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Biological control of gorse in Hawaii

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Abstract. In 1926 and again in the 1950s, researchers attempted biological control of gorse in Hawaii. Both efforts proved unsuccessful and a new programme was initiated in 1984 and completed in 1995. Four agents have been released and are established. The seed-weevil *Apion ulicis*, the only agent successfully established during the earlier programmes, is now established on two islands and is attacking up to 85% of the pods. The moth *Agonopterix ulicetella*, released in 1988, is established and is causing conspicuous defoliation. The thrips *Serciothrips staphylinus*, released in 1991, is established at all release points, but its natural spread through the gorse areas is slow. The mite, *Tetranychus lintearius*, was released in 1995 and is now established. A fifth agent, the moth *Pempelia genistella*, has been approved and is scheduled for release in 1996. Before considering introduction of additional agents, we plan to continue monitoring the five agents to determine if they will satisfactorily control gorse.

Introduction

Gorse, *Ulex europaeus* L. (Fabaceae), is a spiny, dense-growing, woody shrub native to western Europe that was introduced into Hawaii during the early part of this century. At mid-elevations (1000-2000 m), gorse has become well established on pasturelands and open forests on the islands of Maui and Hawaii (Markin *et al.* 1988). Gorse was targeted for biological control in Hawaii in 1926 and again in the 1950s, but these early efforts resulted in the successful establishment of only one biocontrol agent, the seed-feeding weevil *Apion* (*Exapion*) *ulicis*. A review of these earlier biocontrol efforts has been published (Markin and Yoshioka 1989). The establishment of *A. ulicis* has reduced the production of gorse seed and may have played an important role in a successful containment programme for gorse on Maui, but has had little impact on existing stands of gorse. Therefore, a new effort at biological control for gorse was undertaken in 1984. Fortunately, New Zealand had begun a programme to achieve biological control of gorse in the late 1970s. Their work greatly simplified ours and provided the basis for a very successful international co-operative programme which eventually also included the state of Oregon (United States of America). The Hawaii programme was completed in 1995, at which time eight agents had been considered, five released, and a sixth scheduled for release in 1996 (Table 1). In this paper we review the results of the current campaign.

Agents released in Hawaii

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

Successfully introduced to the island of Maui in 1956, this seed-pod-attacking weevil was soon established on all parts of the gorse range (Markin and Yoshioka 1989). During the present programme, it consistently attacked 80-95% of the gorse pods through most of the range of the weed. However, at elevations below 1000 m, *A. ulicis* populations fluctuated greatly, and attack of new pods ranged from 5-85%. The variations in the weevil populations resulted from periodic outbreaks of a fungal pathogen, *Hirsutella* sp., which killed the adult weevils. A parasite, *Eupelmus cushmani* (Crawford) (Hymenoptera: Eupelmidae), attacked late-instar larvae and pupae at low elevations

Table 1. Summary of biological control agents released or tested during the 1984-1995 gorse programme in Hawaii. * - released on island of Hawaii, already established on Maui.

Agents	Year released	Year established	Status
Apion (Exapion) ulicis	1984*	1985	78% of pods attacked
Apion (Perapion) scutellare	1989-1991		not established
Agonopterix ulicetella	1988	1989	conspicuous damage
Sericothrips staphylinus	1990	1992	well established, spreading
Tetranychus lintearius	1995	1995	unknown
Pempelia genistella	1996(?)		releases planned
Dictyonota strichnocera	not released		
Anisoplaca ptyoptera	not released		

on Maui, but parasitism never exceeded 5%.

On the island of Hawaii, *A. ulicis* was introduced in 1956, declared established in 1962, but was accidentally exterminated in a subsequent gorse control programme (Markin and Yoshioka 1989). Since this weevil was not found on the island of Hawaii at the beginning of the present programme, approximately 10000 adults were reintroduced from the island of Maui in 1984. The weevil readily established at eight of the ten release sites, successfully reached all parts of the gorse range by 1993, and was attacking 78% of the pods by 1994 (Markin and Yoshioka in press).

In Hawaii, adults of *A. ulicis* feed on the older gorse foliage throughout the year. At the end of winter, in areas with high weevil-populations, cumulative feeding-damage was often extensive enough to turn the plants grey. At this time, local outbreaks of a pathogenic fungus, *Colletotrichun* sp., frequently occurred, discolouring the plants and occasionally killing shoots or entire branches. We suspect that adult feeding may make the plants more susceptible to this ubiquitous pathogen. Huffaker (1964) also surmised that feeding by adult *A. ulicis* killed some gorse stands in California. We speculate that the importance of adult feeding was overlooked in the past and needs further investigation.

Apion (Perapion) scutellare *(Kirby) (Coleoptera: Apionidae)*

Females of this larger gall-forming weevil insert their eggs into soft, growing gorse-shoots in spring. The resulting galls (1-1.5 cm in diameter) reduce or halt further shoot growth. This agent was unsuccessfully released in the 1950s programme (Markin and Yoshioka 1989) and was reintroduced during the present programme. All releases were on the island of Hawaii and were of adults reared from galls collected in north-western Spain. Adult weevils were introduced onto young plants in areas that were recently-burned or that had regenerating stands of the weed. Releases were made in 1989 (100 adults), 1990 (643 adults), and 1991 (45 adults). This effort to establish *A. scutellare* was again unsuccessful. While adults lived in field cages for up to three months, no galls were found during subsequent surveys of the release sites.

Agonopterix ulicetella *(Stainton) (Lepidoptera: Oecophoridae)*

Adults of this moth over-winter within the dense foliage at the centre of the gorse plants and emerge in early spring (April-May) to oviposit in the new shoots. The developing larvae begin feeding in the tips of the shoots, but as the shoot grows beyond them, they construct a feeding shelter and continue feeding on the developing green spines (Hill *et al.* 1995). An initial release of 500 adults was made in November 1988. A mass-rearing programme allowed over 5000 adults to be released in the spring and summer of 1989 and 1990. By 1995, *A. ulicetella* had reached all parts of the gorse range. Several of the initial release sites contained at least one or more larvae per shoot in areas up to 100 ha. Their extensive feeding damage was conspicuous.

The population's rapid increase on the island of Hawaii occurred despite the presence of three pupal parasites, *Pimpla punicepes* (Cresson), *Gambrus ultimus* (Cresson), and *Melanichneumon rubricundus* (Cresson) (Hymenoptera: Ichneumonidae). The first *A. ulicetella* pupae in June displayed few signs of parasitism, but as summer progressed, parasitism increased until it reached 90% in the last cohort of pupae in September. Despite this parasitism, the population increased by almost ten-fold during some years. An intensive survey failed to reveal any larval parasites; however, eggs were attacked rarely by

Trichogramma sp. (Hymenoptera: Trichogrammatidae).

At high elevations (>1000 m), the populations of *A. ulicetella* on Maui have paralleled the performance of those on the island of Hawaii, causing extensive defoliation. However, the species has failed to become established at low elevations (<1000 m).

Sericothrips staphylinus *Haliday (Thysanoptera: Thripidae)*

This small (1 mm), flightless thrips has multiple generations, each requiring approximately 60 days, during the summer. In Hawaii's mild winters, the species remains reproductively active and nymphs are found at all times of the year. Initial specificity-testing was done in England (Hill 1990) and completed in quarantine in Hawaii. The first release was made in 1990 at five sites on the island of Hawaii. The insects became established at each site although it often took two years before populations built up significantly. From 1991-1993, a colony was mass-reared at Hilo, Hawaii, and an average of 1000 additional thrips were released monthly in the gorse area. Mass-rearing was discontinued in 1994 when field populations were high enough to allow redistribution from established colonies. The thrips has moved slowly, spreading 100-500 m in five years. In 1995, populations at the core of the release sites numbered 5-10 thrips per 15-cm gorse shoot, but were not sufficiently abundant to cause noticeable damage.

Tetranychus lintearius *(Dufour) (Acari: Tetranychidae)*

This gorse mite is a highly gregarious species that resembles the common red spider mites, *T. urticae* and *T. turkestani*, from which it is reproductively isolated (Hill and O'Donnell 1991b). On infested gorse bushes, large colonies spin a protective silk sheath over part of a bush, which protects the colonies as they pierce and feed on the cell contents of the spines and stems (Hill *et al.* 1991a).

The quarantine facility in Hawaii was not adequate for containing mites, so all host-testing was conducted in Europe and in New Zealand (Hill and Gourlay 1993; Hill and O'Donnell 1991a). In New Zealand, the agent was released in 1989 and is now established (Hill *et al.* 1991). The population released in Hawaii was obtained from New Zealand through Oregon (USA) where it was introduced and established in 1994. This mite was received in Hawaii in June 1995 and used to establish a laboratory colony, then subsequently released at 26 field sites between late July and August on the island of Hawaii. Three months later, the mite was established in small colonies at most of the release sites that were checked. The mite has also been released on the island of Maui and is believed to be established. In Oregon, where the mite was introduced in the fall of 1994, populations remained small and inconspicuous during the winter. The populations increased the following spring and then exploded during the summer, causing extensive damage (E. Coombs personal communication 1995). We hope that the mite populations in Hawaii will follow the same pattern.

Agent to be released in 1996

Releases of *Pempelia genistella* (Duponchel) (Lepidoptera: Pyralidae) are planned for the spring of 1996. In Europe, the over-wintering larvae of this moth pupate in early June. Adults emerge in late June and early July and lay eggs on the older spines near the base of the growing shoots of gorse. The larvae feed on mature spines and grow through the fall (autumn) and winter. They often feed gregariously with three to six larvae enclosed in a 10-cm bundle of silk, frass and cut-gorse spines, at the base of the shoot. Their feeding often girdles and kills the branch. The life cycle and ecological niche of *P. genistella* marginally overlaps that of *A. ulicetella*. *Agonopterix ulicetella* usually feed near the terminal ends of the new shoots in summer, while *P. genistella* larvae feed in winter near the base of the shoot.

We found *P. genistella* through most of gorse's range in Europe, but it was only abundant on Portugal's coast, north of Lisbon, the source of colonies tested and to be released in Hawaii. Release of *P. genistella* was approved in 1995 but too late in the season for releases to be made that year.

Insects tested but not released

In our 10-year study, at least 20 other potential agents were collected and evaluated in the field. However, only two were studied abroad and later tested in quarantine on native Hawaiian plants.

In England, the lace bug, *Dictyonota strichnocera* (Fieber) (Hemiptera: Tingidae), is a common insect associated with gorse. Nymphs and adults feed by sucking fluids from the mesophyll tissue of the current-year's foliage (Brown 1981). Initial studies in England and subsequent tests in quarantine in New Zealand

revealed that *D. strichnocera* could only develop on plants in the leguminous tribe, Genisteae, to which gorse belongs and which has no natural or economically important representatives in Hawaii. Unfortunately, in quarantine in Hawaii, *D. strichnocera* oviposited and developed to adulthood on two native woody legumes, *Sophora chrysophylla* (Salisb.) and *Acacia koa* Gray. While development was protracted and survival was less than that on gorse, the potential threat to these important forest trees was enough to merit discontinuation of testing.

The larva of the moth *Anisoplaca ptyoptera* Meyrick (Lepidoptera: Gelechiidae) mines the branches of gorse, usually girdling and killing them (Butler 1974). *Anisoplaca ptyoptera* is endemic to New Zealand, where it feeds on species of legumes in the tribe Carmichaeliae, but it has accepted gorse as a host plant (Holden 1990; Hoddle *et al.* 1991). Because of our desire to have a stem-mining agent as part of the biocontrol complex on gorse, and because none of the legume genera or tribes that *A. ptyoptera* feeds on in New Zealand are native- or economically-important plants in Hawaii, we believed that this agent might be restricted to gorse in Hawaii. Unfortunately, during quarantine tests in Hawaii, *A. ptyoptera* also laid eggs on the native Hawaiian leguminous trees, *S. chrysophylla* and *A. koa*. The larvae readily fed on these plants and consequently the species may not be considered further.

Conclusion

Diminished funding and support for the gorse programme in Hawaii in 1994 led to the cessation of all foreign exploration and quarantine work in the spring of 1995. However, with the establishment of four biocontrol agents by 1995 and the approval and planned release of *P. genistella* in 1996, the natural-enemy complex has a good chance of severely impacting gorse. The population increase and damage caused by *A. ulicetella* and the impact of *T. lintearius* in New Zealand and Oregon lead us to believe that these two agents will spread through most of the gorse areas in Hawaii and will prove to be highly damaging to the plants. Feeding damage caused by *S. staphylinus* and *P. genistella* (once it is released) during the winter season, may complement the summer damage caused by *A. ulicetella* and *T. lintearius*. The combined effect of these new agents, along with *A. ulicis*, should stress the gorse plants enough to reduce the plants' rate of growth and halt regeneration. The gorse programme in Hawaii has therefore shifted to monitoring the population changes and impact of the five agents on the target weed.

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