice for some time, dating back to the release of two defoliating beetles, *Chrysolina quadrigemina* (Suffrian) and *C. hyperici* Forster (Coleoptera: Chrysomelidae) on St. Johnswort, *Hypericum perforatum* L. (Clusiaceae), in 1948 (Roemhild 1956). However, the approach was not taken seriously in the State until the early 1970s when concern over the rapid spread of spotted knapweed, *Centaurea maculosa* Lamarck (Compositae), in western Montana prompted a group of farmers and ranchers to request biocontrol research of the weed by Montana State University. The tremendous public support to the subsequent research effort plus increasing concern over yet another weed, leafy spurge, *Euphorbia esula* L. (Euphorbiaceae), led to the development of a full-time research program of biological weed control by Montana State University in 1976. There are currently two scientists working full-time on the program.

Montana Biocontrol of Weeds Program

A total of 22 insect species have been introduced in Montana as biological control agents against nine exotic weeds of Eurasian origin since 1948. An additional weed-

feeding insect, the tephritid fly, *Urophora quadrifasciata* (Meigen) (Diptera: Tephritidae), introduced in British Columbia, Canada, against both spotted and diffuse knapweed, *C. diffusa* Lamarck, in 1972, has migrated into Montana. Of these 23 insects, five species are well-established, four appear to be established in small numbers, and nine failed to establish. The status of five newly released species has not been determined.

There are currently seven rangeland weeds targeted for biocontrol research in Montana, but the emphasis is on three weeds: spotted knapweed, diffuse knapweed, and leafy spurge.

Priority Projects

Spotted and diffuse knapweed. Spotted knapweed is the fastest spreading rangeland weed in Montana, currently infesting approximately 8,000,000 ha (2 million acres) (French and Lacey 1983). The majority of the infestation occurs west of the Continental Divide but it is rapidly spreading eastward (Story and Anderson 1978). The plant is very competitive, due largely to its allelopathic effect on other vegetation. The plant has long been considered a biennial or short-lived perennial, but recent data suggest that the plant commonly lives up to 7 yrs (unpubl. data). The plant reproduces solely by seed.

Diffuse knapweed is very similar to spotted knapweed except it is a biennial and grows on slightly drier sites. Diffuse knapweed is much less abundant than spotted knapweed, infesting an estimated 600 ha (M. Jackson, pers. comm.). Since it is known that many weed workers are mistaking diffuse for spotted knapweed, the actual infestation is probably much greater. The serious threat posed by this weed, combined with the availability of diffuse knapweed-attacking insects already established on spotted knapweed in Montana and in Canada, easily justify efforts against the plant.

A small tephritid fly, *Urophora affinis* Frauenfeld, that attacks flower heads of both spotted and diffuse knapweed, was released at 14 sites in western Montana during 1973–77. Larvae form galls (1 larva/gall) in flower heads, which reduce seed production.

The fly became established, has increased rapidly, and has dispersed to a radius of at least 8 km (5 miles) at all sites. A 4-yr study (1977–81) on its increase and dispersal since release in 1977 at five sites was concluded in 1982. Percent fly-infested seed heads and average number of fly galls/seed head increased significantly at all five sites during the 4-yr period (Story and Nowierski 1984). Percent of fly-infested seed heads in the final year of the study (1981) was 63–99%, and average number of galls/seed head was 2.1–9.3. Up to 24 galls were found in individual seed heads.

Spider predation, an unusually cold winter, and seed head predation by rodents appeared to be the only factors adversely affecting the fly populations. Although winter mortality appears to occur, the fly is capable of surviving the winters of west-central and eastern Montana; large populations of the fly now occur at release sites near Butte, Townsend, Livingston, Geyser, and Roundup, despite extended temperatures of −41°C (−50°F) at some sites during the winter of 1983–84.

Data collected in 1980 showed that fly populations at several release sites were large enough to facilitate large-scale collection and redistribution efforts. Thus, beginning in 1981, public-collection field-days have been held each spring for 4 yrs at a release site near Missoula. Due to tremendous public response, the four field days have resulted in redistribution of an estimated 5 million flies at over 900 spotted-knapweed-infested areas throughout Montana.

U. quadrifasciata, another gall-forming tephritid that attacks the flower heads of spotted and diffuse knapweed, is also established in Montana. This fly, introduced for biocontrol of knapweed at Ned's Creek, British Columbia, Canada, in 1972 (Harris 1980*a*), was found in 1981 to be migrating into western Montana at a rapid rate. Surveys in 1982 and 1983 revealed the fly was established in small numbers throughout much of the knapweed-infested areas of the State.

Although very similar in appearance, the two flies have differences: in contrast to *U. affinis*, which has only one generation/yr, *U. quadrifasciata* normally has two generations/yr, forms thinner galls, and attacks more mature flower heads than *U. affinis* (Harris 1980*a*).

U. quadrifasciata is spreading noticeably faster than *U. affinis*, even though the latter insect is well-established in both British Columbia and Montana. The faster spread of *U. quadrifasciata* is probably due to the fly's two-generation/yr seasonal cycle, but it could also be a behavioral trait.

Of special interest are complementary effects of the two flies on spotted knapweed. Since they attack flower buds at different plant growth stages, those immature flower buds escaping attack by *U. affinis* are attacked later by *U. quadrifasciata*. As a result, the most significant spotted knapweed seed reductions are probably occurring where the two fly species coexist. Preliminary data in 1983 showed that seed reductions of approximately 60% occurred at one site in Montana where a high density of *U. affinis* was associated with a low density of *U. quadrifasciata* (unpubl. data). In British Columbia, where both fly species are well-established, spotted knapweed seed reductions of 95% have been reported (Harris 1980*b*).

A third insect released on the knapweed project is the moth, *Metzneria paucipunctella* Zeller (Lepidoptera: Gelechiidae), whose larvae feed on florets and seeds of spotted knapweed. Four releases of this moth were made in western Montana during 1980–83. Seed head data collected in 1982 yielded an 11.2% infestation in a field cage compared to only 1.0% at a field-release area. However, no viable moth larvae were found in seed heads sampled at all sites in May 1984, following the unusually cold winter of 1983–84. Although attempts to re-establish the moth in field cages are underway, it appears the moth may be better suited for release in the warmer climates of Idaho, Oregon, and Washington.

The two seed-head-fly species can significantly reduce seed production. Thus, a study was initiated in 1983 to evaluate the extent of competitive interference between the moth and the two fly species, since all three insects attack the flower heads. First-year data (1983) showed that the moth larvae did compete with larvae of *Urophora* spp. The moth larvae burrowed into the hard galls of *U. affinis* and killed the fly larvae in up to 30% of moth-fly-infested seed heads. The moth's effect on *U. quadrifasciata* was not determined.

Despite this competition, the combined presence of the three insects significantly reduced seed production in attacked seed heads below the level caused by the two fly species alone ($P < 0.05$). Mean number of seeds/seed head ($\pm SE$) collected randomly within field cages containing only the two fly species versus cages containing both the moth and the two fly species was 7.59 ± 0.91 and 5.73 ± 0.45, respectively (unpubl. data). Although the moth has an obvious impact on spotted knapweed seed production, further assessment of its compatibility with the two fly species is needed before further releases are made. The moth probably only affects seed production in attacked seed heads, while the fly galls affect seed production on the entire plant (Harris 1980*b*). Thus, potential for reduced seed production caused by a large moth population must be weighed against possible increased seed production caused by the moth's destruction

of fly galls. A fourth knapweed insect released in Montana is a beetle, *Sphenoptera jugoslavica* Obenb. (Coleoptera: Buprestidae), that mines roots of diffuse knapweed. Small numbers of the beetle were released in 1983 near Superior; status of the beetle has not yet been determined.

Small numbers of *Agapeta zoegana* (L.) (Lepidoptera: Cochylidae) and *Pelochrista medullana* Stgr. (Lepidoptera: Tortricidae), two root-mining moths that attack both spotted and diffuse knapweed, were released near Stevensville in July 1984. The insects were collected in Europe by the Commonwealth Institute of Biological Control (CIBC) in Delemont, Switzerland, under contract with Montana State University. Status of the two insects is not yet known.

Leafy spurge. Leafy spurge is the rangeland weed causing the greatest concern on a statewide basis. This perennial plant is very competitive, very persistent, and is extremely difficult to control with herbicides. Statewide in distribution, the plant infests an estimated 200,000 ha (500,000 acres). The plant reproduces both by seed and rhizomatous roots.

A defoliating moth, *Hyles euphorbiae* L. (Lepidoptera: Sphingidae), was released at numerous sites in Montana in 1966 and 1973 (Story 1979). Since, by 1981, no moths had been recovered, the moth was considered a failure. However, in 1982, 9 yrs after release, *c.* 100 larvae were found at a release site near Bozeman, Montana. Several thousand larvae were found at the same site in 1984 (N. Rees, pers. comm.). Small number of *Hyles* larvae were also found at a release site near Missoula in 1983 and 1984. In view of the insect's obvious establishment in Montana, work with this insect has been renewed. Rearing efforts at both Corvallis and Bozeman resulted in the release of *c.* 1000 *Hyles* in Montana, while 300 *Hyles* were sent to North Dakota for release.

Small numbers of the root-mining beetle, *Oberea erythrocephala* (Schrank) (Coleoptera: Cerambycidae), were released on leafy spurge at three sites in 1982 and 1983. Adults successfully emerged in 1984 (1 yr after release) at a release site near Columbus (N. Rees, pers. comm.). The status of the insect at two other sites is not known.

A root-mining moth, *Chamaesphecia tenthridiniformis* (Schiff.) (Lepidoptera: Aegeriidae), released in 1977, failed to establish.

Other Projects

Although current emphasis is on the three above-mentioned weeds, some work is also being done on four other weeds: musk thistle (*Carduus nutans* L.; Compositae); Dalmation toadflax (*Linaria dalmatica* [L.] Mill.; Scrophulariaceae); Canada thistle (*Cirsium arvense* [L.] Scop.; Compositae); and St. Johnswort (*H. perforatum*).

Musk thistle. Musk thistle is a problem in many areas of western Montana where it forms heavy infestations that reduce pasture utilization. The plant is a biennial and reproduces solely by seed.

Two insects, a seed-head weevil, *Rhinocyllus conicus* Froelich, and a crown weevil, *Trichosirocalus horridus* (Panzer) (both Coleoptera: Curculionidae), have been released on musk thistle. *R. conicus*, first released near Bozeman in 1969, became established over a 1280 km^2 area within 5 yrs (Hodgson and Rees 1976). Due to numerous redistribution efforts, the weevil is now established at nearly all musk-thistle-infested areas of the State. Rees (1977) reported that the weevil appeared to be reducing musk thistle seedling density. The other weevil, *T. horridus*, released in 1978–81 at several sites near Corvallis, failed to establish.

Dalmation toadflax. Dalmation toadflax is a serious problem in extreme western Montana where an estimated 16,000 ha (40,000 acres) of rangeland are infested with the plant. The plant is very aggressive, very persistent, and is difficult to control with herbicides.

A defoliating moth, *Calophasia lunula* (Hufnagel) (Lepidoptera: Noctuidae) was released near Whitehall and Yellowstone National Park in 1972 and 1975, respectively, but failed to establish (Story 1979). Efforts in 1984 to mass-rear the moth resulted in release of *c.* 1100 larvae at sites near Plains and Missoula, and shipment of 500 larvae to Oregon. The status of these new releases has not been determined.

Canada thistle. Canada thistle is a statewide problem, infesting an estimated 280,000 ha (700,000 acres) of crop-, pasture-, and rangeland. Three insects have been released on Canada thistle: a stem-mining weevil, *Ceutorhynchus litura* (F.) (Coleoptera: Curculionidae), a stem-gall tephritid fly, *Urophora cardui* (L.), and a defoliating beetle, *Altica carduorum* Guérin-Méneville (Coleoptera: Chrysomelidae).

C. litura, released near Bozeman in 1973, became well-established but, by 1978, had dispersed only 203 m from the release point. Recently, however, the weevil has begun to disperse much faster and can now be found out to 3.2 km (2 miles) (N. Rees, pers. comm.). Redistribution of *C. litura* larvae in 1979 resulted in its establishment at sites near Corvallis and Plains, in western Montana.

U. cardui was released at three sites near Corvallis during 1978–82. The fly failed to establish at two open, relatively dry sites, but appears to be established in small numbers at a low, moist, and well-protected site.

A. carduorum, released at several sites in western Montana in 1966, failed to establish.

St. Johnswort. St. Johnswort is a localized problem in rangeland and forests of western Montana. The first attempt to control a weed with insects in Montana occurred against this plant in 1948 when two defoliating chrysomelid beetles, *C. quadrigemina* and *C. hyperici*, were released at several sites in western Montana (Roemhild 1956). *C. quadrigemina* became established and has dispersed throughout most of the St. Johnswort-infested areas of the State but has had no noticeable effect on St. Johnswort density. *C. hyperici* was initially recovered in small numbers but its present status is not known. The status of the leaf-gall fly, *Zeuxidiplosis giardi* Kieffer (Diptera: Cecidomyiidae) released near Bozeman in 1983 is not known. *Agrilus hyperici* (Cr.) (Coleoptera: Buprestidae), a root-boring beetle released in 1955 and 1976, failed to establish.

Terminated Projects

Two root and stem weevils, *Microlarinus lareynii* (Jacquelin duVal) and *M. lypriformis* (Wollaston) (Coleoptera: Curculionidae), released in 1963 (Maddox 1976) on puncturevine (*Tribulus terrestris* L.; Zygophyllaceae) near Billings, and two moths, *Coleophora parthenica* Meyrick and *C. klimeschiella* Toll (Lepidoptera: Coleophoridae), released on Russian thistle (*Salsola iberica* Sennen & Pau; Chenopodiaceae) in 1979 and 1981–82, respectively, in central Montana failed to establish. No further work with these two weeds is planned.

References

French, R.A., and Lacey, J.R. 1983. Knapweed: Its cause, effect and spread in Montana. *Montana Coop. Ext. Serv., Circ. No.* **307**, 13 p.

Harris, P. 1980*a*. Establishment of *Urophora affinis* Frfld. and *U. quadrifasciata* (Meig.) (Diptera: Tephritidae) in Canada for the biological control of diffuse and spotted knapweed. *Z. Ang. Ent.* **89**: 504–14.

_____. 1980*b*. Effects of *Urophora affinis* Frfld. and *U. quadrifasciata* (Meig.) (Diptera: Tephritidae) on *Centaurea diffusa* Lam. and *C. maculosa* Lam. (Compositae). *Z. Ang. Ent.* **90**: 190–201.

Hodgson, J.M., and Rees, N.E. 1976. Dispersal of *Rhinocyllus conicus* for biocontrol of musk thistle. *Weed Sci.* **24**: 59–62.

Maddox, D.M. 1976. History of weevils on puncturevine in and near the United States. *Weed Sci.* **24**: 414–9.

Rees, N.E. 1977. Impact of *Rhinocyllus conicus* on thistles in southwestern Montana. *Env. Ent.* **6**: 839–42.

Roemhild, G. 1956. Status of the Chrysolina beetle project. Mimeo. report, Montana St. Univ., St. Ent. Rep.

Story, J.M. 1979. Biological weed control in Montana. *Montana Agric. Exp. Sta. Bull. No.* **717**, 15 p.

Story, J.M., and Anderson, N.L. 1978. Release and establishment of *Urophora affinis* (Diptera: Tephritidae) on spotted knapweed in western Montana. *Env. Ent.* 7: 445–8.

Story, J.M., and Nowierski, R.M. 1984. Increase and dispersal of *Urophora affinis* (Diptera: Tephritidae) on spotted knapweed in western Montana. *Env. Ent.* (*in press*).