BIOLOGICAL CONTROL OF GORSE IN HAWAI'I: A PROGRAM REVIEW

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Abstract. Gorse (*Ulex europaeus*), a spiny, leguminous shrub, has invaded pasturelands and natural ecosystems on Maui and Hawai'i. An interagency effort to implement long-term control of gorse included support for a biological control effort. Between 1984 and 2000, seven insect natural enemies and one plant pathogen were tested, six of which were eventually released in Hawai'i. This paper reviews the history, organization, and cost of this program and the lessons we learned in an attempt to identify information that might be useful in planning similar, future programs.

Keywords: *Apion scutellare, A. ulicis, Agonopterix ulicetella, Anisoplaca ptyoptera, Chlorophorus trifasciatus, Cydia lathyrana, Dictyonota strichnocera, Pempelia genistella, Sericothrips staphylinus, Sitona* spp., *Tetranychus lintearius, Ulex europaeus, Uromyces pisi* f. sp. *europaei*.

INTRODUCTION

Gorse (*Ulex europaeus* L.; Fabales, Fabaceae), a spiny, leguminous shrub from Western Europe, was used extensively to form hedges for containing livestock before the invention of barbed wire. Gorse was distributed widely throughout the world for this purpose but in almost all new localities it quickly escaped from cultivation and became a serious weed (Holm *et al.* 1979). It probably was introduced to Hawai'i around the turn of the century (Degener 1975) and by 1925 was recognized as a serious weed on Maui. At that time, biological control was attempted but none of the introduced agents established (Julien & Griffiths 1998). By the 1950s, the change from sheep- to cattle-ranching on the island of Hawai'i resulted in the realization of gorse as a major weed and another biological control program was undertaken. Fourteen insects were evaluated; most could not be reared in quarantine or failed specificity testing. Only three were released, all weevils of the genus *Apion* (Chrysomelidae: Curculionidae). Only the seed weevil, *A. ulicis* (Forster), became established on Maui but with no noticeable impact on the spread of gorse (Markin & Yoshioka, 1989).

In the absence of an effective complex of biological control agents, prisoners stationed at the Olinda correctional facility were used to control gorse on Maui by manual removal and by planting pines as shade trees. On the island of Hawai'i, chemical control was undertaken between 1976 and 1978, funded through the federal Comprehensive Employment Training Act. This program was so successful that by

1980, gorse was considered controlled and further management efforts dropped on Hawai`i. Unfortunately, no one considered the long-lived seeds in the soil. By 1983, gorse had recolonized the entire original area. In 1984, Department of Hawaiian Home Lands and Parker Ranch attempted to organize a new gorse management program, which included a renewed effort to develop effective biological control agents. By 1996, initial work to find, test, and release a new complex of insect agents had been completed; at least four insect biological control agents were established which attacked different parts of the plant (Markin *et al.* 1996). A plant pathogen was released in early 2000. The program has now shifted to monitoring the impact of these agents on gorse.

A description of the agents and their release in Hawai'i has been presented elsewhere (Markin *et al.* 1996). The purpose of this paper is to review the history and organization of the program and to identify the lessons learned in conducting a biological control program in Hawaiian natural ecosystems.

HISTORY OF PROGRAM: 1980-2000

On October 27, 1983, the "Big Island Resource Conservation and Development Committee", a local program of the USDA Soil Conservation Service (SCS), met at Mauna Kea State Park to discuss the spread and management of gorse on the Big Island. The meeting was followed by a field trip to the Humu'ula infestation on the southeast slopes of Mauna Kea (for a map of the gorse infestations in Hawai`i, see Markin *et al.* 1988). The committee was so impressed by the massive resurgence of a plant everyone believed had been controlled that they formed a gorse-control committee to look into the implementation of a new management program. In recognition of the fact that herbicides would probably be ineffective in limiting the spread of gorse because of the massive seed bank, the committee recommended a renewed biological control effort.

The first official meeting of the Hawai'i Steering Committee on Gorse Control was held in 1983. The Committee reviewed research results including testing of new herbicides, management through burning and grazing, biological control, and a long-term integrated control program. The Committee comprised representatives from Hawaiian Homelands, Parker Ranch, several adjacent ranches infested or threatened by gorse, Hawai'i Department of Agriculture (HDOA), the Hawai'i Division of Lands and Natural Resources, and the U.S. Army Pohakuloa Training Area. The USDA-SCS Resource Conservation and Development (RC&D) Office at Waimea accepted the committee and its program as an official RC&D program, allowing the Committee to solicit funds, write contracts, and submit grant proposals.

For the first year, most effort focused on increasing local awareness of the problem with some attempts at direct control and containment. A previously released agent, the gorse seed weevil (*A. ulicis*), previously established on Maui, was introduced to Hawai'i (Markin & Yoshioka 1989).

Ernest Yoshioka, HDOA entomologist on Hawai'i with previous gorse experience during the 1950's biological control effort and George Markin, entomologist with the USDA Forest Service Institute of Pacific Island Forestry (IPIF) became involved in the gorse control project at this time. While primarily a weed of pastures, gorse also was invading the lower edge of the pukiawe shrub zone on Mauna Kea and its seeds were carried down watercourses into the lower elevation rain forest. Therefore it was judged a suitable weed for study by IPIF. The National Park Service (NPS) was interested in

supporting the program also because gorse was an invasive weed in Haleakala National Park on Maui. Because HDOA had been unable to rear gorse insects in their Honolulu quarantine facility, the gorse biological control agents were evaluated in the new high-elevation quarantine facility at Hawaii Volcanoes National Park.

In the 1980's, the most active biological control program on gorse was being conducted in New Zealand (NZ) under the leadership of Dr. Richard Hill, NZ Department of Scientific and Industrial Research (DSIR, presently Landcare Research). From field exploration in England, he had selected ten insects with the most potential as biological control agents of gorse (Hill 1982). NZ was supporting initial evaluation of several agents in England and *Agonopterix ulicetella* (Stainton) (Lepidoptera, Oecophoridae) was already in quarantine. In 1985, an informal cooperative effort with New Zealand was established and the first shipment of *A. ulicetella* arrived in Hawai`i in 1986.

By 1986, the Gorse Steering Committee had increased to 15 active members, mostly local landowners and representatives of state and federal land management agencies, with a mailing list of over 50 interested participants on Maui and Hawai'i. The Committee actively supported biological control. Grants from the County of Hawai'i and U.S. Fish and Wildlife Service [USFWS]) were used to rear, screen, and test *A. ulicetella* and other potential gorse biological control agents. HDOA directed the program as a continuation of earlier biological control efforts against gorse, and selected test procedures and species for specificity tests. In 1987, another small grant was received from the County of Maui, and the State of Oregon became involved as a partner in 1987. Gorse is a major problem along the west coast of Oregon where it hinders forest management (Hermann and Newton1968) and recreation and creates a significant fire danger (Holbrook 1943).

By this time, the Gorse Steering Committee had obtained two influential members: Ken Autry from the USDA-SCS office in Waimea provided organization and dynamic leadership and Francis Pacheco, a local consultant for the sugar industry, brought the Committee political contacts within the state. Under the guidance of these two sometimes-conflicting personalities, the Gorse Steering Committee undertook new public education campaign through newspaper releases, public field days, and an aerial tour for legislators. Through this effort, the Committee was able to attract the support of local state legislators who facilitated its 1988 approach to the Governor's Agricultural Coordinating Committee (GACC) and the legislature for funding. With wide public awareness, support of local legislators, and testimony from the Gorse Steering Committee, the bill passed and was fully funded. These state funds were matched or exceeded by IPIF and NPS contributions in salaries and facilities.

Hawai`i now was able to participate in the development of biological control agents in Europe. Hawai'i and New Zealand established a formal agreement and funded Commonwealth Agricultural Bureau (now CABI Bioscience) to conduct the needed studies. By supplementing the research funding from NZ, a member nation of CABI, Hawai'i and Oregon were able to support more research in Europe than would have been possible otherwise.

The first new agent, *A. ulicetella*, was released in the fall of 1988. IPIF, in cooperation with New Zealand, coordinated the foreign work, conducted the final host testing in quarantine in Hawai'i, and obtained release permits. HDOA established mass rearing facilities to produce large numbers of insects, which were released throughout gorse infestations in Hawai'i. Permanent study plots were set up to monitor growth of gorse and impact of the biological control agents.

The next agent, the gorse thrips, *Sericothrips staphylinus* Haliday (Thysanoptera, Thripoidae) was released in 1990. At about this time, two agents were rejected because they showed some ability to feed on two native trees, koa (*Acacia koa* Gray – Fabales, Fabaceae) and mamani (*Sophora chrysophylla* (Salisb.) Seem. – Fabales, Fabaceae) (Table 1).

In 1991, the program was delayed when HDOA's Plant Quarantine Branch stopped releases of all new weed agents while new regulations were written and implemented. The new regulations, in place by 1994, established the requirement of a federal environmental assessment for all new releases and increased the permit review time from six months to 1-2 years. Under the new review process, the gorse spider mite (*Tetranychus lintearius* (Dufour) - Acari, Tetranychidae) was released in 1995 and the moth, *Pempelia genistella* (Duponche) (Lepidoptera, Pyralidae), in 1996.

Table 1. Summary of insect biological control agents in *et al.* (1996).

Agents	Year Released	Year Established	Status
Insects Tested			
Apion (Exapion) ulicis	1984*	1985	78% of pods attacked
Apion (Perapion) scutellare	1989		Not established
Agonopterix ulicetella	1988	1989	Well established
Sericothrips staphylinus	1990	1992	Established, spreading
Tetranychus lintearius	1995	1995	Well established
Pempelia genistella)	1996		Not established
Dictyonota strichnocera	Not released		
Anisoplaca ptyoptera	Not released		
Plant Pathogens			
Uromyces pisi t.sp. *europaei*	2000		Fate unknown
Insects Selected, But Not Tested			
Cydia lathyrana (root moth from England)			
Sitona spp. (root weevils from England)			
Chlorophorus trifasciatus (root-feeding beetle from Portugal)			

* Released on island of Hawai'i, already established on Maui.

Unfortunately, by the time the new regulatory process was implemented, the state was encountering severe financial problems and in 1993 the legislature stopped funding the program. Several root-feeding insects whose development had been delayed were therefore never tested (Table 1). Loss of funding greatly reduced the HDOA effort toward mass rearing, release, and redistribution of agents in the field and halted a long-term monitoring program. With IPIF and Oregon state funding, the gorse program was able to obtain release permits for the last two agents. In 1995 the mite, *T. lintearius*, was released from quarantine and further work in Hawai'i discontinued. Quarantine work on the last insect, *P. genistella*, was continued at Bozeman, Montana

during 1995-96 and testing of new insects discontinued after the release of this agent in 1996.

During this period HDOA constructed a new plant pathogen quarantine facility at Honolulu. One of the first pathogens to be brought into it was *Uromyces pisi* J. Schröt. f.sp. *europaei* (Uredinales, Puccinaceae), a rust fungus obtained from England. This agent was released in the spring of 2000.

At least four of the agents are now established (Table 1). Superficial observations from entomologists and land managers familiar with the Mauna Kea gorse infestations suggest that the biological control agents may have reduced flower production and annual shoot length. Plants frequently appear sickly and yellowing with numerous dead and dying branches often covered with webbing from the mite. The ultimate impact of these agents probably will not be known for another 5-10 years.

CONCLUSIONS

While it is too early to determine the success of this program, the original goal of finding, testing, and establishing a complex of at least four biological control agents in Hawai'i was accomplished. We can, however, estimate what a new biological control program might cost, how long it might take, and identify information that might be useful in planning, organizing, and conducting programs in Hawai'i.

Cost.

Establishing the cost for the insect portion of this program is difficult because of the many different sources of funding that supported it and the contributions in salary, time, and materials made by the different agencies. A rough breakdown over the 11-year period indicates that the insect work required almost $1,500,000 (Table 2). An additional $200,000 was spent over 7.5 years evaluating the insect pathogens, for a total cost of roughly $1,700,000. Cooperation with NZ yielded an additional $1 million benefit, since they paid the cost of all the preliminary work in Europe to find, select, and study the agents that were eventually brought into our quarantine. Also, utilizing the data obtained in NZ's host testing of these agents significantly reduced quarantine studies. Finally, an additional $250,000 would probably have been necessary to run a long-term post-release monitoring study to complete this program.

A similar biological control program on a totally new weed of Hawaiian natural ecosystems is expected to cost around $3 million. While this may seem high, it falls within the range of estimates for other weed biological control programs. Estimated costs for a complete weed biological control program 20 years ago were between $1 to 2 million (Andres 1977, Harris 1979).

Conclusion: To undertake a totally new weed biological control program in Hawai`i will probably cost around $3 million.

Time.

The insect component of this program took over 11 years from its conception in 1984 until the release of the last insect in 1996. During this period, two years' delay were necessitated while the governing regulations were changed. An additional year's delay occurred due to a request by USFWS for additional testing of endangered species of Hawaiian plants. However, the program was shortened by the fact that NZ had previously spent several years doing the preliminary studies necessary to identify the natural enemies of gorse. Quarantine evaluation of the species proceeded fairly

Table 2. Program Costs. Estimates of funding or values of contributed services that supported the insect portion of the Hawai'i Gorse Biological Control Program from 1984-1996.

U.S. Forest Service, Institute of Pacific Island Forestry (estimated that 80% was for salaries)	$ 775,000
National Park Service Contribution (Operation, Electricity, and Maintenance of Hawai'i Volcanoes National Park Quarantine)	$ 45,000
Salaries, Hawai'i Department of Agriculture, Plant Pest Control Personnel, Hilo	$ 121,000
State of Hawai'i, Legislature-appropriated Funds	$ 450,000
Oregon Department of Agriculture	$ 50,000
Use of Montana State University Insect Quarantine Facility to study and ship two agents to Hawai'i	$ 20,000
Outside Grant	$ 35,000
TOTAL	**$1,496,000**

smoothly, each taking 2-3 years. Initially, approval for their release could be obtained in as little as 6 months. However, with the need now to do an environmental assessment and with the new regulations that allow outside agencies such as the USFWS to request re-testing or additional testing, it is expected that each insect would now require 3 to 5 years.

While the scientific work and review process for each agent proceeded reasonably smoothly, this long time span (11 years) had several major undesirable effects. The program was totally dependent on the gorse steering committee to provide the political support to raise money. From 1984-1990, there was excellent support from this committee, but once money from the state had been obtained and the first agents were in the field, interest and participation in this committee dropped off. When the budget crisis hit Hawai'i in 1993, the strong local committee needed to see that the program continued was no longer available. The second problem was that the legal regulations under which this work was conducted constantly changed in response to interacting laws and regulations.

Conclusion: Future programs (at least the finding, testing, and release of the new agents) should be tightly organized and conducted within as short a timeframe as possible. Drawing out the timeframe will allow burnout and loss of your local outside supporters and expose the program to changes in regulations, causing delays and increasing costs. Ideally, the testing in quarantine, even if it means rearing and testing a large number of different species of insects simultaneously, and the approval process should be concentrated, if at all possible, in a 5-year period.

Steering Committee.
The chance of finding a single, permanent, long-term source of funding for a biological control program for a weed of Hawaiian natural ecosystems is probably impossible. Therefore, the need to locate and use multiple sources of funding will probably be the norm. The most effective approach is by means of a local steering committee composed of land managers, landowners, and other interested parties who are already fighting the weed and willing to commit their time and effort to fund raising. Any weed biological control program needs the political support of the local community, therefore, another function of the steering committee is education and increasing public awareness. The steering committee can also coordinate the work of different agencies involved. Besides supporting biological control, the gorse steering committee supported testing other management efforts, including testing of new herbicides, shading by reforestation, effectiveness of burning, grazing by goats, and the use of different grazing regimes. The long-term solution to the gorse problem in Hawai'i will probably require a combination of several management approaches.

Conclusion: Local land managers and private landowners should be recruited into a steering committee during conceptual discussions of a new biological control program to solicit the necessary funding and provide support to the scientists.

Leadership.
Researchers should not be expected to provide leadership for multi-agency, politically driven programs such as the gorse program. They are too involved in day-to-day work with insects and the research involved. There is also a potential conflict of interest. The outside leadership contributed substantially to the success of the scientific program providing political support, obtaining funding, maintaining a focus in the research and demanding results and reports. The success was largely the result of the commitment of the steering committee, particularly the chairman.

Conclusion: A successful program needs leadership provided by well-informed, politically savvy outsiders (non-researchers) committed to seeing the program succeed.

Outside Cooperators.
The complexity of the scientific research that identified, evaluated, and tested the complex of insects required the involvement of many cooperators in other countries. Previous work in NZ and England and cost sharing considerably benefited this project by saving time and research. Finding another country that was interested in gorse control, *i.e.*, NZ, and running a closely coordinated, highly cooperative program with them is probably one of the major factors that contributed to our success.

Conclusion: Look for outside cooperators.

Lead Scientist.
The studies necessary to progress from locating a natural enemy in its homeland to its release as a biological control agent in the field in Hawai'i have become so complicated, time-consuming, and costly that conducting a program for a single weed can demand the full time and attention of the responsible scientist. The majority of the time involved in a new biological control program will be spent in interaction with other people such as members of the local steering committee, foreign scientists, and the administrative bureaucracy that must be navigated to obtain permission to ultimately release the new agents. Finally, the scientist in charge must be able to train and supervise the technicians who will do most of the routine handling of the insects, from

their arrival in quarantine to their release.

Conclusion: Each weed targeted for biological control needs a single, full-time scientist responsible not only for the necessary entomological studies, but for coordinating and guiding all stages of the program. Since overall administration and coordination will be more time-consuming and critical than any single, scientific study that might be conducted, the lead scientist should be judged on the number of new biological control agents released, established in the field, and attacking the weed, instead of on the number of peer-reviewed papers published in a scientific journal.

Expect outside criticism.

While in general the program experienced excellent local support, there was criticism. In conducting biological control, it is common to take the shortsighted view that it is just another management tool. It is difficult to realize that many people outside the field do not understand the goals, and through ignorance, fear, or for personal motivations, will attack it.

During this program, Howarth (1983, 1991) published his articles questioning the safety of biological control. He primarily looked at problems with many of the earlier biological control programs aimed at insects and did not address weed biological control, however, several mainland scientists used his findings to question the practice of weed biological control in general, and this program specifically. These outside criticisms were beneficial in that they required a re-examination of the program, testing procedures, and the need to educate another group of people, outside scientists. The second objection came from the USFWS, some members of which felt that under the Endangered Species Act insufficient attention was paid to the potential threat to endangered plants in Hawai'i. Their objections did not significantly harm this program – just necessitated that another group of plants be included in the host range testing – but it did emphasize that the regulations under which biological control is conducted are not fixed in stone but are constantly changing.

Conclusion: A continually new audience of people are watching and reviewing the work and will be questioning its values and safety. Future biological control of weeds programs, therefore, must expect some criticism, be flexible enough to identify the basis for the attacks, and be prepared to work to resolve them.

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