FOREST PEST BIOLOGICAL CONTROL PROGRAM IN HAWAI'I

Clifford W. Smith
Department of Botany, University of Hawai'i at Manoa, 3190 Maile Way, Honolulu HI 96822, U.S.A.
Email: cliff@hawaii.edu

Abstract. Forest weeds were not considered to be a major management problem in Hawai'i until the latter quarter of the last century. Most previous biological control programs in the state were against agricultural pests. An interagency committee (U.S.D.A. Forest Service, National Park Service, Hawai'i Department of Agriculture, Hawai'i Division of Forestry and Wildlife, and the University of Hawai'i) was established to encourage studies of forest pests, develop biological control agents and foster the implementation of their recommendations. The progress of biological control efforts against the following weeds in Hawai'i are presented: *Clidemia hirta, Hedychium gardnerianum, Miconia calvescens, Myrica faya, Passiflora mollissima, Psidium cattleianum, Rubus ellipticus*, and *Tibouchina herbacea*. Recommendations are made for the establishment of oversight (action) committees for each targeted species, long-term commitment to a program once started, more thorough studies in the native range of the target species using local experts and students and a full-time advocate scientist for forest pest biological control in the Islands.

Keywords: *Clidemia hirta, Hedychium gardnerianum,* Melastomataceae, *Miconia calvescens, Myrica faya,* Myrtaceae, *Psidium cattleianum, Passiflora mollissima,* Passifloraceae, Rosaceae, *Rubus ellipticus Tibouchina herbacea,* Zingiberaceae.

INTRODUCTION

Biological control has been an integral part of forest management in Hawai'i for 100 years. Forest weeds, however, were not considered to be a major management problem until the latter quarter of the last century. This indifference was in large part the result of the influence of Charles Lyon who had promoted the introduction of species to the Islands for watershed reforestation. Also, until quite recently, most naturalists were interested in native species, particularly the endemics. While they decried the weeds, they generally did little to control them even in the most critical areas let alone consider biological control as a management approach. In the early 1980's attitudes began to change. The National Environmental Protection Act required that federal agencies develop resource management plans for resources under their jurisdiction. This formalized planning and review process resulted in a professional transformation and expansion of the National Park Service (NPS) natural resources management program. Somewhat similar but less extensive modifications occurred in state programs.

The state biological control program operated by the Hawai'i Department of Agriculture (HDOA) was willing to assist in the development of biological control agents for forest pests but only as an adjunct to their own mandates. In addition, their quarantine space was limited and located at sea level in Honolulu, unsuitable for species from high elevations the typical habitat of the forest weeds that were initially targeted. Forest managers also realized that a more focused program to promote development of biological control agents targeting forest weeds was needed. The issue came to a head during an annual performance review of NPS natural resource management programs and the Cooperative Pacific Science Unit by NPS Regional Chief Scientist Dennis Fenn in 1983. He requested that interested agencies meet to discuss the problem. Realizing that no single agency could support such a program on its own, five agencies committed to cooperate in a forest pest management program that focused primarily on biological control.

A Memorandum of Agreement was established between NPS, USDA Forest Service (USFS), Hawai'i Department of Agriculture (HDOA), Hawai'i Department of Land and Natural Resources (DLNR), and the University of Hawai'i (UH). The NPS agreed to convert one of their greenhouses at Hawaii Volcanoes National Park into a quarantine facility as well as provide a plant pathologist to work on the development of agents. The US Forest Service agreed to provide a biological control specialist to work on insects in the quarantine facility as well as act as the quarantine officer for the facility. HDOA was an important contributor because of its legislated mandate to oversee all biological control efforts in the state. DLNR proposed to lead the committee and fund programs. UH agreed to conduct research particularly on the post-release fate of agents through a monitoring program. All agencies agreed to fund biological research whenever possible. The Memorandum of Agreement was signed in 1985. Since then eight projects have come under the review and sponsorship of the Committee to varying degrees. They are summarized below.

SPECIES TARGETED

Clidemia – *Clidemia hirta* (L.) D. Don (Myrtales, Melastomataceae).
See Conant (this volume).

Clidemia is substantially controlled in open ranchland by the thrips, *Liothrips urichi* Karny (Thysanoptera, Phlaeothripidae). The leaf spot fungus (*Colletotrichum gloeosporioides* f. sp. *clidemiae* Trujillo Deuteromycotina, Melanconiaceae) has reduced some populations in rainforest areas. Clidemia is now spreading into lowland dry forest. Control is by no means complete and further agents are still needed for this species. As Conant (ibid) notes there are several potential insect agents. None, however, show much potential to control this weed. It may well be that there is no realistic hope to contain it in rainforest situations.

The negative impact of this species needs to be reevaluated in light of recent introductions. It may be too early to tell if the seed predators are having any impact but Myers' (this volume) comments on their potential efficacy suggests that we should not expect any dramatic effects. Further studies should be conducted in Central America and directed at stem borers and defoliators. The studies should be long-term, conducted year-round, and focus on forested areas.

Banana poka – *Passiflora mollissima* (Kunth.) L.H. Bailey (Passifloraceae).
This project has been led by DLNR since the early 1980's with considerable involvement of U.S.F.S. in the 1990's. Pemberton (1989) conducted the initial exploratory research in South America and noted that there was considerable potential to manage this species with biological control agents. Later exploratory research was focused in Colombia on his recommendation. However, the political instability of the region, a lack of leadership in the program and the absence of an oversight committee has hampered the project. The USFS sponsored research in Merida, Venezuela, for several years. The following insects have been studied and some released.

Pyraustra perelegans Hampson (Lepidoptera: Pyralidae) feeds on leaves and buds. It has been released in 1991 with little effect. It is established on the Big Island but population levels are extremely variable. Most people assume that the insect was unable to overcome the many generalist lepidopteran parasitoids in the Islands. R. Leen (pers. comm.) suspects that a species of the fungus *Metschnikowia* (Ascomycete: Saccharomycetales) is responsible for the poor performance of the insect.

Unfortunately, no definitive study has been conducted to differentiate between these two hypotheses. However, other hypotheses need to be considered also, e.g., the climatic conditions are unsuitable. Unfortunately, the reason why a released insect does not live up to its potential is rarely studied formally. A few anecdotal notes are sometimes published.

Cyanotrica necyria Felder (Lepidoptera: Notodontidae), a leaf feeder from Ecuador and Colombia was released in 1988. It has established but has had no demonstrable effect. Further work on this species is desirable because it has a high potential completely defoliating plants.

Josia fluonia Druce (Lepidoptera: Notodontidae), a defoliator, has been recommended for release but is awaiting final approval. One experiment suggested that it could complete its life cycle on apple but the few insects that did complete their life cycle were in very poor condition. Recent experiments have shown that it can survive on the edible passionfruit (*P. edulis* Sims f. *flavicarpa* Deg.) suggesting that the proposal for release should be reconsidered. Further work on this species is not recommended because the insect does not appear to have a significant impact on the target plant.

Josia ligata Walker (Lepidoptera: Notodontidae), a defoliator, was brought into quarantine but the colony did not survive.

Zapriotheca nr. *nudiseta* (Diptera: Drosophilidae) larvae feed on flower buds. It has passed host specificity testing, but has not been proposed for release yet. This colony is certainly highly inbred. It appears to have considerable potential in disrupting the reproductive cycle of banana poka. Further importation of the insect is recommended to overcome genetic problems and enable host screening to be completed. It will be extremely difficult to assess the impact of this insect because large plants are needed. The logistics of handling such plants in quarantine are unrealistic and field studies in South America would be extremely difficult under current political conditions.

A fungus, *Septoria passiflorae* Sydenham (Deuteromycetes, Dothidiaceae), was released 1996 and has had an apparently dramatic defoliating effect in Laupahoehoe, Hawai'i Island (D. E. Gardner, pers. comm.). Confirmation of the cause of defoliation is important in this case because previous defoliation events were attributed to drought conditions. Thorough evaluation of the effects of previous releases in the banana poka biological control program should be conducted before further work is considered.

Species of *Odonna* (Lepidoptera, Oecoriphoridae), a root crown borer, and *Dasyops* (Diptera, Lonchaeidae), a stem borer, should be studied in South America to obtain data on life history, host specificity, and impact. The *Dasyops* has been brought into quarantine in Hawai'i where though the insects failed to mate they laid eggs profusely. These insects are known to attack banana poka but were set aside because facilities for handling them experimentally were not available at that time.

Two other species are becoming serious weeds the sweet granadilla (*P. ligularis* Juss.) and yellow granadilla (*P. laurifolia* L.). Unlike the established melastomes, all of which can be targeted because the whole family is considered noxious, one member or the family, *P. edulis,* is a marginal agricultural crop. Many people, however, harvest it in the wild for desserts, jams, etc.

P. mollisima is a species which illustrates the weakness of the recent approach to biological control against forest pests in the Islands. During the 1950-70's there was considerable enthusiasm for the establishment of a forest industry in the state. Banana poka was a threat to the prized koa timber market because it smothered the natural regeneration of the forest as well as damaging large trees due to the weight of the vines, especially when wet. When it was realized that large-scale forestry was unfeasible interest in forest problems declined and with it support to combat banana poka. It is still a serious problem in native forests on the Big Island and has also become established in

Kula, Maui. Other weeds, e.g., miconia, strawberry guava have supplanted interest and financial support for banana poka. The whole program is now in abeyance. Cooperation with similar control efforts in New Zealand is possible.

Himalayan raspberry – *Rubus ellipticus* Sm. (Rosales, Rosaceae).
A small cooperative exploratory program was established with the Chinese Academy of Agricultural Sciences Institute of Plant Protection, Beijing, in 1996 to look for diseases and insects that attack this species as well as *R. niveus* Thunb. in the Himalayan region of China. Earlier attempts in India to identify potential agents targeting this species failed due to various problems but particularly the remote locations of most known collection sites. No evaluation of potential agents in northern Thailand has been attempted.

Attempts to establish a *Rubus* action committee have not been successful because nobody wants to lead it even though there is a strong interest to control the plant in the conservation, hunting and recreation communities. An action committee to coordinate the project, provide the necessary oversight and develop funding is necessary if this project is to move forward.

The danger of non-target impacts is significant because of the coexistence of two native congeners, *R. hawaiiensis* Gray and *R. macraei* Gray. Previous agents introduced against *R. argutus* Link have attacked these species (Pemberton this volume) although with little apparent negative effect. Since no long-term monitoring was established when the insects were released, retrospective evaluation is virtually impossible. It is somewhat surprising that nobody has used the release of biological control agents to study the epidemiology of new arrivals in the Islands. Excellent opportunities for studying fundamental principles of island biology are being missed. Biological control is also without fundamental information that would probably enhance the success of future releases, particularly when so many previous releases failed.

Fayatree - *Myrica faya* Ait. (Myricaceae).
A previous attempt to control fayatree failed (Hodges & Gardner 1985). *Eucosma smithiana* (Walsingham) (Lepidoptera, Tortricidaae) was released in 1956. It is established on *M. cerifera* but not *M. faya*.

The current project, coordinated by the Fayatree Action Committee, was led by the "Big Island Resource Conservation and Development Committee" in 1987, a local program of the USDA Soil Conservation Service (SCS), U.S. Department of Agriculture Resource Conservation and Development Agency on Hawai'i Island. The committee eventually stopped meeting in 1995 after many years of effective work soon after the RC&D lead person left the islands. Strong political support from Big Island legislators continued funding through the Governor's Agricultural Coordinating Committee that was ultimately subordinated into the Hawai'i Department of Agriculture. Some of this funding was later reprogrammed into similar work on melastomes at the suggestion of agency personnel.

Caloptilia nr. *schinella* (Lepidoptera, Gracillaridae) from the Azores and Madeira was released in 1991. It is established but has had no demonstrable effect. It is possible that leaf miner parasitoids may be attacking this moth (Conant, this volume). Cooperative programs with the University of the Azores failed to find any further suitable biological control agents for *M. faya* in its native range in the Azores or Madeira. Most insects found on fayatree had alternate hosts, such as *Vaccinium,* that made them unsuitable agents. A *Septoria* leaf spot fungus did cause premature leaf fall, but we were unable to obtain fertile material. A similar species, *Septoria hodgesii* Gardner (Deuteromycetes, Dothideaceae), from *M. cerifera* L. in the eastern US was released at

Volcano, Hawai'i Island in 1998, but with no noticeable impact to date. Trujillo (pers. comm.) has suggested that acid rain around the Volcano area inhibits spore germination, and that the fungus may be more successful if tested elsewhere.

We have a single species in quarantine from Madeira, *Phyllonorycter myricae* Deschka (Lepidoptera, Gracillaridae) that is may be suitable for release. However, the colony has undergone considerable inbreeding and it has not been possible to replenish the stock. In addition, establishment success of this microlepidopteran likely would be jeopardized by parasitoids already established in the Islands. Furthermore, we have little evidence that this agent would have a significant impact on its target. This species was probably a poor choice as a potential agent using Balciunas' criteria (this volume).

The absence of significant agents in Macaronesia may be explained by the fact that the Macaronesian colonies of fayatree were components of an isolated vegetation type now an outlier of the once more widely distributed laurisilva (sub-tropical rainforest) widespread in the Mediterranean and near East during the Tertiary. Insects adapted to fayatree may not have reached the distant Macaronesian Islands that are at least 1000 km from the Iberian Peninsula. Populations of fayatree in many areas of Portugal north of Lisbon appear to have been planted. Natural populations from the Algarve, Portugal, and the Atlas Mountains were not relocated.

We have also started work on the herbivores of related species of fayatree in Venezuela where several potential agents, including a promising stem borer, have been identified. Further development of these species is on hold awaiting their shipment to Hawaii. There is little hope of getting the necessary permits until the political situation in the country has settled down.

Fayatree continues to expand in natural areas and ranchland. Though not a high profile weed, Vitousek and Walker (1989) have shown that it modifies ecosystem processes. These modifications are of such magnitude that fayatree remains among the highest priority weeds for the Forest Pest Biological Control Program.

Kahili ginger – *Hedychium gardnerianum* Roscoe (Zingiberales, Zingiberaceae). Anderson and Gardner (1999) have studied a strain of *Ralstonia solanacearum* (E.F. Smith) Yabuuchi *et al.* (Bacteria, Pseudomonaceae) that attacks kahili ginger. They expressed considerable optimism that this fungus has the potential to bring about long-term control of this pest including the suppression of seedling establishment.

The slow-acting nature of this pathogen may be beneficial in that native species will have a chance to recover before weeds overwhelm them. The establishment of the bacterium is somewhat difficult generally requiring physical damage. Nevertheless, the bacterium has been established in some populations in the Islands. Evidence suggests that the density of plants in these areas is declining. Perhaps the most encouraging aspect of this disease is that seeds do not germinate or damp off soon thereafter where the bacterium is present in the soil. EPA approval may be required before the fungus can be broadcast as a biocide. In the meanwhile, use of this pathogen is limited to local application only though experiments on mass culture, optimal dosage, and alternative inoculation techniques are underway.

A potential conflict of interest is that it attacks edible ginger (*Zingiber officinale* Roscoe - Zingiberales, Zingiberaceae). The difficulty of dissemination and establishment of the bacterium suggests that this concern is not a significant problem. The infestations of kahili ginger are well above the areas were ginger is grown commercially.

Miconia – *Miconia calvescens* DC (Myrtales, Melastomataceae).
See Killgore (this volume).

As a consequence of an exploratory trip report by Burkhart (1996), the initial focus of biocontrol research on *Miconia* targeted pathogens. The project initially was supervised by the Tri-Isle RC&D's Melastome Action Committee, which did an admirable job soliciting funds, while the HDOA funded exploratory work and the screening of the first agent. Well over $1M was obtained to contain the *Miconia* infestations while exploration for biological control agents was underway. Funding and in-kind resources came from diverse sources, including the affected counties, Hawai'i Legislature, The Nature Conservancy—Hawai'i and the government of French Polynesia. Eliminating large fruiting trees principally by spraying herbicide from helicopters was the first priority. Some trees in steep sided gullies could not be treated. Most were later controlled by crews abseiling down the gully walls. Manual eradication of juvenile trees and seedlings continues. The infestations have been reduced substantially.

The Melastome Action Committee subsequently became the Maui Invasive Species Committee (MISC) in 1998. This development diffused the focus of the Action Committee somewhat. It might have been more effective as a separate entity targeting *Miconia* control specifically, albeit under MISC. Development of effective biological control agents is sporadic. Though money has been obtained for the containment program, funding for the biological control program has been erratic. The biological control development project itself has solicited funding and, in one instance, has run into conflict with MISC. These potential conflicts are a significant problem in Hawai'i's attempt to manage established alien species. There are so many that need attention that it will be extremely difficult to maintain sufficient focus on the research necessary to establish an adequate biological control program against one particular species. The consequent stop-and-go already evident in the *Clidemia* and *Myrica* programs could become the norm.

Burkhart (1996) recommended that pathogens should be the initial focus in biological control. His exploratory work in Central America had not identified an obvious insect candidate. Several other factors (ease of handling, lack of potential biotic interference, rapid spread) also suggested that pathogens would be the best candidates in this instance. Mycological studies in Brazil had already identified an anthracnose disease causing agent, *Colletotrichum* species (see Kilgore, this volume). The fungus was released in 1997. After some preliminary disappointing results, the fungus is now established on the Big Island, spreading and having noticeable effects on at least one of the major infestations. Seedlings appear to be particularly susceptible but leaves are lost from the canopy increasing light levels on the forest floor. Quantitative studies are now underway to determine the magnitude of the impact.

Four other potential fungal control agents are known:

a black pimple leaf disease, *Coccodiella myconae* (Duby) Hino & Katuamoto (Phyllacorales, Phyllacoraceae), which causes extensive damage. It is an obligate parasite, which has been difficult to transfer from plant to plant. In Brazil, five hyperparasitic fungi have been collected from the pimples;

a leaf spot disease, *Pseudocercospora tamonae* (Chupp) Braun (Deuteromycotina, Dematiaceae), which also causes extensive damage. It also attacks seedlings of some myrtaceous species and will need extensive evaluation before consideration for release;

a tar spot disease, *Guignardia* sp. (Dothideales, Mycosphaerellaceae), a new species. Its potential is not fully understood but it could be very useful;

a leaf blight, *Kuronomyces* sp. (Mycelia sterilis, ?Basidiomycetes), which has not been evaluated nut produces a strong blight on affected leaves.

The *Miconia* infestation in Hawai'i is conceived generally to be such a significant threat that further exploratory work on potential insect agents has been encouraged recently. A cooperative exploration and development effort has been established with the University of Costa Rica supported by a variety of funding sources. A psyllid (*Haplaphalara* sp. – Homoptera, Psyllidae) that attacks shoot tips appears to have promising potential. It can be manipulated easily in the greenhouse. An evaluation of its impact on the plant is underway. Further work on a processionary caterpillar *Euselasia chrysippe* (Bates) (Lepidoptera: Riodinidaae) has just started. Another species *E. bettina* (Hewitson) is also under consideration.

There is also a leaf-mining nematode (*Ditylenchus drepanocercus* Goodey – Nematoda, Anguinidae) that causes extensive damage and appears to be host-specific. Nematodes have not been used for biological control in Hawai'i that may preclude its consideration.

Strawberry guava – *Psidium cattleianum* Sabine (Myrtales, Myrtaceae).
See Wikler (this volume).

This project is high priority because of the severe impacts of the weed and consensus that it is the most widespread, disruptive species in native rainforests (Smith 1985). The program was sponsored by the National Park Service principally and later transferred to the US Geological Survey. A major constraint on development of agents has been the requirement that it not attack the closely related common guava (*P. guajava* L.). Initial skepticism in finding an agent with this degree of specialization was overcome by our Brazilian colleagues who found five host-specific gall-forming insects, one of which (*Tectococcus ovatus* Hempel - Homoptera, Eriococcidae) should be the subject of a release petition in the near future. At least three potential candidates were rejected because they occasionally attacked common guava.

Although requiring considerable travel and communication, the cooperative effort with the College of Forestry, University of Paraná, Curitiba has worked well. The majority of the research has been published. In this particular case the lack of an oversight committee for the project was only a minor impediment because funding came from a single agency that acted as the oversight body.

The project has taken ten years and the work conducted principally by graduate students. Since strawberry guava has been a dominant element in native communities for at least 75 years, the long duration of the project has not been seen as a problem. Speed of resolution was less of a priority than the host specificity of potential agents and verification that the impact of potential agents is significant.

Tibouchina – *Tibouchina herbacea* (DC) Cogn. (Myrtales, Melastomataceae).
Our success with development of the strawberry guava project led to several other collaborations with Brazilian entomologists, including exploration for agents targeting *Bidens pilosa* L. (Asterales, Asteraceae), *Pomacea caniculata* (Gastropoda, Ampullaridae), and *T. herbacea*. The *Bidens* project was abandoned when it became clear that obtaining sufficient material of the many endangered endemic species in this family for host screening would be difficult, if not impossible. The *Pomacea* studies focused on egg parasites; none have been found to date.

T. herbacea is part of a complex of closely related species in southeastern Brazil. Species are distinct though the delimitation of some probably needs revision. Although our surveys are by no means complete it appears that a common suite of insects attacks all species but a few appear to attack only one or two species. We had enormous difficulties locating *T. herbacea* populations initially because it is an ephemeral, ruderal species and most of the previously collected sites were disturbed. The size and behavior of the plant in Brazil and Hawai'i is very different. In Brazil it is a geophyte rarely above 1m in height dying back each year. In Hawai'i it can grow up to 3-4m and the previous year's stems survive the dormant period forming rank sprawling stems from which new shoots arise the following year. The thickets that are formed are difficult to traverse and exclude all other species. The sprawling nature of the growth smothers adjacent bushes, gradually increasing the size of the infestation.

Syphrea uberabensis (Coleoptera: Chrysomelidae) appears to be specific to *T. herbacea* and one or two other closely related species. It damages the leaves heavily essentially skeletonizing them. The magnitude of the impact is under investigation.

A species of *Schrenkensteinia* (Lepidoptera: Schrenkensteiniidae), a leaf skeletonizer, is a promising potential biological control agent. One species from the genus, *Schrenkensteinia festaliella* has been released against *Rubus argutus* Link (Florida prickly blackberry) in Hawai'i. It has been quite effective even though the eggs are heavily attacked (up to 50%) by the egg parasitoid *Trichogramma chelonis*. The larvae are infrequently parasitized (Ramadan, pers. comm.). Even with this high level of parasitism, damage to the target plants is high though there is considerable variation in different situations. We expect to find a similar pattern of parasitism on the Brazilian species and hopefully the same level of feeding activity on the target plant. We have not progressed very far with this species because it is not abundant.

There are also two species of *Anthonomus* (Coleoptera: Curculionidae) that appear promising; they now are undergoing life history and impact studies in Brazil. A species of *Margaradisa* (Coleoptera: Chrysomelidae) also may prove to be useful but we do not know which plant species the larvae attack.

Other forest weed projects.
At least two efforts to develop biocontrol agents have been conducted outside the auspices of the Steering Committee as a result of the specific interests of the researchers involved. The most successful of these was the use of *Entyloma compositarum* (Basidiomycetes: Ustilaginales) against Maui pamakani, *Ageratina adenophora* (Spreng) R. King & H. Robinson (Trujillo 1985, Trujillo *et al.* 1988). Infestation of plants during wet periods coupled with the impact of previously introduced insects has resulted in other plants invading monotypic stands and in some cases replacing them. I know of no quantitative evaluations of the impacts to date.

The studies on banana poka conducted in Colombia were supported by DOFAW outside the oversight of the Committee. The leaf spot fungus mentioned earlier was discovered, evaluated and released under this program.

DISCUSSION

Development of biological control agents for forest weeds is generally taken as a last resort after all other control methods have failed. The only exception to date has been the *Miconia calvescens* project for which research on potential biological control solutions was included with conventional control strategies initially. This unusual concurrent approach was the result of almost unanimous agreement that containment could be only a stopgap measure while exploratory studies were underway. Subsequent discovery of the wide distribution of *Miconia* in Hawai'i illustrated our inadequate understanding of the extent of the invasion and convinced the skeptics that biological control was the only long-term management option.

To date, the priority of forest weeds to target for biological control research has been simple; species attracting funding support receive the highest priority. Thus research has been dictated by whichever management group has had funding to support a project. Neither the creation of priority lists nor the scientific basis of such lists had much impact on implementation of a research program. Interest groups from each island have different priorities. For example, miconia was a candidate for biological control on Maui after its escape into the forests above Hana was discovered. That support continues with strong encouragement and funding. On Kaua'i and O'ahu miconia was contained immediately after the threat was understood. Continuing control programs should extirpate it within a few years. On the Big Island, however, initial indifference was followed by aggressive containment until even the most skeptical were convinced that biological control was the only long-term solution. Unfortunately, this realization by the latter group has not resulted in contributions to the biological control research program to date.

Consensus, however, has developed recently in a general focus on melastomes. This family, many or most of which are early colonizers, generally is perceived as totally undesirable in Hawai'i; only one species, *Medenilla magnifica*, has not become a problem so far, although recent observations suggest that it too can reproduce in Hawai'i. It is still too early to tell whether or not this consensus will result in an adequately funded program. Much of the decision-making revolves around key enthusiasts. Another family high on every manager's list for control is the grasses. However, biological control has not been considered against this group because of the perception that species-specific agents would be difficult to find and a general misconception that state law forbids importing organisms that attacked grasses as a protection of the once-dominant sugar industry.

For a number of reasons scientists resident in the native range of pest plants are often better able to conduct exploratory and host-screening studies more effectively. More thorough evaluations of the insect fauna and pathogens can be made during year-round studies. The life history of potential agents can be studied in natural surroundings, providing valuable insights into host specificity, the impact of the potential agent on the target organism, rearing techniques, etc., all of which reduce the time required for quarantine work in the US. In addition, impacts of parasitoids, predators and hyperparasites can be evaluated. Of course, for this model to be successful, the lead scientist in Hawai'i must be prepared to travel, work with the foreign counterparts and to spend considerable time working on administrative necessities.

This research model can also be highly cost effective because of the lower costs compared with sending highly paid research scientists from the U.S. Some countries may be prepared to add scholarships or facility enhancement to projects bringing in foreign funding. Promotion, development and/or expansion of entomological, plant pathology and biological control research abroad are decided benefits. Our cooperative programs in Brazil have enabled Australian and South African projects to develop their own cooperative programs there. In fact, many countries now require scientific cooperation with local scientists without which export permits become unobtainable.

The main costs of this approach are that it generally takes longer than aggressively focused foreign work by U.S. biological control specialists because most studies are part of student postgraduate training. Since most forest weeds do not cause emergency management situations, a few extra years before the introduction of potential agents is not a major problem. High administrative responsibilities and occasional breakdowns in communication also present challenges.

In Hawaii, the formation of an action committee for each weed has proven highly effective. The committee has included representatives from federal and state agencies, NGOs (in Hawai'i principally The Nature Conservancy Hawai'i), ranching, plantation and horticulture industries, the conservation community, in some instances the hunting community, and researchers. That is, the committee should represent the entire spectrum of interests, both *pro* and *con*, regarding the management of the weed. The committee chair should be willing and able to meet frequently, write testimony, lobby, enable the various interest groups to interact effectively, etc. Without good leadership these committees soon disassociate. The committee's focus should be management of the weed using all effective strategies not just biological control. It should support research on all promising methodologies. Biological control projects require oversight to provide focus and an interface with a community increasingly opposed to any species introductions. The action committee also provides an important review of the scientific program. The research team is more effective if freed from fund-raising and other administrative duties. See Markin (this volume) for further discussion on action committees.

The program on biological control of forest weeds in Hawai'i now is in need of a scientific leader, who is prepared to champion biological control, discuss the issues, lead the research program, and work in foreign countries supervising and collaborating with foreign cooperators. The head of an action committee and the scientific leader, however, should not be the same person. From my own experience, I found it difficult to lobby for money for projects I was supervising. It creates the appearance of ethical problems due to a conflict of interest. The scientific leader should be available as a resource person to the chair of the action committee during the lobbying process.

In my view, the broadening of interest of invasive species committees has become one of the biggest impediments to effective development of biological control agents for forest pests. Island-based invasive species committees compete for state funding. There is now a Big Island Invasive Species Committee in addition to the original committee on Maui. Committees for other islands are being formed. These will compete for resources because each island's needs are somewhat different. Invasive species committees also focus on all pest species, not just weeds, so their attention is spread thinly over an ever-increasing array of species. Biological control is likely to become a lower priority management strategy when such a broad array of pests is considered. Some people disapprove of biological control because of the problems associated with the introduction of predators for mongoose, carnivorous snails, etc., many years ago. Unfortunately, their anathema carries over to the biological control of weeds where the track record of success with few side effects is very good (Pemberton, this volume, Reimer, this volume). Because these broad-based committees are effective solicitors of funds, their success may effectively reduce funding for biological control projects. Nevertheless, the invasive species committees may replace single species action committees with good results if they are prepared to foster biological control studies over the necessary 7-10 year research and implementation period.

Another major problem facing biological control of natural area weeds is the lack of a critical mass of specialists. All too often programs disintegrate once a key individual moves elsewhere or retires. The gradual dissolution of the Fayatree Action Committee was the result of the chairman's rotation back to the continental U.S. Active members in the program felt uncomfortable stepping into his shoes. Other members did not have the time or inclination to manage the necessarily frank discussions. The research program itself is also susceptible to disruptions from personnel changes. The banana poka project died when the principal investigator took another job. His replacement had a different research agenda. Having someone take over a program midstream is extremely disruptive. Without very careful job performance management the project can fall apart rapidly.

Perhaps the most important element of a successful biological control program is an effective advocate: someone who will promote biological control to all audiences (from administrators to legislators to land managers to conservationists); a person who maintains a network of colleagues around the world; someone prepared to manage cooperative agreements with researchers in the countries of origin of target organisms; someone who can work with federal, state and NGO funding agencies or individuals; someone who appreciates the biotic interference problems in the state. It might be said that such a person could no longer be a research scientists. However, there are ample opportunities for collaborative work especially with foreign collaborators as well as preparing synthesis papers. Without such a person the "Forest Pest Biological Control Program in Hawai'i" will lurch along perhaps with some successes, more likely not, until it disappears.

LITERATURE CITED

Anderson, R., & Gardner, D. E. 1999. An evaluation of the wilt-causing bacterium *Ralstonia solanacearum* as a potential biological control agent for the alien kahili ginger (*Hedychium gardnerianum*) in Hawaiian forests. *Biological Control* **15**: 89-96.

Burkhart, R. 1996. The Search For Biological Control Of *Miconia calvescens:* Photographic Documentation of Natural Enemies of *Miconia calvescens* (Melastomataceae) found in Central and South America between July 1993 and September 1995. **http://www.botany.hawaii.edu/faculty/cw_smith/mc_control.htm**

Conant, P. this volume. Classical biological control of *Clidemia hirta* (Melastomataceae) in Hawai'i using multiple strategies

Hodges, Jr., C. E., & D. E. Gardner. 1985. *Myrica Faya* : Potential Biological Control Agents. Technical Report 54. Cooperative National Park Resources Studies Unit, University of Hawai'i at Manoa.

Killgore, E. M. this volume. A case study in weed biological control practices: *Miconia calvescens* DC and three fungal pathogens

Pemberton, R.W. 1989. Insects attacking *Passiflora mollissima* and other *Passiflora* species: field survey in the Andes. *Proceedings, Hawaiian Entomological Society* **29:** 71-84.

Pemberton, R. W. this volume. Predictable risk to native plants in biological control of weeds in Hawai'i.

Smith, C. W. 1985. Impact of alien plants on Hawaii's native biota. pp. 180-250, In: *Hawaii's Terrestrial Ecosystems: Preservation and management.* Stone, C. P. and J. M. Scott (ed). Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu.

Trujillo, E. E. 1985. Biological control of Hamakua pamakani with *Cercosporella* sp. in Hawaii. pp. 661-671 in *Proceeding of the VI symposium on the biological control of weeds. August 19-25, 1984.* E. S. Delfosse, ed. Vancouver, Canada. Agriculture Canada.

Trujillo, E. E., M. Aragaki, and R. A. Shoemaker. 1988. Infection,disease development, and axenic culture of *Entyloma compositarum*, thecause of Hamakua pamakani blight in Hawaii. Plant Disease **72:** 355-357.

Vitousek, P.M., and L.R. Walker. 1989. Biological invasion by *Myrica faya* in Hawai`i: plant demography, nitrogen fixation, ecosystem effects. *Ecological Monographs* **59:** 247-265.

Wikler, C. & Smith, C.W. this volume. Strawberry Guava (*Psidium Cattleianum*): Prospects for Biological Control