

Biological Control of Weeds in Washington: Status Report

Gary L. Piper

Department of Entomology, Washington State University, Pullman, WA 99164, U.S.A.

Abstract

A summarization of biological control of weeds activities conducted in Washington since 1948 is presented. To date, 26 natural enemies have been released against 14 exotic weeds in the State. Of the organisms introduced, 18 (69%) have successfully become established. The role of natural enemies in suppressing population development of St. Johnswort (*Hypericum perforatum*), rush skeletonweed (*Chondrilla juncea*), tansy ragwort (*Senecio jacobaea*), and the knapweeds (*Centaurea* spp.) is discussed.

Lutte Biologique Contre les Plantes Nuisibles dans l'État de Washington

L'auteur fait brièvement l'histoire de la lutte biologique contre les plantes nuisibles, entreprise dans l'état de Washington depuis 1948. A ce jour, 26 ennemis naturels de 14 plantes nuisibles exotiques ont été libérés dans l'état. Sur ce total, 18 organismes (69%) se sont établis. Le rapport traite du rôle des ennemis naturels de l'herbe squelette (*Chondrilla juncea*), des millepertuis perforés (*Hypericum perforatum*) et des séneçons Jacobée (*Senecio jacobaea*) dans l'élimination de ces mauvaises herbes ainsi que des programmes futurs de lutte biologique.

Introduction

During the past decade there has been increased interest in the biological method of weed suppression in the State of Washington. This interest has been stimulated by: several recent successful projects; continual increases in herbicide, fossil fuel and labor costs; herbicide toxicity concerns; increased demand for higher agricultural productivity; and the need to utilize marginally productive areas.

Most of the land in Washington is non-cropland. Such areas include non-irrigated pasture and rangeland, forests, highway and railroad right-of-ways, and vacant commercial and residential properties. Non-croplands are colonized by a diverse mixture of exotic and native weeds. Poisonous and unpalatable plants restrict land use for grazing and livestock production. Other weeds tend to limit natural reforestation by retarding seedling development of various timber species. Weeds of non-croplands frequently serve as alternate hosts for pest arthropods and plant pathogens which often invade agronomic or horticultural crops grown in the vicinity of the non-cultivated areas. Non-cropland weeds also are reservoirs of seed which is frequently transported into nearby agricultural or urban areas by man, animals, wind or water.

Over 50% of the noxious weeds occurring in non-cropland areas of Washington are exotics. These plants have attained undesirable densities primarily because they lack host-specific predators and pathogens which act as population regulators in the weeds'

native homelands. In an effort to slow down or halt the often explosive increase of an alien weed, natural enemies are sought out in the weed's area of indiginity for eventual introduction into the invaded areas. This 'classical biological control' approach has been the only form of biological control utilized to date in Washington.

In recent years, several papers have appeared in the literature which summarize the status of biological control of weeds activities in North America (Goeden *et al.* 1974; Andres and Kok 1981) and elsewhere in the world (Goeden 1978; Julien 1982). Unfortunately, such accounts are usually incomplete due to the inability of the compilers to access all natural enemy release, establishment, and distribution records. In Washington, no comprehensive accounts of the progress of introduced weed-damaging organisms have been published heretofore even though this weed suppression method has been utilized since 1948. During the 36 years which have elapsed, 26 natural enemies have been imported and liberated against 14 alien plant species. Of these introduced agents, 18 (69%) have successfully established and contributed substantially to the non-cropland weed management effort.

Biological Control of Weeds Projects

St. Johnswort, *Hypericum perforatum* L. (*Clusiaceae*)

St. Johnswort, a plant of Eurasian origin, is a particularly troublesome weed in some areas of Washington. The weed is very aggressive and readily establishes itself in abandoned cropland, along transportation right-of-ways, and in open range grazing areas, greatly depreciating their carrying capacities through the displacement of desirable forage plants. St. Johnswort also may adversely affect livestock which feed upon it.

This weed has been successfully controlled in many areas with natural enemies (Goeden 1978). Two species of European leaf-feeding beetles, *Chrysolina hyperici* (Forster) and *C. quadrigemina* (Suffrian) (Coleoptera: Chrysomelidae), were first released in Washington in 1948 for the control of the weed (Johansen 1957). Defoliation by *Chrysolina* adults and larvae decreases photosynthesis, which induces a decline in stored food reserves in the root, ultimately leading to plant death. Partial defoliation results in reduced plant vigor and loss of competitive ability (Holloway and Huffaker 1951). The beetles, particularly *C. quadrigemina*, have spread throughout the State and have markedly reduced *Hypericum* infestations.

In some areas, where for various reasons the beetles do not occur or are occasionally inhibited from attaining damaging levels, stands of St. Johnswort still persist. In such instances it is necessary to re-establish the beetles to effect control. Since 1979, nearly 362,000 adult *C. hyperici* and *C. quadrigemina* have been collected for redistribution to 11 counties in eastern Washington.

In 1954 and 1955 an unspecified number of adult *Agrilus hyperici* (Creutzer) (Coleoptera: Buprestidae) were released in Whitman County in southeastern Washington (Johansen 1957). This root-borer established, but populations have never reached large densities in those areas where it is known to occur. The impact of the insect on *H. perforatum* and its distribution in the State have not been ascertained.

In an effort to reduce St. Johnswort populations in beetle-impooverished areas and enhance weed suppression at *Chrysolina* spp. infested sites, field releases of the leaf bud gall-forming midge *Zeuxidiplosis giardi* Kieffer (Diptera: Cecidomyiidae) were made in 1955 in Pierce County in western Washington and in 1981, 1982, and 1983 in Whitman County, with all release stock originating in California. Gall presence inhibits the development of upright flowering shoots which results in decreased seed production.

Heavily galled plants suffer a notable loss of vigor and exhibit reduced foliage and root development (Wilson 1943; Holloway and Huffaker 1953). The midge readily galled potted plants grown in the greenhouse but failed to successfully colonize in the field when released. Additional importation of *Z. giardi* does not seem warranted at this time.

Rush Skeletonweed, Chondrilla juncea L. (Compositae)

Rush skeletonweed, a perennial plant native to central Asia and Europe, was inadvertently introduced into Washington during the late 1930s. The weed has since spread to infest over 810,000 ha of rangeland, semi-arid pasture land, transportation right-of-ways, residential properties, and croplands in eight eastern counties. Heaviest infestations are confined to rangeland where the weed displaces livestock and wildlife forage plants but encroachment of *C. juncea* into dryland wheat production areas has increased considerably in recent years. The plant's extensive root system enables it to effectively compete with crops for moisture and nutrients. The wiry, latex-exuding stems of mature plants can obstruct harvest machinery, making harvesting costly and difficult, if not impossible. Presently, two biotypes, designated 'Washington early-flowering' and 'Washington late-flowering', have been identified with the latter form being predominant in most infested areas.

Natural enemy releases were begun in 1976 and have been continued annually since 1978 in an effort to rapidly saturate rush skeletonweed infested sites with the control agents. Organisms released thus far include a rust fungus, *Puccinia chondrillina* (Bubak & Sydow) (Uredinales), a gall-forming midge, *Cystiphora schmidti* Rübsaamen (Diptera: Cecidomyiidae), and a gall-forming mite, *Eriophyes* (= *Aceria*) *chondrillae* (G. Canestrini) (Acarina: Eriophyidae).

The rust fungus attacks the seedling and regenerative rosettes produced during the fall and spring. Leaf surfaces become covered with numerous spore-containing pustules. As the rosette leaves die from infection, the pathogen attacks the stems, buds, and flowers (Hasan and Wapshere 1973). Open lesions produced as a consequence of spore formation cause desiccation, reduce photosynthetic surface area, and increase plant susceptibility to arthropod attack or other injury (Wapshere 1970, 1973). *P. chondrillina* most successfully controls seedlings and young plants which possess inadequate root reserves to permit re-establishment after attack (Adams 1982). Growth rate, root regenerative capacity, stem and bud production, and seed viability are reduced in older plants. Since 1979, over 100 releases of the fungus have been made in seven counties. Establishment and subsequent spore dissemination has occurred at over 90 release sites.

C. schmidti was initially released in Spokane County in 1976. The midge females deposit eggs in leaves and stems and blister-like galls develop around the plant-tissue-feeding larvae. Infested plants produce up to 63% fewer buds than do unattacked plants of comparable size and age (Mendes 1981). Seeds which are produced on attacked plants exhibit decreased viability and weigh less than seeds from healthy plants. Midge galls physically reduce the photosynthetic surface area of the almost leafless stems. This effect, combined with desiccation resulting from epidermal damage caused by emerging midges, leads to stunting, stem yellowing, and shoot-tip withering. When seedlings are heavily galled plant mortality usually results. Over 50 releases of the insect have been made thus far in all counties infested by the weed. The midge could be much more damaging to *C. juncea* if it were not for the presence of the parasitoid *Mesopolobus* sp. (Hymenoptera: Pteromalidae) which often destroys up to 95% of the late season midge populations (Wehling 1984).

The gall mite infests the developing vegetative and flower buds of rush skeletonweed, transforming them into leafy hyperplastic galls (Caresche and Wapshere 1974). The buds are completely destroyed as a result of gall formation, thereby curtailing seed production and in some instances totally suppressing it. Heavily galled plants exhibit premature chlorosis, are stunted with epinastic stem growth, and are unable to compete effectively with other vegetation. In excess of 100 releases have been made in seven counties. The mites have successfully colonized each site with no exceptions. *E. chondrillae* appears to be a highly effective biological control organism in Washington.

All agents attack the late-flowering biotype prevalent in the State but only the midge and mite can develop on the early-flowering form of the weed. Suppression of rush skeletonweed has been excellent in many areas and is expected to improve in other locations in time as the natural enemy populations increase.

Diffuse and Spotted Knapweed, Centaurea diffusa Lam., C. maculosa Lam. (Compositae)

Diffuse and spotted knapweed are short-lived perennials of European origin that have become the most important rangeland weeds in Washington. These weeds jointly infest an estimated 400,000 ha in at least 20 of the State's 39 counties. Both species are of economic importance because they reduce forage production (up to 90%), decrease range carrying capacity, have little nutritive value for stock and wildlife, and form solid stands as a consequence of their allelopathic effects on indigenous and/or introduced grasses and forbs. Additionally, dense infestations, especially of diffuse knapweed, diminish wildlife habitat quality and often preclude utilization of large tracts of land for recreational purposes.

Biological control efforts against the knapweeds were begun in 1974 in Washington when 2400 adult *Urophora affinis* Frauenfeld (Diptera: Tephritidae) were released in Chelan, Kittitas and Okanogan Counties. another release consisting of 3100 adults was made in Chelan County in 1975. In 1979 and 1980, a total of 1672 adults were liberated in Spokane and Whitman Counties. All releases resulted in fly establishment with both knapweed species being utilized as hosts. Females deposit eggs into developing flower heads and the larvae induce gall formation within the heads. The larvae feed on nutritive cells which line the gall interior. These cells increase the size of the metabolic sink in the seed head so that the plant supplies more nutrients to attacked heads. A reduction in the amount of nutrients available for plant growth and development results which is expressed as terminal or lateral bud abortion, reduced seed production, and decreased seed viability (Harris 1980). *U. affinis* presently occurs in 12 of the 20 knapweed-infested counties east of the Cascade Mountains.

U. quadrifasciata (Meigen), another seed-head gall fly, was first discovered in Spokane County in 1979. The insect invaded the State from British Columbia where Canadian weed control specialists had previously made releases and it now can be found in all counties east of the Cascades. Larvae attack the floral ovaries, transforming them into papery-thin galls. Damage to both knapweed species is similar to that produced by *U. affinis*. Since 1980, redistributions of this species have been made to south-central and eastern Washington counties where fly densities are still somewhat low.

According to Harris (1980), both *U. affinis* and *U. quadrifasciata* have reduced seed production by 95% in Canada since their release in that country 14 years ago. A study is presently being conducted in Washington to quantitatively assess the impact of the flies on populations of *C. diffusa* and *C. maculosa*.

Sphenoptera jugoslavica Obenberger (Coleoptera: Buprestidae), the larvae of which feed in the taproot of diffuse knapweed and cause galls to develop which structurally

weaken the root and reduce plant vigor (Zwölfer 1976), has been introduced into the State. Twenty-seven adults were released in Spokane County in 1980, 47 adults in Okanogan County in 1983, and 48 adults in Whitman County in 1984. No establishment was recorded for the 1980 release and the remaining release areas have not been sampled to determine beetle presence or absence.

In 1981, 810 adult *Metzneria paucipunctella* Zeller (Lepidoptera: Gelechiidae) were released in Spokane and Whitman Counties on spotted knapweed. The moth larvae feed upon the developing florets and seeds in the flower heads, consuming most of the seeds in the head (Englert 1971). Establishment was confirmed at both sites in 1982 and redistribution of *Metzneria* to other areas began in 1984.

Russian Thistle, Salsola iberica Sennen & Pau (Chenopodiaceae)

Russian thistle or tumbleweed, indigenous to southeastern Russia and western Siberia, is a multibranched annual that occurs throughout much of eastern and central Washington. The plant's efficient root system, abundant seed production, reduced leaf surface, and photosynthesizing branches well adapt it to disturbed, semi-arid agricultural environments where it competes with more desirable plants for water and nutrients.

Natural enemy introductions were started in 1979. At a site in Whitman County, 353 *Coleophora klimeschiella* Toll (Lepidoptera: Coleophoridae), the larvae of which feed both internally and externally upon the leaves and cause damage especially during the weed's early developmental stages (Khan and Baloch 1976), were colonized. During 1980 and 1981, 46 and 1000 additional individuals, respectively, were released at the same site. Establishment has been achieved but moth populations remain low and no discernible reduction in weed density has been observed.

A second coleophorid species, *C. parthenica* Meyrick, whose larvae tunnel the stems and branches (Hawkes and Mayfield 1976) contributing to reduced seed production and viability, stunting, or even death, was released in 1979, 1980, and 1981 (133, 48, and 64 individuals, respectively). This insect did not establish in Washington and no further releases are contemplated.

Musk Thistle, Carduus thoermeri Weinmann (Compositae)

This European plant is a serious biennial or winter annual of overgrazed pastures and rangeland in several eastern Washington counties. Although effective chemical suppressants are available, they are costly and must be repeated to eliminate plants developing from seed in the soil.

The seed-head weevil, *Rhinocyllus conicus* Froelich (Coleoptera: Curculionidae), was first released in the State in 1982. Approximately 5000 adults were collected near Belgrade, Montana, and distributed to Okanogan and Walla Walla Counties for release on musk thistle. Establishment was confirmed in 1983. Adults released in isolated stands of *Cirsium arvense* (L.) Scop., *C. undulatum* (Nutt.) Spreng., and *Onopordum acanthium* L. (all Compositae), all previously reported hosts for *R. conicus* (Rees 1978), failed to colonize.

In 1983, 25,585 adults were again obtained from Montana and transported to Ferry, Okanogan, Stevens, and Walla Walla Counties to enhance existing weevil populations or to initiate new infestations, especially in Ferry and Stevens Counties. A check of the release sites in these areas revealed musk thistle was being utilized by *R. conicus*. At another site in Stevens County, 2000 adults were placed on plumeless thistle, *Carduus acanthoides* L. The status of this release has not yet been determined.

Canada Thistle, Cirsium arvense

Canada thistle, a weed of Eurasian origin, is the most widespread and important noxious weed infesting cropland and non-cropland areas in Washington. The obnoxious character of this plant is due primarily to the highly successful vegetative propagation carried on by the creeping horizontal roots which survive perennially and give rise to numerous aerial shoots.

The first insect introduced specifically for *C. arvense* control was *Altica carduorum* Guérin-Ménéville (Coleoptera: Chrysomelidae). Two hundred individuals were released in Whitman County in 1966 followed by the release of 106 additional beetles in 1968. As no evaluation studies were ever conducted and no progeny ever collected, it may be assumed that the releases failed. No subsequent importations were made.

In 1974 the first release of *Ceutorhynchus litura* (F.) (Coleoptera: Curculionidae) was made in Benton County. The larvae of this weevil mine rosette leaves and young shoots of plants. The 200 adults released failed to establish at the site. In 1984 a decision was made to try to establish the beetle once again. A shipment of 100 adults was received from California and released in Whitman County.

Urophora cardui (L.) (Diptera: Tephritidae), whose larvae induce the formation of galls in primary or secondary stems, shows promise for the biological control of Canada thistle. Gall development prevents seed production and disrupts the vascular system, causing a reduction in plant biomass and vigor (Peschken and Harris 1975; Shorthouse and Watson 1976). The fly was first liberated in 1982 in Whitman (375 adults) and San Juan (181 adults) Counties. Establishment was confirmed for Whitman County only, the flies producing 1-3 galls/plant during the year of the release. A total of 422 galls were removed from the site in the spring of 1983 and held in the laboratory to yield 1174 adults. These flies were divided into variously sized allotments and released in eight counties across the State. The tephritid was able to colonize successfully five of the areas. Additional releases of 686 adults were made in three counties in 1984. No impact studies have been undertaken yet to assess the agent's damage potential under Washington conditions.

Bull Thistle, Cirsium vulgare (Savi) Tenore (Compositae)

This plant, an introduced European native, is a nuisance in grazed pastures, rangeland, logged areas, wasteland, and along transportation right-of-ways. In 1983 the seed-head-damaging fly *Urophora stylata* L. (Diptera: Tephritidae) was obtained from Canada for release in eastern Washington. Females deposit eggs in unopened buds and the larvae destroy floral tissue and feed on developing seeds. Thick-walled galls surround the larvae in the receptacle. The presence of *U. stylata* may reduce seed production by 60% (Persson 1963; Schroeder 1980).

In 1983, 1300 adults were released at three sites in Whitman County and 600 adults at two sites in Klickitat County in south-central Washington. Establishment occurred at all release sites. In 1984, 172 flies were distributed amongst two sites in Whitman County and another 240 were set free at a site in Spokane County.

Puncturevine, Tribulus terrestris L. (Zygophyllaceae)

This annual plant, native to the Mediterranean area, is a pest of cultivated fields, waste areas and utility right-of-ways. The weed produces many seeds which are contained within spined fruits. These fruits interfere with hand-harvesting of crops, cause a downgrading of agricultural products, and may injure the mouths and digestive tracts of livestock upon ingestion (Johnson 1932).

The seed weevil, *Microlarinus lareynii* (Jacquelin du Val), and the stem weevil, *M. lypriformis* (Wollaston) (Coleoptera: Curculionidae), were introduced from Italy to control puncturevine. *M. lareynii* larvae feed upon the developing seeds while the larvae of *M. lypriformis* tunnel the stems (Kirkland and Goeden 1978a,b). High larval populations reduce plant size and the quantity of seeds produced. Both species are established in the United States and have reduced the abundance of the weed (Maddox 1976).

Releases of weevils field-collected in Italy were made in 1961 in Washington. In Benton County, 209 adult *M. lareynii* and 88 *M. lypriformis* were released. Another release of 100 *M. lareynii* adults was made in Franklin County at the same time. Establishment was not achieved at the sites (Maddox 1976). In 1963, a total of 400 adult *M. lareynii* and *M. lypriformis* field-collected in California were distributed in Grant County. This release also failed. Apparently the curculionids were unable to survive the harsh eastern Washington winter weather.

In 1982, cold-tolerant biotypes of both species were obtained from Colorado and released in Whitman County. No plant injury was observed following the liberation of 189 individuals and no evidence of establishment was found in 1983. Further attempts will be made to establish *Microlarinus* spp. in Washington.

Dalmation Toadflax, Linaria dalmatica (L.) Miller (Scrophulariaceae)

Dalmation toadflax, a short-lived perennial herb native to the Mediterranean, has become a serious weed of disturbed soils and depleted rangelands. Livestock generally avoid eating the weed and several plants/m² reduce the yield of grasses and forbs by 50–60% (Polunin 1969).

Calophasia lunula (Hufnagel) (Lepidoptera: Noctuidae), utilized in Canada in the 1960s for control of butter-and-eggs, *Linaria vulgaris* Miller, and Dalmation toadflax, was initially obtained for release in Washington in 1968. Moth larvae consume the foliage, floral buds, and flowers. Feeding damage reduces seed production, halts photosynthesis and depletes carbohydrate reserves in the roots, thereby lessening the plant's competitive ability.

A release of 250 larvae was made in Spokane County at several sites during 1968 and another release of 200 larvae was made in the same County the following year. No establishment occurred at any site where the moths were liberated. In 1970, at an *L. dalmatica* infested site in Whitman County, 185 larvae were released. No insect activity was discernible at the site the following year.

Another attempt to establish *C. lunula* was made in 1982. A total of 450 larvae were released in Spokane County at three sites, 325 larvae in Klickitat County, 171 larvae in Ferry County, and 100 larvae in Yakima County. The natural enemy did not establish at any site even though feeding on Dalmation toadflax was observed in the field following the releases. In 1983 another 100 larvae were released in Spokane County but no progeny could be located in the vicinity of the release during 1984.

Gorse, Ulex europaeus L. (Leguminosae)

Gorse is a densely-branched, spiny shrub which grows primarily in coastal areas in western Washington. The plant spreads rapidly in burned-over timber or brush areas, preventing the return of native forage plants as well as conifers, thus greatly interfering with reforestation efforts.

In 1964, the gorse seed weevil, *Apion ulicis* Forster (Coleoptera: Culculionidae), was introduced to decrease the rate of spread of the plant. Larvae of the insect inhabit the

seed pods and eat the developing seeds. Seed crop reductions in excess of 95% have been realized at some sites. A release of 765 adults was made in San Juan County and dispersal of *A. ulicis* from the release area to other gorse infestations has transpired during the past two decades.

Russian Knapweed, Centaurea (Acroptilon) repens (L.) DC. (Compositae)

This plant, a native of Asia, forms dense infestations in Washington pastures, along transportation right-of-ways, along irrigation ditches and agricultural field borders, and sometimes invades cereal grain and alfalfa fields. The weed spreads primarily via its creeping horizontal root system but also by seed to some extent.

In the plant's native homeland, it is frequently damaged by the nematode *Paranguina picridis* Kirjanova & Ivanova (Nematoda: Tylenchidae). The first attempt to establish this organism in Washington was made in 1984 with material supplied from Canadian biological control cooperators. The nematode penetrates the emergent shoots of Russian knapweed in the spring and its presence leads to gall development on the root crown, stems, and leaves. Infected plants are severely distorted and stunted and reproduction by seed or vegetative means is reduced (Ivanova 1966).

Two releases of the organism were made in Okanogan County. Examination of the sites several months after the releases revealed the presence of *P. picridis* but only a small number of plants were infected at the sites. It is unknown whether the nematode will be able to successfully overwinter under Washington conditions.

Tansy Ragwort, Senecio jacobaea L. (Compositae)

Tansy ragwort, a European biennial or short-lived perennial, is a major noxious weed of poor quality pasture and range areas throughout most of the counties west of the Cascades in Washington. *S. jacobaea* displaces desirable forage plants and is also toxic to cattle and horses. Pyrrolizidine alkaloids in the plant, when consumed by livestock, produce progressive and irreversible liver damage.

The cinnabar moth, *Tyria jacobaeae* (L.) (Lepidoptera: Arctiidae), was first released in Washington in 1960. During the decade that followed, thousands of larvae were released amongst infestations of the weed. Larvae feed on leaves, buds, and flowers, frequently defoliating all plants in an area. The insect presently can be found in most tansy ragwort-infested sites in the State and annual redistributions are carried out by noxious weed control personnel.

A second organism was introduced for the control of this weed in 1968. The ragwort-seed-head fly, *Hylemya seneciella* Meade (Diptera: Muscidae), whose larvae feed within the floral buds consuming the developing seeds, was released in Clark County (3348 adults) (Frick 1969). Field recovery of individuals was made later the same year. A search of the release site and surrounding area during succeeding years failed to provide evidence for fly survival. During 1981, tansy ragwort damaged flower heads were brought in to county extension agents by several landowners in southwestern Washington. An examination of the areas where the plants had been found revealed that *H. seneciella* was well-established and was destroying c. 30% of the seed heads produced.

The last insect species to be imported into the State for tansy ragwort suppression was the ragwort flea beetle, *Longitarsus jacobaeae* (Waterhouse) (Coleoptera: Chrysomelidae). Adults damage foliage in fall, and larvae feed in the root crown and rosette leaf petioles during fall and spring causing extensive damage. Releases of several thousand adults were made in various southwestern Washington counties during 1970,

1972, 1974, and 1975. *L. jacobaeae* is now well-established and has effectively reduced tansy ragwort population by itself or more frequently complements the damage inflicted by the cinnabar moth and/or ragwort seed fly.

References

- Adams, E.B. 1982. Use of a plant pathogen (*Puccinia chondrillina*) to control rush skeletonweed (*Chondrilla juncea*). Ph.D. thesis. Washington State Univ., Pullman, WA.
- Andres, L.A., and Kok, L.T. 1981. Status and prospects for biological control of weeds in the U.S.A. In: Use of Beneficial Organisms in the Control of Crop Pests. Coulson, J.R. (ed.). Joint American-Soviet Conference, Washington, D.C., pp. 27-33.
- Caresche, L.A., and Wapshere, A.J. 1974. Biology and host specificity of the *Chondrilla* gall mite *Aceria chondrillae* (G. Can.) (Acarina, Eriophyidae). *Bull. Ent. Res.* **64**: 183-92.
- Englert, W. 1971. *Metzneria paucipunctella* Zel. (Gelechiidae, Lepidoptera): A potential insect for the biological control of *Centaurea stoebe* L. in Canada. *Commonw. Inst. Biol. Contr. Prog. Rept. No. 28*, 12 p.
- Frick, K.E. 1969. Attempt to establish the ragwort seed fly in the United States. *J. Econ. Ent.* **62**: 1135-8.
- Goeden, R.D. 1978. Biological control of weeds. In: Introduced Parasites and Predators of Arthropod Pests and Weeds. Clausen, C.P. (ed.). *USDA Agric. Handbk. No. 480*, Washington, D.C., pp. 357-414.
- Goeden, R.D., Andres, L.A., Freeman, T.E., Harris, P., Pienkowski, R.L., and Walker, C.R. 1974. Present status of projects on the biological control of weeds with insects and plant pathogens in the United States and Canada. *Weed Sci.* **22**: 490-5.
- Harris, P. 1980. 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.
- Hasan, S., and Wapshere, A.J. 1973. The biology of *Puccinia chondrillina* a potential biological control agent of skeleton weed. *Ann. Appl. Biol.* **74**: 325-32.
- Hawkes, R.B., and Mayfield, A. 1976. Host specificity and biological studies of *Coleophora parthenica*, an insect for the biological control of Russian thistle. A Commemorative Vol. in Ent., Dept. of Ent., Univ. of Idaho, pp. 37-43.
- Holloway, J.K., and Huffaker, C.B. 1951. The role of *Chrysolina gemellata* in the biological control of Klamath Weed. *J. Econ. Ent.* **44**: 244-7.
- _____. 1953. Establishment of a root borer and a gall fly for control of Klamath Weed. *J. Econ. Ent.* **46**: 65-7.
- Ivanova, T.S. 1966. Biological control of mountain bluet (*Acroptilon picris* C.A.M.) (in Russian). *Izv. Acad. Nauk. Tadzhik. SSR Otdel. Biol. Nauk.* **2**: 51-63.
- Johansen, C.A. 1957. History of biological control of insects in Washington. *Northwest Sci.* **31**: 57-79.
- Johnson, E. 1932. The puncture vine in California. *Univ. Calif. Agric. Exp. Sta. Bull.* **528**: 42 p.
- Julien, M.H. 1982. Biological Control of Weeds: A World Catalogue of Agents and Their Target Weeds. *Commonw. Inst. Biol. Contr.*, Slough, U.K., 108 p.
- Khan, A.G., and Baloch, G.M. 1976. *Coleophora klimeschiella* (Lepidoptera: Coleophoridae) — a promising biocontrol agent for Russian thistles, *Salsola* spp. *Entomophaga* **21**: 425-8.
- Kirkland, R.L., and Goeden, R.D. 1978a. Biology of *Microlarinus lareynii* (Col.: Curculionidae) on puncturevine in southern California. *Ann. Ent. Soc. Amer.* **71**: 13-8.
- _____. 1978b. Biology of *Microlarinus lypriformis* (Col.: Curculionidae) on puncturevine in southern California. *Ann. Ent. Soc. Amer.* **71**: 65-9.
- Maddox, D.M. 1976. History of weevils on puncturevine in and near the United States. *Weed Sci.* **24**: 414-9.
- Mendes, R.S. 1981. Effectiveness of *Cystiphora schmidti* (Rübsaamen) (Diptera: Cecidomyiidae) as a biological control agent of rush skeletonweed, *Chondrilla juncea* L., in eastern Washington. M.S. thesis, Washington State Univ., Pullman, WA.
- Persson, P.I. 1963. Studies on the biology and larval morphology of some Trypetidae (Dipt.). *Opusc. Ent.* **28**: 33-69.
- Peschken, D.P., and Harris, P. 1975. Host specificity and biology of *Urophora cardui* (Diptera, Tephritidae), a biological control agent for Canada thistle (*Cirsium arvense*). *Can. Ent.* **107**: 1101-10.
- Polunin, O. 1969. Flowers of Europe. A Field Guide. Oxford Univ. Press.
- Rees, N.E. 1978. Interactions of *Rhinocyllus conicus* and thistles in the Gallatin Valley. In: Biological Control of Thistles in the Genus *Carduus* in the United States. A Progress Report. Frick, K.E. (ed.). USDA-SEA, New Orleans, LA, pp. 31-8.
- Schroeder, D. 1980. The biological control of thistles. *Biocontr. News Info.* **1**: 9-26.
- Shorthouse, J.D., and Watson, A.K. 1976. Plant galls and the biological control of weeds. *Insect World Digest* **3**: 8-11.

- Wapshere, A.J. 1970. The assessment of biological control potential of the organisms attacking *Chondrilla juncea* L. Proc. I Int. Symp. Biol. Contr. Weeds, March 6-8 1969, Delemont, Switzerland. Simmonds, F.J. (ed.). *Commonw. Inst. Biol. Contr. Misc. Publ. No. 1*: 81-9.
- _____. 1973. Recent work on the assessment of the biological control potential of the *Chondrilla juncea* organisms. Proc. II Int. Symp. Biol. Contr. Weeds, October 4-7 1971, Rome, Italy. Dunn, P.H. (ed.). *Commonw. Inst. Biol. Contr. Misc. Publ. No. 6*: 95-112.
- Wehling, W.F. 1984. Biology and ethology of *Mesopolobus* sp. (Hymenoptera: Pteromalidae), a parasitoid of *Cystiphora schmidti* (Rübsaamen) (Diptera: Cecidomyiidae), a biocontrol agent of rush skeletonweed, *Chondrilla juncea* L., in eastern Washington. M.S. thesis, Washington State Univ., Pullman, WA.
- Wilson, F. 1943. The entomological control of St. Johnswort (*Hypericum perforatum* L.) with particular reference to the insect enemies of the weed in northern France. *Aust. Coun. Sci. Indus. Res. Bull.* **169**: 1-88.
- Zwölfer, H. 1976. Investigations on *Sphenoptera (Chilostetha) jugoslavica* Obenb. (Col., Buprestidae), a possible biocontrol agent of the weed *Centaurea diffusa* Lam. (Compositae) in Canada. *Z. Ang. Ent.* **80**: 170-90.