Biological Control of Introduced Weeds of Native Hawaiian Forests

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Abstract: Among the many threats to the continued existence of the remaining native forests and other native ecosystems of the Hawaiian Islands, the most severe and the most difficult to control are the invasion and replacement by introduced species of plants. Because conventional methods of plant management have failed to control this invasion, a multiagency, state and federal program was initiated in 1980 to attempt control through the use of classical biological control: the introduction, release, and establishment of the natural enemies of the weeds, including both insects and pathogens. Currently, active programs are under way against six different introduced weeds: banana poka (Paspalum notatum), finetree (Myrica faya), gorse (Ulex europaeus), introduced blackberry (Rubus arbutifolius), Koster’s curse (Clidemia hirta), and strawberry guava (Psidium cattleianum). Under the present program, five insects and one pathogen have been tested and released in Hawaii. Three more insects are awaiting final approval, and one pathogen has been approved but not released. Ten other insects and pathogens are being tested in Hawaii, and we are supporting scientists in five foreign countries who are studying the plants in their native ecosystems to identify further agents for us. On the basis of the high rate of success of previous programs for biological control of agricultural weeds in Hawaii, we hope that this program will be a successful tool for managing forest weeds. It will also offer a relatively cheap, safe, and effective method of vegetative management in forest ecosystems on other Pacific islands.

The native forests of Hawaii are unique. Evolving over millions of years on the most isolated pieces of land in the world, most of the trees, shrubs, and ferns that compose the forest and the associated birds, arthropods, and most other invertebrates are native only to the Hawaiian Islands (Carlquist 1980). This complex represents a unique ecosystem, but unfortunately one that is rapidly disappearing. The destruction of the Hawaiian forest began when the first Polynesian settlers began clearing land for farming, but accelerated greatly after contact with the rest of the world (Smith 1990).

Fortunately, some of the most pristine of our remaining forest ecosystems are now protected in state forest reserves, natural areas, parks, and wildlife refuges. Even in these protected areas, these ecosystems are not safe, because they are subjected to continual degradation, mostly from introduced species of animals, particularly cattle, goats, and pigs, as well as from replacement by introduced species of plants.

Most of our problem weeds were introduced to Hawaii as desirable plants, i.e., for their flowers and fruits or for agricultural use. But soon they escaped into the wild, where, without their complex of natural enemies, they spread and multiplied unrestricted. The problems the weeds cause in these native ecosystems, and particularly in forests, are only now being recognized (Vitousek, in press) and include physical displacement of other species, competition for sunlight and moisture, competition for nutrients, interference with nutrient cycling and shading out or smothering of regenerating native species. The full impact of introduced weeds on Hawaii’s native forests has not been fully studied, but it is estimated that if their invasion remains unchecked, our native forests and their complex of associated animals could be extinct within 50 to 100 years.

Invading plants can be controlled by conventional methods including grazing, herbicides, and mechanical weeding (Smith 1990). All these methods have been tried, but all were found to be expensive, often as destructive to the native forest as the weeds to be controlled, and at best, suitable for only limited areas. It was obvious that a new approach to forest weed management was necessary and in 1980 an interagency cooperative program between the State of Hawaii’s Department of Land and Natural Resources, the Hawaii Department of Agriculture, the University of Hawaii, the USDA Forest Service, and the USDI National Park Service was established to attempt the use of biological control as a means to control forest weeds in Hawaii.

Biological control is based on the observation that plants, when introduced by humans to a new area, have often escaped from the constraining influence of the complex of natural enemies with which they evolved in their natural homeland (DeBach 1964). Biological control, therefore, is simply an effort to locate the original homeland of a weed, identify its natural enemies (usually insects or plant pathogens) and import and introduce these enemies into the new area, where they can once again attack their original host.

In Hawaii biological control has been tried against more than 20 species of agricultural weeds (Funasaki and others 1988), mostly found in pasture lands, and has been successful in more than half the attempts (Markin and others, in press). On a worldwide basis, this approach has been tried on more than 75 different weeds with about the same ratio of success (Julien 1987).

Exploratory work to study the weeds in their original homeland to identify their natural enemies began in 1982. An insect quarantine facility, which is the key to our insect biological control program, was constructed at Hawaii Volcanoes National Park in 1984, and the first shipment of insects from a foreign country was received in December of that year. More than 20 weeds have been identified as problems in our National Forests (Gardner and Davis 1982), and 12 cause problems serious enough to justify immediate control efforts (Smith 1990). Biological control programs are active against six of these.

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Progress to Date

Clidemia hirta (Melastomataceae) (Clidemia)

Clidemia, or Koster’s curse, is a native of low-elevation lands of the northern parts of South America. It was introduced into Hawaii probably as an ornamental plant for its veined and attractive leaves (Wester and Wood 1977). Near sea level in Hawaii, it has invaded moist areas on all major islands except Lanai. Once established, it forms dense stands 1 to 2 m high that exclude all native and most other introduced plants. Clidemia also at one time was a major problem in grazing lands in Hawaii, but programs in the 1950’s introduced two insects that eliminated it in open areas (Nakahara and others, in press). Unfortunately, the insects were not effective in shade, particularly where clidemia grows as an understory in the forests. A new program has resulted in the release of a disease agent, the fungus Colletotrichum gloeosporioides (Trujillo and others 1988), in 1987, and the leaf mining beetle Lius poseide, in 1988, both of which are now well established. Many other insects have been discovered and tested in Trinidad (Nakahara and others, in press), but the expense and work necessary for releasing them is being postponed until the impact of the two new agents, in combination with the two earlier established agents, can be studied to determine whether they are capable of exerting sufficient control.

Passiflora mollissima (Passifloraceae) (Banana Poka)

Locally known as banana poka or banana passion fruit because of its elongated yellow fruit, this weed is a domestic plant grown throughout the Andes of South America. Introduced to Hawaii around 1900, it soon escaped from cultivation and found the higher-elevation (1,000 m and above) native forests of Hawaii a perfect habitat (La Rosa 1983). It is now established on three of the Hawaiian islands, where it infests 40,000 ha and is still spreading (Warshauer and others 1983). In areas where it is well established, banana poka forms mats of vegetation that can cover native trees and breaks them with their weight, or increases their chance of blowdown during storms. On the ground these mats of vegetation smother shrubs, seedlings, and even small trees. Where banana poka is well established, regeneration of Hawaii’s native forests has ceased to occur (Markin and Nagata 1989).

Exploration in South America to find natural enemies of banana poka began in 1982 and although many potential biological control agents are now known (Pemberton 1989), the inaccessibility and political instability of most of the countries of the Andes make it difficult to conduct the necessary studies of this plant in its native homeland. To date, only two insects have been released. An attractive blue moth Cyanotricha necria (Lepidoptera: Diptidae), the larvae of which feed on the leaves, was released in 1988 (Markin and others 1989). A second moth, Pyrausta perelegans (Lepidoptera: Pyralidae), the larvae of which attack the flower buds, was released in February 1991. We hope that once P. perelegans is established, destruction of flower buds will reduce fruit set and slow the further spread of this weed. Four other insects are presently in quarantine undergoing evaluation, and under a new cooperative program, entomologists in Venezuela are searching for additional species. Two plant pathogens, a vascular wilt fungus (Fusarium oxysporum) and a powdery mildew (Acremonium sp.), are also being studied. The powdery mildew has been approved for use in Hawaii, but has not actually been released in the field.

Ulex europaeus (Leguminosae) (Gorse)

Gorse is a spiny, dense-growing shrub native to western Europe that was extensively used for hedges to contain livestock before the development of barbed wire. As a beneficial plant, it was exported to many parts of the world by European settlers, but it soon escaped from cultivation (Markin and Yoshioka 1989). Around the Pacific, gorse is a problem in Australia, New Zealand, Chile, northwestern United States, as well as in Hawaii. In Hawaii, gorse is established on only two islands, usually at elevations between 1,000 and 2,000 m. It currently infests only 14,000 ha, but despite extensive efforts to contain, or eradicate it, it continues to spread (Markin and others 1988).

In recognition of gorse’s role as a rangeland pest, Hawaii has had a long-standing program to find and introduce biological control agents for the weed, although the earlier programs succeeded in establishing only the seed weevil Apion ulicus (Coleoptera: Curculionidae) (Markin and Yoshioka 1989).

Gorse, also a forest weed, is capable of invading open forest lands, where it competes with native species, interferes with forest access and management, and competes with seedlings planted for reforestation. Because gorse is primarily a rangeland weed, the present program is still headed by the Hawaii Department of Agriculture, but receives assistance from our forest weed biological control program, as well as from cooperators in Chile, New Zealand, and Oregon. The present program has evaluated more than 10 species of insects, mainly from England and Portugal, and in 1989 released the foliage feeding moth Agaonopterix ulicetella (Lepidoptera: Oecophoridae). This insect is now well established with an expanding population. In 1990 we also released a gall-forming weevil (Apion scutellare (Coleoptera: Apionidae)), and this summer we will begin releasing a small foliage feeding thrips (Sericothrips staphylinus (Thysanoptera: Thripidae)). Our cooperators in New Zealand have also successfully established a gregarious web-forming mite, Tetranychus lineatius (Acari: Tetanychidae), that is already killing gorse plants at some locations. We hope to introduce this mite along with several other insects still in quarantine within the next few years.

Because of the support of the agricultural community in Hawaii, cooperation from several foreign countries, and the ease of working with a plant from Europe, the gorse program is our most advanced, and we tentatively plan to discontinue the search for and testing of new insects by 1993. At that time we hope to have established a complex of at least five species of arthropods, each attacking a different part of the plant. We will then enter a phase of redistribution and monitoring for a 5- to 10-year period to allow the populations to expand and determine their impact before we decide whether further releases are necessary.
Additional Weeds Targeted for Biological Control

Ann Miller (University of California) has been working with the California Cooperative Pest Management Program to identify and target weeds that are potential candidates for biological control. Her research has focused on the use of parasitoids and predators to control weeds in agricultural and natural ecosystems. Miller and her team have identified several species of insects that show promise as biological control agents for certain weed species. These include ladybird beetles, parasitic wasps, and leafhoppers. Miller's work has been instrumental in advancing the field of biological weed control and has led to the development of new strategies for managing problematic weeds in California's diverse landscapes.
by this grass have recently destroyed hundreds of hectares of
dryland native ecosystems and forests (Tunison, in press).
Biological control has never been tried against any species of
grass because of the potential danger that an introduced agent
might also attack some related agriculturally important spe-
cies (Pemberton 1980). The experience and techniques devel-
oped in biological control over the past 90 years have now
reached the level that crossover by an introduced agent from
its target weed to another plant is no longer a danger. Fountain
grass would be an ideal species on which to attempt the first
effort at biological control of a grass species.

Conclusions

Our program in Hawaii, we believe, is the first to attempt
specifically to control introduced weeds of forests and other
native ecosystems using biological control, although a similar
program is currently under development for the Everglades of
Florida. Although our program is only 10 years old, we already
have released six agents and are ready to release four more.
Several of the released agents are well established, increasing in
numbers, and spreading through the range of their target weeds.
It is still too early to tell which of these agents will be successful,
since establishment and population buildup to sufficient levels
to damage the plant usually require 5 to 10 years or more. On
the basis of the success of earlier programs against agricultural
weeds in Hawaii, we are confident that most of our programs
will eventually be successful.

Our experience in Hawaii has shown us that biological
control has several disadvantages. It is neither fast, nor cheap,
and occasionally conflicts of interest arise with groups opposed
to such a program, because to them the target weed may be
beneficial (Markin 1989, Markin and Yoshioka, in press). How-
ever, we have also learned that in many instances biological
control is the only tool available to us for managing weeds in
forest ecosystems and when successful will give a permanent
solution.

As we have watched our program progress and now see
insects and pathogens that we introduced attack the weeds, we
believe the program is showing the first sign of success and that
biological control will eventually become a key method for
weed management in forest areas and other natural ecosystems
here in Hawaii and probably on other Pacific islands.

References

Hawaii Agricultural Representative Service, Honolulu, HI. 100 p.

Brummett, Elgin; Field, Ross P. 1984. Occurrence and spread of Phragmites
vulgaris on blackberry (Rubus fruticosus) in Victoria, Australia. In:
Delfosse, E. S., ed. Proceedings of the VI International Symposium on
Biological Control of Weeds, 19-25 August 1984, Vancouver, Canada.

Tropical Botanical Garden.

DeBack, Paul Ed. 1964. Biological control of insects pests and weeds. New

Funasaki, George Y.; Lai, Po-Yung; Nakahara, Larry M.; Beardsley, John W.;
Ota, Aster K. 1988. A review of biological control introductions in
Society 28: 105-160.

Gardner, Donald E.; Davis, Clifton J. 1982. The prospects for biological
control of nonnative plants in Hawaiian National Parks. Technical Report
45, Honolulu, Hawaii. Cooperative National Park Studies Unit, Dep. of
Botany, Univ. of Hawaii at Manoa; 55 p.

Gardner, Donald E.; Markin, George P.; Hodges, Charles S., Jr. 1988. Survey
for potential biological control agents for Myrica faya in the Azores
National Park Studies Unit, Dep. of Botany, Univ. of Hawaii at Manoa;

Hodges, Charles S., Jr.; Gardner, Donald E. 1985. Myrica faya: Potential
Cooperative National Park Studies Unit, Dep. of Botany, Univ. of Hawaii
at Manoa; 42 p.

Julien, M. H. 1987. Biological control of weeds, a world catalogue of agents

La Rosa, Anne M. 1983. The biology and ecology of Passiflora mollissima in
Park Studies Unit, Dep. of Botany, Univ. of Hawaii at Manoa; 168 p.

Markin, George P. 1989. Alien plant management by biological control. In:
Stone, Charles P.; Stone, Danielle B., eds. Honolulu, Hawaii. Conservation
biology in Hawaii’s, Stone, Univ. Hawaii Press, Univ. Hawaii Coop-
erative National Park Resources Studies Unit; 70-73.

Markin, George P.; Dekker, Laurel A.; Lapp, Joyce A.; Nagata, Roddy F.

Markin, George P.; Nagata, Roddy F. 1989. Host preference of Cynotrichia
neckaya Felder (Lepidoptera: Dioptidae), a potential biocontrol agent of the
weed, Passiflora mollissima (H.B.K.) Bailey in Hawaii’s forests. Technical
Report 67, Honolulu, Hawaii. Cooperative National Park Resources
Studies Unit, Univ. of Hawaii at Manoa; 35 p.

and behavior of the South American moth, Cynotrichia neckaya Felder
(Lepidoptera: Dioptidae), a potential biocontrol agent in Hawaii of the
forest weed, Passiflora mollissima (H.B.K.) Bailey. Proceedings of the
Hawaiian Entomological Society 29:115-123.

Markin, George P.; Yoshioka, Ernest R. 1989. Present status of biological
control of the weed gorse (Ulex europaeus L.) in Hawaii. In: Delfosse, E.
S., ed. Proceedings of the VII International Symposium on Biological
Control of Weeds, Rome, Italy, Instituto Sperimentale per la Patologia
Veggetale Ministro dell’Agrocultura e delle Foreste; 357-362.

Markin, George P.; Yoshioka, Ernest R. Evaluating proposed biological
control programs for introduced plants. In: Stone, C.P.; Smith, C. W.;
Tunison, J. T., eds. Alien plant invasions in native ecosystems of Hawai’i:
management and research. Honolulu, Hawaii. Univ Cooperative
National Park Resources Studies Unit [In press].

Markin, George P.; Lai, Po-Yung; Funasaki, George Y. Status of biological
control of weeds in Hawaii and implications for managing native ecosys-
tems. In: Stone, C.P.; Smith, C. W.; Tunison, J. T., eds. Alien plant
invasions in native ecosystems of Hawai’i: management and research.
Honolulu, Hawaii. Univ Hawaii Cooperative National Park Resources
Studies Unit [In press].

Nagata, Roddy F.; Markin, George P. 1986. Status of insects introduced into
Hawai’i for the biological control of the wild blackberry Rubus argutus
Link. Proceedings of the Sixth Conference of Natural Science, Hawaii
Volcanoes National Park; 541-547.

Nakahara, Larry M.; Burkhardt, Robert M.; Funasaki, George Y. Review and
status of insects for biological control of Cithamia hirta in Hawaii. In:
Stone, C.P.; Smith, C. W.; Tunison, J. T., eds. Alien plant invasions in
native ecosystems of Hawai’i: management and research. Honolulu,
Hawaii. Univ Hawaii Cooperative National Park Resources Studies Unit
[In press].

Neal, Marie C. 1965. In gardens of Hawaii. Bernice P. Bishop Museum,


Proceedings of the Session on Tropical Forestry for People of the Pacific.