PROJECT STATUS: New, not previously funded.

PROJECT NUMBER: R5-1998-02

PROJECT TITLE: Development of Application and Evaluation Technology for Four Biological Weed Control Agents in Hawaiian Forests

SUBJECT: Biological Control of Non-Indigenous Forest Weeds

PROJECT OBJECTIVES:
1. To develop effective means of delivering and establishing four biological control agents for three invasive weed species.
2. To develop and implement post-release evaluation to determine spread and effectiveness of target weed control by these biological agents in the field.

BRIEF DESCRIPTION OF PROJECT: This project develops and applies technology for improving release methodology and evaluating control effectiveness for four biological control agents of three forest weeds in Hawaii. The agents considered are two moths (Carposina bullata and Mompha trithalama, for the control of Koster's curse, Clidemia hirta) and two fungal leaf spot pathogens (Septoria myricae for control of fayatree, Myrica faya; and, Colletotrichum gloeosporioides f. sp. miconiae for the control of Miconia calvescens). All agents have undergone rigorous host-specificity testing and been approved for release. Technology development will focus on methodologies (1) to improve establishment probabilities for these agents and (2) for the design and implementation of post-release monitoring of weed control by each agent.

FHP PERSON WHO WILL LEAD THE PROJECT: Duane Nelson, Forest Health Coordinator,
Institute of Pacific Island Forestry, USDA Forest Service, Hilo, HI.

JUSTIFICATION: Hawaii is the invasion capital of the United States; the establishment of over 1,000 alien plant species poses real threats to Hawaii's unique ecosystems and the sustainable use of its forests. The three invasive weed species described in this proposal are among the most severe threats to forest watersheds and biodiversity in Hawaii (Smith 1992, Whiteaker and Gardner 1992, Medeiros et al. 1997). All three also threaten commercial forestry projects. Fayatree and Koster's curse are widespread and currently spreading on a large scale; chemical/mechanical control (C/M) was abandoned years ago on almost all state and private lands, although the National Parks Service continues to use C/M to protect restricted areas of special ecological value (Special Ecological Areas). Miconia, viewed by many as one of the most threatening invasive species in the Pacific, is in the incipient stages of invasion in the Hawaiian Islands. Because of the perceived severity of the threat and the incipient stage of the invasion, statewide C/M control efforts are underway against Miconia, but will probably prove to be economically

unsustainable on some islands. Development of effective biological control, integrated with C/M efforts, is essential.

URGENCY: The invasive ability of Miconia and its ability to exclude all other plants in native forests has been clearly demonstrated in French Polynesia, where it has quickly (since its introduction in 1937) come to dominate 60% of the forests in Tahiti, threatening 50-60 endemic plant species with extirpation (Meyer and Florence 1997). The current concerted Hawaii-wide C/M control efforts against Miconia are based on the recognition that if Miconia is not controlled in Hawaii before it becomes widespread, a similar devastation will occur in Hawaiian forests. The threat posed by Miconia is further illustrated by the unprecedented C/M work by National Park Service staff outside the boundaries of both national parks in Hawaii (Conant et al. 1997).

Clidemia is listed as a threat in ten of 22 endangered species recovery plans for plants prepared by the U.S. Fish and Wildlife Service in Hawaii (C. Russell, USFWS, pers. comm.). In American Samoa, it has become the dominant plant in the Ta'u extension of the National Park of American Samoa and locally heavy infestations occur elsewhere (C. Smith pers. comm).

Fayatree has already established itself in dense stands in and near Hawaii Volcanoes National Park (Whiteaker and Gardner 1992) and in Kokee State Park on Kauai. A nitrogen fixer, fayatree readily alters successional sequences in Hawaiian forest ecosystems, and displaces native vegetation in both dry and wet forests.

LINK TO NATIONAL FHP TECHNOLOGY DEVELOPMENT PRIORITIES:
* Provide forest health protection for all lands: The three alien weed species threaten ecological integrity of sub-tropical forests throughout the state of Hawaii and on other Pacific islands.
* Anticipate and respond to new/increasing forest health risks/threats: Populations of these three invasive forest weeds are rapidly expanding in Hawaii. The potential range of Miconia on the Big Island, alone, is estimated to be nearly 450,000 acres.
* Prevent, detect and manage non-indigenous pest infestations: The three species targeted for biocontrol in this proposal are invasive non-indigenous weeds in Hawaiian forests.

SCOPE OF APPLICATION: The scope of application for this project includes the State of Hawaii and U.S. territories (Guam, American Samoa - Waterhouse and Norris 1987).) where these weeds are serious invaders and other U.S. affiliated islands in the Pacific (e.g., the "high islands" including Kosrae and Pohnpei) where they threaten to invade. Biocontrol technology developed in this proposal will also be applicable to other Pacific islands, including French Polynesia, which already has a formal agreement with the state of Hawaii for cooperation in control of Miconia. Furthermore, the applicability of

technology developed in relation to release and evaluation is not limited to these specific agents but has general application for biological control programs in Hawaii and elsewhere.

RESEARCH BASIS:

Each of the three weeds dealt with in this proposal are targets of ongoing classical biocontrol programs of the Hawaii Department of Agriculture (HDOA) in cooperation with University of Hawaii (UH). All four of the natural enemies proposed for release have been thoroughly tested by HDOA and UH to confirm host specificity and have been approved for release by USDA-APHIS and reviewed by USFWS.

Although the success of some lepidoptera biocontrol agents in Hawaii has been limited by alien generalist parasitoids (Reimer and Beardsley 1986), the life histories of the two Clidemia moths indicate that larvae should be well protected from parasitism and predation through their feeding within flowers and fruits of their plants (R. Burkhart, pers. comm.).

Technology developed for increasing the efficacy of "mycoherbicides" in agricultural systems (Boyette et al. 1991) can be applied in classical biological control of forest weeds to increase the probably of successful establishment of fungal pathogens. In previous biocontrol programs, Norman and Trujillo (1985) developed a spore preservation and application procedure that enhanced the infectivity of both Septoria passiflorae and Colletotrichum gloeosporoiodes f. sp. clidemiae, fungal pathogens of banana poka and Clidemia. Morris (1989) also used a dried formulation of wheat bran and the fungus Colletotrichum gloeosporioides to control Hakea sericea in South Africa. Liquid based formulations such as spores mixed with water and surfactants (Boyette & Walker 1985, Walker 1980), water and sucrose (Wymore & Watson 1986) have already been developed. Disease severity of several plant pathogens is also known to increase in conjunction with applications using various chemical herbicides (Katan and Eschel 1973, Wymore et al. 1988, Bruckart et al. 1988).

METHODS:

Release protocols

Insect agents. Both moth species will be reared in their native range on the island of Tobago (Republic of Trinidad and Tobago, West Indies) by a contract entomologist and shipped as pupae to Hawaii. Either the HDOA quarantine insectary in Honolulu or the USDA Forest Service quarantine insectary at Volcano, Hawaii will receive the pupae. The pupae will be held for emergence of adults and destruction of parasitoids. During rearing in Tobago, samples of both species will be sent directly to a contracted insect pathologist in Berkeley, California, to check for pathogenic organisms in the culture.

Contaminated colonies in Tobago will be destroyed. Initial releases of the two moth species will be made on the island of Hawaii. A maximum of ~200 pupae of each species can be produced per month in Tobago. All emerging adults will be field released because they are known to be difficult to rear. Refrigeration may be used to synchronize emergence.

Fungal agents. We will evaluate the effectiveness of four delivery media (kaolin, sucrose solution, alginate, and a herbicide) for their ability to increase establishment of fungal pathogens (as measured by the number of lesions per leaf) under field conditions. Inoculation spore concentrations of 1 x 106 spores per ml in water will be applied using each medium. Three sites for each target species (Miconia and Myrica) will be selected and the four treatments will be applied to five trees selected at random from each site in a randomized block design. Each site will be matched for sunlight, rainfall and substrate conditions. After an initial incubation period of two months, the number of lesions per leaf will be counted on ten leaves selected at random from each tree of each treatment. The average number of lesions per leaf for each tree will be ranked and these ranks used as the response variable in a one-way ANOVA to evaluate treatment effectiveness. The number of lesions per leaf will be measured every month for one year and the data analyzed using a repeated measures one-way ANOVA.

Evaluation protocols

Each biocontrol agent released in this project will require a different method of monitoring/evaluation to determine how much control can be attributed to each agent. Distinct hypotheses must be tested for each agent, although each is predicted to cause some measurable damage to the target weed. Releases will be monitored monthly to determine if the agent is reproducing at a release site. Thereafter, regular surveys will be taken in a prescribed manner in order to document the establishment and spread of the biocontrol agents.

Insect agents. (1) Mompha trithalama. Larvae of this moth feed within the fruit of Clidemia. Seed production of plants at release sites should decrease in comparison to control sites. Control sites will be selected to match sunlight, rainfall and substrate conditions at the release sites. Ripe fruit of Clidemia will be randomly sampled and the presence/absence of larvae will be recorded. Counts of mature seeds per ripe fruit will be compared between release and control sites using a Rank-Sum test, a non-parametric test resistant to problems caused by non-normally distributed populations and outliers. (2) Carposina bullata. Larvae feed upon flowers and fruit both Clidemia and Miconia (although Carposina bullata is not yet documented to specifically attack Miconia calvescens). Fruit production should be reduced at release sites in comparison to control sites. Control sites will be matched

with release sites as above. Fruit production per randomly chosen 0.5m x 0.5m x 20cm unit of terminal growth will be both measured and compared at monthly intervals at release and control sites. Fruit production counts at the two sites will be ranked and compared using a Rank-Sum test.

Fungal agents. Monthly surveys of all release sites of the pathogens (C. gloeosporioides f. sp. miconiae, and S. myricae) will be undertaken. All plants checked for infection will be divided into size classes: seedlings (5 cm-1m), saplings (1m-2m), small trees (2m-5m), and trees (>5 m). This documentation will consist of searching in sequentially enlarging concentric circles around the release site, as infected plants are found farther away. Distance moved per month will be recorded and photo stations will also be set up to document any gross change in canopy cover as the disease spreads.

Based on laboratory observations, both S. myricae and C. gloeosporioides f. sp. miconiae should cause premature leaf drop on the target weeds, Myrica faya and Miconia calvescens respectively. Other effects are unknown, but Miconia panicles may become infected and fruiting could be reduced. To quantify damage (leaf drop) to Miconia caused by C. gloeosporioides, infected plants will be tagged and similar-aged uninfected plants under similar sunlight exposure regimes at a control site will also be numbered. Twenty plants used in the comparison will be randomly selected from those tagged. For each plant, counts of number of leaves, total number of panicles, number of infected panicles, and number of actively growing terminals will be recorded monthly. Evaluation of the fungus S. myricae will be conducted in an almost identical manner (i.e., by quantifying leaf drop).

Data collected within one week for each month for the infected and uninfected plants will be compared using a three-way ANOVA with interaction by ranking the number of leaves lost over time as the response variable, with dbh class and sunlight exposure as two explanatory variables. Ranks will be used since counts of leaves and other plant parts will not be normally distributed. Interaction terms are included in the analysis because synergistic conditions may increase the ability of the fungus to cause leaf drop. Other measurements may be compared statistically if potential differences (infected vs. control) are detected during data collection.

MEASURES OF SUCCESS: 1) establishment of biocontrol agents in the field; 2) decline in target weed populations; 3) development of more efficient and effective means of applying the biological control agents in the field; and 4) extension of use of technology developed by the project in future releases of the same and other biocontrol agents.

COOPERATORS: Hawaii Department of Agriculture, Hawaii Department of Land and Natural Resources, University of Hawaii, USDA Forest Service, USDI (National Park Service, Biological Resources Division of USGS).

PRODUCTS: 1) establishment of four biocontrol agents in the field; 2) an effective procedure for application of fungal inoculum; 3) insects available, not parasitized, for transport and establishment elsewhere; 4) standardized techniques for post-release monitoring of fungi and insects; 5) publications documenting the effort and results.

PUBLICATION: Project participants will aim for publication in the journals Biological Control and Conservation Biology.

TECHNOLOGY TRANSFER: These products will have general application, not limited to these particular biocontrol agents nor their weed hosts. American Samoa and foreign nations in the South Pacific can gain from the technology developed in this project. Transfer will occur through training/demonstration projects, and through community-based meetings.

PROJECT DURATION: Establishment and initial monitoring will be completed in FY 1998. Follow-up monitoring will be completed through contributed services of HDOA, USFS-IPIF, and USGS/BRD. No additional STDP funds will be needed.

LONG TERM BUDGET: One year project, see below

FY 1998 BUDGET REQUEST:

	Item	FHP	Other Sources
Equipment	None	0	0
Contracting:	Insect Rearing (in Trinidad)	$28,000	0
	Pre-shipment path. screening	$ 1,500	0
Salary:	Field Tech.	$10,500	$44,500
	Statistician	$ 3,000	0
Other	Misc. Supplies	$ 1,950	0
	Travel	$ 8,000	0
	Shipping	$ 800	
Subtotal		$53,750	
Overhead (@4.5%)		$ 2,418	
Total		$56,168	$44,500

Citations:

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Enclosure 2a

STDP PRODUCTION FUNCTION

PROJECT NUMBER: R5-1998-02

PROJECT COST:

STDP Request	Other Sources	Total
$ 56,168.00	$ 44,500.00	$100,668.00

PROJECT OBJECTIVE:

The primary objective of this project is to implement biocontrol of three forest weeds to compliment ongoing chemical/mechanical (C/M) control programs to increase effectiveness of the overall control effort. The benefit of this project used in the economic analysis is cost savings with integrated control (with project) versus C/M control only (without project). Without biological control of Myrica faya, Clidemia hirta and Miconia calvescens, C/M programs will be both too costly and ineffective to contain the weeds and avoid the irreversible loss of native rain forest habitat and degradation of valuable watersheds.

A secondary benefit of this project is the development of release methods and technology for application of the fungi biocontrol agents. Other benefits not quantified include watershed protection, protection of habitat for threatened and endangered species, scenic quality of the landscape, biological diversity of the native forests and social and cultural values .

ASSUMPTIONS:

With the project:

The bio-control agents will have become established through the major populations of target weeds within 3-5 years.

Biological control will reduce the cost of chemical and mechanical control by 25% within 5 years of introduction. This would be due to decreased plant density, vigor and rate of spread.

Benefits of this project will be permanent.

Without the project:

Without biological controls the extent of the infestation of M. faya, C. hirta and Miconia will continue to increase.

Despite increased acres infested, expenditures for control will remain essentially constant due to budget constraints and organizational capability.

BACKGROUND DATA:
General:

Agencies will continue to fund C/M control projects for these three weeds for the next 10 years.

Myrica faya
Estimated area infested is 85,900 acres.
Average area treated per year is 500 acres.
Average cost per acre is $250.

Miconia calvescens
Estimated area infested is 11,360 acres.
Average area treated per year is 1250 acres.
Average cost per acre is $200.

Clidemia hirta
Estimated area infested is 283,000 acres.
Average area treated per year is 200 acres.
Average cost per acre is $200

EXPENDITURE & OUTPUT VALUES (EOV) WITHOUT PROJECT:
= sum[(C/M treatment costs*acres)/(1.04)^0-19= -$ 5,865,585

EXPENDITURE & OUTPUT VALUES (EOV) WITH PROJECT:
=Project cost + sum[(C/M treatment costs*acres)/(1.04)^0-4]+sum[(C/M treatment costs*0.75*acres)/(1.04)^5-19]= -$ 4,891,522

BENEFIT (CHANGE IN EOV) ATTRIBUTABLE TO PROJECT:
=(cost without project)-(cost with project)= $ 974,063

BENEFIT/COST RATIO:
=(Benefit attributable to project)/(Total Project Cost)= 9.68

BENEFIT ATTRIBUTABLE TO STDP:
= (STDP fund request)*B/C= $ 543,481

PNV OF PROJECT:
=(Benefit attributable to the project)-(Total Project cost)= $ 873,395

PNV OF STDP:
=(benefit attributable to STDP funds)-(STDP request)= $ 487,313