

Status of Biological Control of the Shrub Gorse (*Ulex europaeus*) on the Island of Hawaii

G. P. Markin¹ and P. Conant²

¹USDA Forest Service, Rocky Mountain Research Station, Bozeman, MT USA 59717
gmarkin7039@yahoo.com

²Hawaii Department of Agriculture, Hilo, HI USA 96720, Pat.Conant@hawaii.gov

Abstract

On the island of Hawaii, gorse (*Ulex europaeus* L.) is limited to an isolated core infestation of approximately 2000 hectares with scattered plants and small patches in the surrounding 10,000 hectares. Between 1985 and 2000, seven biological control agents were introduced, five of which successfully established. By 2000, their combined impact had reduced the yearly growth of new shoots by over 50%. In 2001/2002, the ranch leasing the area decided to solve the gorse problem with an area wide program of aerial spraying and burning that destroyed over 95% of the gorse in the core area. With no follow up treatment, within three years the gorse had regenerated and was as abundant as before the control program. The effect on the complex of biocontrol agents, however, was devastating. One agent disappeared; the distribution and relative abundance of the other four was permanently altered, and their combined impact now appears to be significantly less than before the control effort.

Introduction

Gorse (*Ulex europaeus* L.) [Fabaceae], a spiny, multi-branched shrub of western European origin, at one time was considered useful as hedge rows and for grazing by sheep. As a desirable plant, European colonists spread it around the world, but in almost all new locations, it soon escaped from cultivation. Gorse has become a major weed in over 22 locations (Holmes et al., 1979) and since 1927 has been the target of numerous attempts at biological control (Coombs et al., 2004; Hill et al., 2008). In the state of Hawaii (USA) it was introduced for use as hedge rows to the island of Maui in the late 1800s, but soon escaped cultivation to become a major weed. However, in Maui a major cooperative management program has kept the original infestation suppressed to an acceptable level in the original area. A much

larger population exists on the adjacent island of Hawaii (Markin et al., 1988).

As a major weed problem in the state of Hawaii, gorse has been repeatedly targeted for biological control. The first program in the mid-1920s targeted gorse on the island of Maui. A second program in the late 1950s and early 1960s resulted in the release of three potential agents. The third and most extensive program was a cooperative international effort between the state of Hawaii, the state of Oregon, and New Zealand between 1985 and 2000 (Markin and Yoshioka, 1988; Markin et al., 1996; Markin et al., 2002). This recent program resulted in a total of seven agents being introduced, primarily to the island of Hawaii, of which four are now well established. This report summarizes the eight known agents that have been introduced to the state of Hawaii, their present status, and their impact on gorse.

Agents Released

Exapion (Apion) ulicis (Forster) [Coleoptera: Apionidae]

The biology of this small (2 to 3 mm long) seed-feeding weevil is tightly synchronized with the phenology of gorse. During flowering the adult female chews a hole in the developing green gorse pod and lays her eggs inside where the larvae develop (Crowel, 1983). In temperate England and New Zealand, gorse flowering occurs in late spring or early summer. However, in Hawaii flowering occurs in mid-winter (Markin and Yoshioka, 1996). This weevil was first released on the island of Hawaii in 1926 from a colony collected in Europe but failed to establish. A repeated attempt in 1949 using insects from New Zealand (but originally from Europe) also failed. Realizing the problem was poor synchronization between the weevil and flowering of gorse, the third effort in 1958 succeeded using weevils collected from southern France where the gorse flowered earlier – at the same time as in Hawaii. After establishment on the island of Maui, the weevil was introduced to the island of Hawaii and declared established a few years later. However, in 1983, in a survey of gorse on the island of Hawaii, no evidence of this weevil could be found. Subsequent talks with the entomologist involved in the release (Clifford J. Davis, Hawaii Department of Agriculture) confirmed that the weevil had been established but only on a small isolated pocket of gorse. Apparently a subsequent chemical control program destroyed this pocket before the weevil had had a chance to spread. Accordingly, in 1986 the weevil was reintroduced from the island of Maui (Markin and Yoshioka, 1998). The population, as indicated by the percent of pods being attacked, steadily built up through 1995 when a total of over 70% were attacked. The attack rate remained stable until 2000. A major control program in 2001/2002 destroyed the gorse bringing about a collapse of the weevil population. Gorse within this core area has rapidly regenerated from the coppicing of the burnt stumps and the soil seedbank. However, because of the large size of the area treated, *E. ulicis* has been slow to reinvade and as of 2010 was attacking only 54% of the pods.

Apion sp. (possibly A. uliciperda Pandellé) [Coleoptera: Apionidae]

During the collection of *E. ulicis* in southern France, a second slightly larger seed pod attacking weevil was found as a contaminant in the shipments made to Hawaii and accidentally introduced. In the 1985 to 2000 program, while tens of thousands of pods were opened to monitor *E. ulicis* (Markin and Yoshioka, 1998), no evidence of this second weevil was found.

Apion scutellare Kirby [Coleoptera: Brentidae, formerly Apionidae], the gorse gall weevil

This weevil is considerably larger and darker than *E. ulicis*. In spring when the new flush of foliage has begun to elongate, the female oviposits in the growing shoot tip. The shoot continues to elongate, but within a month, a 1 cm gall forms in which the larva develops. While the gall does not kill the attached shoot, its growth is halted or significantly reduced. In the late 1950s – early 1960s biocontrol program, adult weevils collected in Portugal were released on the island of Maui, but did not establish. In the recent effort, adults collected in late winter in northeastern Spain were shipped to Hawaii and held on potted gorse plants in quarantine until oviposition was observed, then directly released in the field. A total of nearly 800 adults were released 1989-1991 (Markin et al., 1996), but an effort to establish a laboratory colony failed and no further releases were attempted. To date, an intensive monitoring of shoots for the presence of other agents has failed to detect any sign of galls and we presume this weevil did not become established.

Agonopterix ulicetella (Stainton) [Lepidoptera: Oecophoridae]

In the recent program, New Zealand had already begun testing this moth and provided a colony to Hawaii which was tested and released in 1988. The larvae spin a silk feeding shelter on the elongating shoot in early summer from which they emerge to feed on the adjacent gorse spines. The feeding strips the spines from several inches of the shoot and

attack by multiple larvae can totally defoliate a shoot and kill the developing tip. On the island of Hawaii, *A. ulicetella* readily established and rapidly spread through the gorse area. Populations estimates based on the number of silk feeding shelters per square meter of gorse bush surface showed a continued population build up through 2000. An aggressive area-wide chemical/burning control program in 2001/2002 devastated the moth's population, but being a strong flier it readily reinvaded the treated area after the gorse resprouted. Its population now seems to be increasing and each year we find numerous pockets where larvae are abundant enough they totally defoliate the new flush of foliage. Unfortunately larval feeding is over by mid-July, but the plants continue to put out new vegetative growth during the remainder of the summer which soon hides the feeding damage.

***Sericothrips staphylinus* Haliday**
[Thysanoptera: Thripidae]

This small, normally wingless thrip (1 to 1.5 mm) was selected as a potential biocontrol agent because of its rapid life cycle (a generation per month during the summer) and also the advantage that occasionally alate forms are produced, facilitating dispersal. We had high hopes for the thrips when released in 1991-1992 using colonies obtained in southern England, western France, and central coastal Portugal. The colonies all readily established and, through a redistribution program, by 1995 had spread throughout the gorse infestation. Unfortunately after an early and rapid buildup, the population leveled off at only two to five thrips per branch when beaten into a plastic pan. During beatings the most obvious predator were two species of anthochorid, which in the laboratory readily attacked and fed on the thrips and are suspected of being the primary predators suppressing them.

***Tetranychus lintearius* Dufour**
[Acari: Tetranychidae]

After host testing in Silwood Park, England, the mite was released in New Zealand in 1989. Colonies from New Zealand were sent to the USDA quarantine in Albany, California in 1994 and released in Oregon by the Oregon Department of Agriculture. In the

spring of 1995, an Oregon colony was sent to the Hawaii Department of Agriculture in Honolulu where after two generations in quarantine, they were shipped to the island of Hawaii and released in the summer of 1995. The mite readily established and by 1996, a population explosion was underway. The small (0.4 mm) bright red females feed gregariously in bright red clumps of several hundred that migrate up the gorse shoot, spinning a protective web that covers the colony as it moves. A similar explosion had first been noted in New Zealand but after a few years, attack by a coccinellid beetle, *Stethorus punctillum* Weise, brought about a collapse. In Oregon after four years, the combined attack of this beetle and a predatory mite, *Phytoseiulus persimilis* Athias-Henriot, also devastated the population (Coombs et al., 2004). In Hawaii through 2001, we hoped our isolated population would escape these predators. Unfortunately, in 2001/2002, a major control effort temporarily eliminated gorse over most of the core gorse area and coincided with a collapse of the mite population. While numerous small colonies can still be found, particularly during mid and late summer, the massive sheets of webbing formed by the huge colonies that we had seen previously are no longer present. No evidence of *S. punctillum* has been found but the predatory mite *P. persimilis* is present and is probably the suppressing factor.

***Pempelia genistella* Duponchel**
[Lepidoptera: Pyralidae]

Larvae of the first moth, *A. ulicetella*, are active only during the first half of the flush of new foliage in early summer. It was therefore our desire to find a biocontrol agent which would be active later in the summer and attack the remaining new foliage. The potential agent selected was another moth, *P. genistella*, from the coast of Portugal. Its adults emerge in early summer and lay eggs on the new gorse shoots. The larvae develop slowly and do not begin actively feeding until early fall after the new foliage has hardened. The gregarious larvae form a large silken, trash-laced feeding shelter at the base of the shoot, girdling and usually killing it. Testing began in quarantine in mid 1990s and had just been completed when the project was terminated in 1995. Rather than see this agent dropped after a permit had finally been approved for its release in 1996,

arrangements were made for pupae from Portugal to be sent to the Montana State University quarantine in Bozeman, Montana. Here the adults were allowed to emerge and lay eggs on gorse shoots which were surface sterilized, sent to Hawaii, and tied to gorse plants in the field. In 1996, approximately 1000 *P. genistella* eggs were placed in the field, and this effort was repeated in 1997. By 1998 and 1999, *P. genistella* had become established at two of five sites. These populations remained small and localized through 2000. However, in 2001/2002 all the *P. genistella* sites were sprayed and then burned as part of an area wide control program. Since then, despite intensive sampling, we have failed to find its feeding shelter or distinctive feeding damage and presume the population was eradicated during the control program.

***Uromyces pisi* f. sp. *europaei* Wilson and Henderson [Uredinales]**

Late in the last biocontrol program, this fungus was selected as a potential agent and underwent host testing in the Hawaii Department of Agriculture plant pathogen containment facility in Honolulu. Testing continued even after the insect host testing was terminated in 1995, but was not completed and a permit for its release issued until 2000. In 2000, potted gorse plants infested with the fungus were sent to the island of Hawaii and placed in the field adjacent to healthy gorse plants. Later in the season, what were believed to be the fruiting bodies and symptoms of this disease were seen on several adjacent plants. However, since then, no sign of this disease has been observed in repeated searches.

Results and Discussion

As each new biocontrol agent in Hawaii was established, a method of monitoring its population was developed. However, by 1993 when we knew that three agents were feeding on gorse, a method was needed to measure their cumulative impact. Measuring the annual growth of the new terminal shoots was selected for monitoring overall growth and health of the gorse plants.

Results of this survey from 1994 through 2010 are shown in Figure 1. The decline in growth of the new terminal shoots from 1997 through 2000

corresponds to the steady buildup of the two most common agents, *A. ulicetella* and the gorse mite, although we suspect the spectacular build-up of the mite was the most important factor. The gap for 2001 indicates when a wide scale control program destroyed the gorse at all our sampling sites. The spectacular elongation identified in 2002 and 2003 probably resulted from a flush of nutrients released by the burning. By 2005 four insect agents had begun to re-invade from the outlying, untreated pockets of gorse. The decline in growth of the new terminal shoots from 2006 through 2010 is probably a combination of the exhaustion of the minerals released by the burning and a steady buildup of the agents as their populations recover. Unfortunately without the high populations of the gorse mite, which we feel was having a major impact before the treatment, a new level of yearly growth seems to have been reached but is still greater than before the control event.

The major visible impact we now observe is feeding by *A. ulicetella*. However, the impact of the other two agents, feeding by adult seed weevils and the gorse thrips, cannot be discounted. While their populations are low at any one time, they both are active all year long so their cumulative feeding damage is probably considerably more than would be measured at any one time during the year. In conclusion, there is no evidence that the complex of established biocontrol agents will stop the further growth of gorse, but we are observing an impact on its growth and a reduction in seed production.

Acknowledgements

Over the 15 years of the latest biocontrol effort a very large number of people played a direct or indirect role in the program or in its support. In particular we would like to thank the members of the gorse steering committee who from 1985 through 1995 were instrumental in supporting and guiding the program. During this period, a large number of personnel from Parker Ranch supported our program and provided labor for trail making and building exclosures. We wish to thank Hawaii Volcanoes National Park for the use of their quarantine facility in which much of the biological control testing was conducted. Funding for this program was primarily provided by the

state of Hawaii through special legislations for gorse management between 1985 and 1995 and was administered by the Hawaii Department of Agriculture (HDOA), which was the lead agency on this program. We also wish to acknowledge Dr. Clifford Davis, formerly of HDOA and in charge of the 1950s/1960s biocontrol effort, for his personal input and support for our program and Ernie Yoshioka of the HDOA, who was the senior scientist and manager of this program. Finally, we thank the many personnel of the Dept. of Hawaiian Home Lands, particularly the current manager, Mike Robinson.

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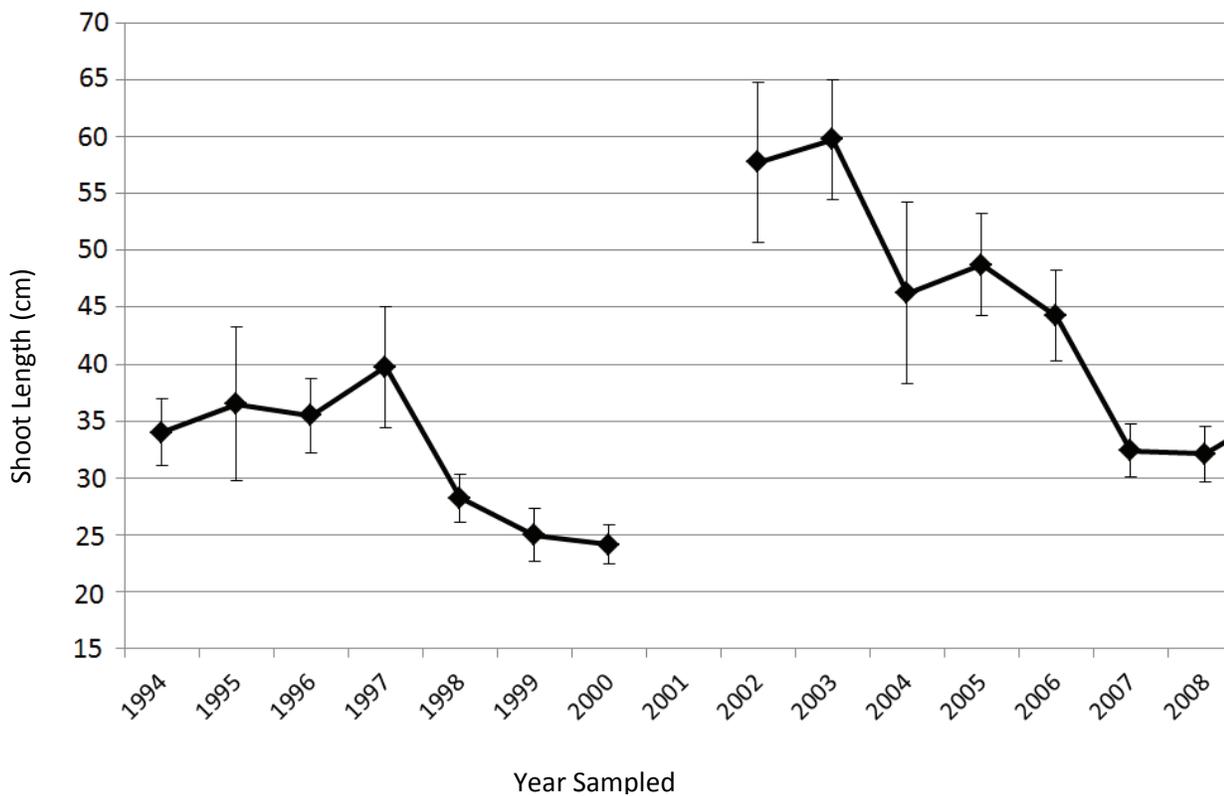


Figure 1. Mean yearly growth in centimeters (and SE) of 300 terminal gorse shoots on the island of Hawaii measured in fall or winter after the summer growth was completed. No sample taken in 2001 because a control program destroyed most of the plants.