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Present Status of Biological Control of the Weed Gorse (*Ulex europaeus* L.) in Hawaii

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Abstract

In Hawaii, the weed gorse (*Ulex europaeus*) is a range, forest and urban problem covering 15,000 ha at elevations between 750 and 2,000 m. After an unsuccessful release of a seed weevil in 1926, efforts at biological control began in earnest in the 1950s. After evaluating more than 10 species of insects, three were released: the seed weevil, *Apion ulicis*; a gall forming weevil, *A. scutellare*; and an unidentified weevil, *Apion* sp. (possibly *uliciperda*). Surveys in the 1960s and early 1980s indicated that only *A. ulicis* became established. On the island of Maui, *A. ulicis* attacked an average of 52% of the pods in 1984. On the island of Hawaii, *A. ulicis* was released in 1956 and declared established by 1962. Exterminated in the mid-1970's by a gorse control program, it was reintroduced in 1984, and is now well-established. In 1986, efforts at biological control were resumed, and the moth, *Agonopterix ulicetella*; a lace bug, *Dictyonota strichnocera*; and a thrips, *Sericothrips staphylinus*; are now in quarantine and undergoing testing.

Introduction

Gorse, *Ulex europaeus* L. (Leguminosae), is a spiny, dense growing shrub native to western Europe. Originally considered beneficial as browse for sheep and goats or as a hedge to contain livestock before barbed wire (Jobson and Thomas 1964), it was spread by European settlers to other parts of the world, where it soon escaped from cultivation to become another introduced weed. The thick, impenetrable stands formed by this plant limit access by humans and domestic animals, replace native vegetation and grasses on rangeland (Hill 1983, Sandrey 1985), and interfere with reforestation and forest management (Balneaves and Zabkiewicz 1981, Hermann and Newton 1968, Zabkiewicz 1976). The shrub is highly flammable. An infestation adjacent to and on vacant lots in Bandon, Oregon, is credited with carrying a wildfire that destroyed the town in 1932 (Holbrook 1943).

Gorse is found in 17 countries or island groups outside of western Europe. It is considered a serious problem in Australia, Chile, New Zealand, and in the United States, the Oregon coast, and in Hawaii (Holm *et al.* 1979). In Hawaii gorse is established on only two islands (Degener 1975): Maui, where the infestation is scattered over 5,985 ha with a dense core area of 1,277 ha; and Hawaii, where it is distributed over 8,262 ha with a dense infestation on 2,509 ha (Markin *et al.* 1988).

In Hawaii, efforts at biological control began in 1926 with the unsuccessful attempt to introduce a seed weevil. A major effort was conducted in the 1950s and resulted in release of three potential biological control agents. By 1980, however, continual spread of this weed and a new awareness of its potential threat to other parts of Hawaii, lead managers to again try biological control.

This paper reviews the history of early efforts based on unpublished Hawaii Department of Agriculture records, describes the status of the three insects that have been introduced, and outlines progress to date in the latest efforts at control.

Earlier Release in Hawaii

Apion ulicis *(Forster) (Coleoptera: Apionidae)*

In 1926, about 500 adult weevils collected near London, England, where released on Maui (Table 1), but did not become established. Release of the same strain of English weevils in 1931 in New Zealand, however, were successful (Julien 1982). Subsequent efforts to introduce the weevil to Hawaii used material collected from New Zealand in 1949, 1951, and 1952. A few adults were seen at the release site in 1953, but none later and all attempts were considered unsuccessful.

After four unsuccessful attempts to introduce an English strain of weevil to Hawaii, the Hawaii Department of Agriculture concluded that the failures were possibly due to the strain not being suitable to Hawaii's climate. In 1955 and 1956 a more "southern" strain was obtained from France and released. By 1962, *A. ulicis* was reported established on both islands.

On Maui, *A. ulicis* was recovered throughout the range of gorse by 1972, but at low numbers, only 1.5% of pods were attacked. We conducted a survey for this weevil on Maui in 1984. Adults were highly abundant over the entire range of gorse, with 52% of pods attacked, although at some sites attacks exceeded 80%. Subsequent surveys over the next 2 years have shown a major decline in rate of attack to 1.5% in December 1986, that has since increased to about 20% in December 1987, that appears to be neither seasonal or related to abundance of flowers and new pods.

A parasite, *Eupelmus cushmani* (Crawford) (Hymenoptera: Eupelmidae), attacks late larvae and pupa, but rate of parasitism is so low (<5%) that we felt it was incapable of causing the decline observed. Adult weevils collected on Maui in November 1986 (Hill, R.L., pers. comm., 1987), when they were at the low point in the weevil decline, soon died and were observed to have fungal (possibly *Hirsutella* sp.) fruiting bodies. A pathogen may have been involved in the observed population cycle.

On the island of Hawaii, we conducted an intense survey in the winter of 1983-84, but found no sign of the weevil, although we identified and resurveyed the original release site. The release site on the island of Hawaii was a small island of soil surrounded by fresh lava flows and 3 km from the main gorse infestation. In discussions with State weed control workers, we learned the site had been treated with herbicides in 1976-77 and then burned. Since then gorse has regenerated, probably from seeds in the soil. The weevil apparently had not migrate the 3 km to the main gorse stand and apparently was eradicated during the control program. In 1984 we successfully reestablished the weevil on the island of Hawaii by using weevils collected from Maui.

Incidental observations during our study turned up an unusual difference between *A. ulicis* in Hawaii, and in England and New Zealand. In England and New Zealand, gorse apparently has two periods of flowering each year, a major bloom in spring that lasts 2 months and a minor bloom in fall that lasts 1- 2 months (Miller 1970), although a few flowers can be found during the rest of the year. In contrast, we found that in Hawaii, flowering begins in early winter (November), peaks from January through May, tapers off in July through August, and reaches a low point from August to October. Flowers, however, are never totally absent at anytime.

The weevil in England and New Zealand is univoltine with its' single generation a year synchronized with the spring bloom of flowers. After emerging, adults apparently hibernate or at least are inactive and not feeding for the rest of the summer and winter (Cowley 1983, Davies 1928, Miller 1970). In Hawaii, adult weevils are active year-round, and feeding is often abundant enough to provide some plants a distinct greyish tint. The weevil also appears to be multivoltine because eggs and feeding larvae can be found in green pods year-round. It is not known whether this difference in weevil biology represent an adaption of the weevil since its introduction to Hawaii or is a characteristic of the French strain which was its source.

Table 1. Releases of the gorse seed weevil, *Apion ulicis* (Forster), in Hawaii (unpublished data, Hawaii Department of Agriculture).

Date	Origin	Successful	Number released	Where released
1927	Near London, England	No	±500	Olinda, Maui
1949	New Zealand	No	1500	Olinda, Maui
	(orig. England)		500	Humuula Sheep Station, Hawaii
1951	New Zealand	No	3600	Olinda, Maui
	(orig. England)		3000	Humuula Sheep Station, Hawaii
1952	New Zealand	No	300	Olinda, Maui
	(orig. England)		3000	Saddle Road, Hawaii
1955	Southern France	Probably	970	Parker Farm, Maui
1956	Southern France	Yes	1335	Saddle Road, Hawaii
			1620	Olinda, Maui

Apion *sp.*

After the failure to establish *A. ulicis* in Hawaii after four attempts, surveys for a more suitable strain were begun in 1954. A similar appearing, but larger, gray weevil that attacks the pods was collected in 1957 in Spain and Portugal by Hawaii's Department of Agriculture Entomologist C.J. Davis. The Hawaii Department of Agriculture confirmed that they were not *A. ulicis*, but apparently a closely related species, possibly *A. uliciperda* Pandelle. Subsequently, 130 weevils were released near Olinda on Maui on July 9, 1958 (Davis 1959). Surveying at the release site in 1959 and 1962 indicated the weevil had not become established. Surveys were discontinued after 1962 because *A. ulicis* had been released nearby in 1955-56 and had become established in the same area. Our resurvey of the same area in 1984-87 found no evidence of a second species of *Apion* attacking gorse pods.

Apion scutellare *Kirby*

The third insect released against gorse in Hawaii was another *Apion* species, but this one attacked growing shoots forming galls. Adult weevils reared from gall collected in Portugal by F. Azevedo e Silva were shipped to Hawaii, and 176 adults released near Olinda, Maui in 1961 followed by a second release of 10 adult weevils in 1962 (Davis and Krauss 1962, 1963). It is unknown if they became established since the release site was burnt shortly afterwards, but all subsequent surveys, including ours in 1984-87, have failed to detect any sign of this weevil or its galls.

Other insects considered

Owing to the failure to establish *A. ulicis* 1949-52, the Hawaii Department of Agriculture focused on finding other potential biological control agents. A major effort was begun in 1954, and a large number of candidate insects were submitted to Hawaii for testing and consideration, besides the three *Apion* spp. (Table 2). Incidental to other work, surveys in Europe in 1954 to 1956 were conducted by State of Hawaii Exploratory Entomologist N.L. Krauss. Besides *A. ulicis* collected in France, several other insects were shipped to a small quarantine facility located at Kaumana above Hilo on the island of Hawaii.

In 1958, a new quarantine facility specifically for gorse was established near Olinda on the island of Maui (elevation 1,000 m.) and Ernest Yoshioka assigned to its operation. State of Hawaii Exploratory Entomologist C.J. Davis was also assigned to work full-time on gorse. And he spent the spring and summer of 1958 in Europe and Morocco, Africa, although most of his work was conducted in Portugal, which was felt climatically might be the most compatible to the Maui gorse infestation. In all, 24 separate shipments of gorse insects were

made to Hawaii in 1958. From 1959 to 1962, N.L. Krauss continued foreign exploration for gorse insects, but eventually contracted F. Azevedo e Silva to continue the work in Portugal. From 1962 to 1967, Azevedo e Silva made an additional 32 shipments of insects to Hawaii.

Table 2. Insects shipped to Hawaii, other than species of *Apion* (Table 1) 1956-67, as potential biological control agents of gorse.

Date	Origin	Species	Collector
1954	England	*Depressaria umbellana* (Lepidoptera: Oecophoridae) (now *Agonopterix ulicetella*)	Unknown
1956	England	*Laspeyresia ulicetare* (Lepidoptera: Tortricidae) (now *Cydia lathyrana*)	Krauss
	England	*Anarsia spartiella* (Lepidoptera: Gelechiidae)	Krauss
		D. umbellana (Lepidoptera: Oecophoridae)	Krauss
1957	Spain	Unidentified weevil (Coleoptera: Curculionidae)	Davis
1958	Portugal and Spain	*Agromyza* sp. (Diptera: Agromyzidae)	Davis
		Chlorophorus trifasciatus (Coleoptera: Cerambycidae)	Davis
		D. umbellana	Davis
		Deilus fugax (Coleoptera: Cerambycidae)	Davis
		Acmaeodera adspersula (Coleoptera: Buprestidae)	Davis
		L. ulicetana	Davis
		Anarsia spartiella (Lepidoptera: Gelechiidae)	Davis
		Unidentified Lepidoptera	Davis
1959	Portugal	*Anarsia spartiella* (Lepidoptera: Gelechiidae)	Krauss
		Unidentified inchworm (Lepidoptera: Geometridae)	Krauss
1960	Portugal	Three unidentified spp. from flowers (Lepidoptera)	Krauss
	England	One unidentified sp. from seed pods (Lepidoptera)	Krauss
	Spain	*C. trifasciatus* (Coleoptera: Cerambycidae)	Krauss
1962	Portugal	Yellow caterpillar from seed pods (Lepidoptera)	Krauss
1964-67	Portugal	*Nephoteryx genistella* (Lepidoptera: Pyralidae)	e Silva
		C. trifasciatus (Coleoptera: Cerambycidae)	e Silva

Besides the three *Apion* spp. eventually released, over 10 other insect species were submitted for consideration (Table 2). Most did not survive in quarantine long enough to be host tested, but two species however were considered to be promising: a moth that fed on new shoots of gorse, *Depressaria umbellana* Steph. (Lepidoptera: Gelechiidae), and a root boring cerambycid beetle, *Chlorophora trifasciatus* F. ((Coleoptera: Cerambycidae)). Neither species could be established and propagated in quarantine, and so both were eventually dropped without being released.

Present Program

With the realization of the high continual cost of yearly control programs for gorse on Maui, and its continual spread on the island of Hawaii, a cooperative program involving state and federal agencies and private landowners was undertaken in 1984 to renew efforts at gorse biological control. Such efforts were coordinated with a larger ongoing gorse biological control program being conducted in New Zealand by the Division of Science and Industrial Research (DSIR).

We received our first shipment of gorse insects, the gorse tip moth, *Agonopterix ulicetella* (Stnt.) (Lepidoptera: Oecophoridae) from New Zealand (it had originated in England near London) in 1986. The moth had already been host tested in New Zealand (R.L. Hill, pers. comm. 1986), but was found unsuitable because it could develop on a plant closely-related to gorse, an introduced European shrub tree lucerne or Taganaste, (*Chamaecytisus palmensis*) (Leguminosae) being promoted in New Zealand for grazing (deLacy 1983). Fortunately the same shrub has not been introduced to Hawaii, and our host tests have shown that *A. ulicetella* cannot develop on any of our introduced or native legumes. We are presently applying for permission for its release in Hawaii. While examining the Hawaii Department of Agriculture's insect collections, we discovered that *A. ulicetella* was synonymous with *D. umbellana*, which had originally been considered one of the more promising insects in the earlier program, but could not be propagated in quarantine. Our success was probably due to use of environmental chambers to break overwintering diapause.

Two additional insects are presently in quarantine in Hawaii and undergoing host testing: the lace bug, *Dictyonota strichnocera* (Fieber (Hemiptera: Tingidae), and a foliage-feeding thrips, *Sericothrips staphylinus* Hal. (Thysanoptera: Thripidae). We are cooperating with New Zealand's DSIR to support the work of Dr. D. O'Donnel, CAB International, Silwood Park, England, in evaluating additional insects.

Conclusion

The total area infested by gorse in Hawaii is relatively small (only 15,000 ha). But the continual cost of control, steady expansion of its range on the island of Hawaii, and the threat it poses to ranchland and native ecosystems on other islands has generated support for a new control program. Work done in the 1950s and 1960s suggests a large number of promising biological control candidates exist. With the completion and certification of a new insect quarantine facility at Hawaii Volcanoes National Park on th island of Hawaii in 1984, and eventual completion of a newer plant pathogen quarantine facility at the Hawaii Department of Agriculture's complex in Honolulu (where the first project will be pathogens of gorse), these new efforts at control of gorse should prove successful.

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