MYRICA FAYA: ONE MAN'S MEAT IS ANOTHER MAN'S POISON

By C. W. SMITH [1], C. LUTZOW-FELLING [1] & D. E. GARDNER [2]

ABSTRACT. Faya is a highly invasive plant in Hawai'i. It alters ecosystem processes. This paper traces the history of the infestation in Hawai'i, its impact on agriculture and native systems, the progression of a consensus to manage if not eradicate it, and the advances made in containing and controlling it.

Myrica faya AITON (faya, fayatree, firetree, or firebush), a Macaronesian endemic, is considered to be one of the twelve most disruptive alien plants in Hawai'i due to its rapid and successful adaptation to the Hawaiian environment (SMITH 1985). It is probably the most serious alien plant threat in open-canopy xeric and mesic Hawaiian montane ecosystems particularly those on nitrogen-poor sites such as young lava flows (VITOUSEK & WALKER 1989). It is also an increasingly significant problem in ranchlands.

Its Macaronesian origin and identity was clearly established from the outset, an enormous advantage for investigators particularly in a genus where species delimitation is so difficult (WHITE 1993). Exploratory work for biological control agents was facilitated therefore; a somewhat fortuitous situation for a naturalized weed in Hawai'i where most weeds go through several name changes before the correct name and thereby the country of origin is verified.

Faya was introduced to Hawai'i at the end of the last century at the time when many Portuguese immigrant labourers were brought to the Islands to work in the sugar cane plantations. It is not really known why they brought this particular plant with them. It has a number of minor cultural uses, none of them seemingly significant enough to ensure its being consciously chosen (LUTZOW-FELLING *et al.* 1995). It has also been suggested that it was taken to Hawai'i merely as a momento of the homeland. Whatever the reason for its introduction, the Hawaiian population is remarkably uniform when compared with the

[1] Department of Botany, University of Hawai'i at Manoa, 3190 Maile Way, Honolulu HI 96822 U.S.A.
[2] Cooperative National Parks Resources Studies Unit, 3190 Maile Way, Honolulu HI 96822 U.S.A.

variation in Macaronesian plants. It suggests a very small subsample, perhaps a few seeds from one or two plants--which one would expect from someone taking material from one place to another without any specific idea for its use.

In the late 1920s, it was one of many species planted in reforestation programs by the then Hawaiian Territorial Government which was trying to revegetate huge areas of watersheds destroyed by herds of wild cattle (YAMAYOSHI 1954). Why faya was chosen as a species suitable for this program is not known. There was no information in the literature about its potential in reforestation and we are not aware of any word of mouth reputation that it was a good candidate from similar projects elsewhere in the world. Indeed, Hawai'i appears to be the only place outside faya's native range where it is established in the wild. Since its ability to fix nitrogen was known, however, and it was already growing and fruiting in a few gardens in Hawai'i it was a reasonable choice for a local "experiment." Seeds were obviously not in plentiful supply since only a few hundred plants were planted in six sites on four islands (SKOLMEN 1979). The largest outplanting was in Hamakua, Hawai'i, an area close to where the stock trees for the planting program were growing.

Initially, the plant did not appear to be a problem. In fact, in almost all areas below 300 m elevation, e.g., Palolo, O'ahu, it did not survive. By the late 1930s, however, ranchers in higher elevation pasturelands, particularly at Hamakua between 1,300 - 2,300 m, were beginning to report it in their pastures and were expressing some concerns regarding its noxious nature; it was unpalatable to livestock and was spreading rapidly. These concerns were consistently expressed by ranchers on the Island of Hawai'i and toward the end of World War II in 1944, the Territorial Government made some efforts to eradicate it. The species was declared a noxious weed (HOSAKA 1945) and some exploratory work was conducted in Macaronesia to look for biological control agents (BIANCHI 1953-1956). No suitable insects or diseases were found and the program was abandoned. No further action was taken until the late 1970s when Hawai'i Volcanoes National Park began efforts to restrict its spread in the Park where it was a recent invader displaying an explosive population expansion. It was not until the mid-1980s that an interagency committee representing various interests, including the National Park Service, the U.S. Forest Service, ranchers, residential property owners, and State of Hawai'i government groups was formed to pressure the state legislature to sponsor a study of various management options and then implement them. The potential habitat was estimated at a minimum of 500,000 ha though the infestation at that time was confined to less than 30,000 ha. The total cost to remove the standing crop was estimated to exceed $20 million and controlling further reproduction another $2.5 million each year decreasing to a few hundred thousand dollars within five years by which time the seed bank would have been exhausted. No estimate of the economic impact of this infestation was made, yet the concerted lobbying made a very deep impression on legislators. Since the mid-80s there has been a flurry of research activity, some of which has been reported at this conference, some of which has already been published, as well as other studies still in progress.

One insect has been released as a biological control agent with little effect to date. Others are still being evaluated for potential release. Almost simultaneously with the management activity P. M. Vitousek, Stanford University, obtained a grant from the National Science Foundation to study the functional role of faya in the Hawaiian ecosystem.

There is a strong contrast in the phenology of faya between Hawai'i and the Açores. SILVA & TAVARES (this volume) noted the highly seasonal phenology on Sâo Miguel, Açores, whereas WHITEAKER & GARDNER (1987) found concurrently that all phenophases could be found in Hawaiian populations, though the strongest flush coincided with the seasonal cycle in the Açores.

Faya is ideally adapted to conditions in Hawai'i, probably a consequence of the many physical similarities to Macaronesia, e.g., both have recent volcanic substrates and mild oceanic climates. Perhaps the most important factor, however, is faya's ability to fix atmospheric nitrogen by means of its symbiotic association with the actinomycete *Frankia*. It nearly quadruples the amount of nitrogen entering these typically nitrogen deficient substrates (VITOUSEK 1992). It is perhaps this singular ability that makes it such a successful competitor in the volcanic, nitrogen-deficient soils of Hawai'i to which most native plants have adapted by various strategies to conserve nitrogenous compounds. The rapid addition of vast amounts of nitrogen enables faya and potentially other faster growing alien weeds to become established and displace the native species. Vegetation disruption, in turn, almost certainly adversely affects native fauna such as birds, land snails, and insects which depend on native vegetation for food and habitat. LIPP (1994) has recently characterized the ecophysiology of faya in Hawai'i. She found that germination and seedling survival were dependent on adequate light (see also WALKER 1990). High and low soil moisture inhibit germination. Physiological adjustments to drought enable some trees to establish themselves resulting in the eventual infestation of a wide variety of habitats. Indications are that faya has not attained its full potential range in the Hawaiian Islands.

Faya is a significant weed in Hawai'i because: 1. It forms dense monotypic stands that contain few, if any, other plants. Faya infestations, therefore, decrease the habitat available for native species, many of which are endangered; 2. It is not utilized as a primary food source by any known native fauna. Alien birds, such as the Japanese white-eye (*Zosterops japonicus japonicus*), however, do forage in the trees and are the principal dispersal agents of the seeds (WOODWARD *et al.* 1990); 3. Faya grows very rapidly. It can overtop the native *Metrosideros* trees within seven years in favourable conditions (WALKER & VITOUSEK 1991); 4. It has a very high seed set. Trees in Hawai'i obviously bear much heavier crops of fruit than those that we have seen in the Açores and Madeira. In some areas, fruitset can be so heavy that the branches bend down under the load; 5. Seedling recruitment is very high. You can nearly always find seedlings associated with parent trees in Hawai'i; something that is not easy to do in Macaronesia in undisturbed habitats. 6. Trees reach maturity early, producing flower and seed after three years. 7. Faya alters nitrogen inputs and can affect

natural succession on primary substrates (VITOUSEK *et al.* 1987).

Faya is an extremely rapid invader (WHITEAKER & GARDNER 1992). In Hawai'i Volcanoes National Park a single plant was recorded in 1961. By 1977, it had infested 620 ha. In 1985, it had spread to 12,200 ha. At this time, park managers began controlling it in important viewsheds in the park as well as trying to contain its spread. Even so, the range expansion has continued. The latest evaluation in 1992 estimated that it was present in 15,100 ha of the park. The rate of spread has slowed considerably, as a consequence of park management action. Control efforts costing in excess of $40,000 last year and approximately $225,000 in total has been spent on its control in the park in the last six years. A recent estimate of the total infestation in the state suggests that faya currently occupies over 40,000 ha and is still expanding its range. It is obviously beyond control by conventional mechanical and chemical techniques in all but small, selected areas.

Various strategies to control faya have been developed and most have failed. Trees were merely felled in early efforts. Though resprouting was minor, the cleared ares, was soon overrun by solid stands of seedlings (YAMAYOSHI 1954). Hand-pulling the seedlings proved to be very time-consuming and, therefore, extremely expensive in Hawai'i with its high labour costs. Both approaches were rapidly abandoned. Attempts to control establishment by intensive grazing failed. Cattle avoided the plants completely; even goats only ate them as a last resort. In the Açores, cattle are fed faya shoots in some areas. Pollarded shoots are cut and taken to the cattle which relish them according to the farmers. It may be that the wilting associated with harvesting makes the foliage more acceptable. However, in Hawai'i, where cattle roam free on the range, this approach is not a viable option.

Faya is very sensitive to many herbicides but they are useful only in restricted areas. Spraying the foliage results in leaf drop followed by rapid resprouting (KIM 1969). Spraying does decrease the vigour and even kills the trees after several applications but concerns about herbicide residues in watersheds, the necessity for multiple treatments and the overall cost-ineffectiveness of such an approach forced managers to seek other solutions. Cut-frill application of herbicides, a labour-intensive method using two herbicides, both now banned in the U.S., was very effective (KIM 1969). Herbicides, particularly imazapyr and metasulfuron, are currently used in intensive management areas using cut-stump treatment or introduction into the plant by various other methods (CUDDIHY *et al.* 1991).

Biological control, which 30 years ago looked very unattractive, is almost our last hope as a permanent control strategy for faya. Several insect species from Macaronesia are under consideration for release (MARKIN & SILVA, this volume). However, because of the lack of a high probability of success with these species and a need for a range of species with a greater variety of feeding behaviours, we are also looking at insects and diseases which attack other *Myrica* species elsewhere in the world. Our attention is focusing on some *Myrica* species in Venezuela which show significant damage from insects.

Our research on potential biological control agents is not cheap by any means. We

have spent just under $1.5 million to date. It is anticipated that this figure will exceed $2.5 million by the time we finish.

It is interesting to note that over the years there has been little attention paid to faya in Europe other than floristic and vegetation accounts. This is not extraordinary because members of the Myricaceae have received little attention in the literature. However, once faya was recognised as a weed in Hawai'i the literature pertaining to this one species has exploded. The work of VITOUSEK and his colleagues (1986-1994), in particular, have been significant in increasing our understanding of many aspects of faya's ecology. These studies were the first to clearly demonstrate how significantly an invading plant species can change the characteristics of an ecosystem (VITOUSEK *et al.* 1987). Other studies, in conjunction with colleagues in the Açores and Madeira, have focused much more on potentially applied aspects and have contributed to an understanding of the entomofauna and diseases of faya. A summary of this work, with a complete bibliography, has recently been published (LUTZOW-FELLING *et al.* 1995).

In conclusion, faya is a significant threat to native Hawaiian ecosystems, the ranching industry and many other interests in Hawai'i. In contrast, in its native Macaronesia, it is declining or rare on some islands and, apparently, is extirpated on one or two. Faya is capable of invading undisturbed native habitats which makes it a very serious problem for managers of natural areas in Hawai'i. Fortunately, it is not too widely distributed to date but the extent of the potential habitat, at least 500,000 ha is alarming (WHITEAKER & GARDNER 1992). We are determined, therefore, to find methods to control this species. We have had the full support of both the U.S. and State of Hawai'i governments who have sponsored much of this work even when funds have been extremely limiting. We have also been very fortunate to have had the full cooperation and assistance of many biologists in Macaronesia, particularly DRS. AGUIAR (Madeira Department of Agriculture), SILVA AND TAVARES (University of the Açores). Their participation has been extremely helpful and is much appreciated. We hope that this interaction will continue to the benefit of both areas.

REFERENCES

BIANCHI, F. A.:

1953-1956. Unpublished file of correspondence with the Hawai'i Territorial Board of Agriculture documenting exploration for biocontrol agents in the native habitats of fayatree.

CUDDIHY, L. W., G. L. SANTOS, & C. P. STONE:

1991. *Control of firetree (*Myrica faya *Aiton) with herbicides in Hawai'i Volcanoes National Park.* Technical Report 82. University of Hawai'i Cooperative National Park Resources Studies Unit, Honolulu. 46 pp.

HOSAKA, E. Y.:

1945. Noxious weeds of Hawai'i. Report to the Board of Commissioners of Agriculture and Forestry, Honolulu.

KIM, J. Y.:

1969. "Myrica faya" control in Hawai'i. Down to Earth **25**: 23-25.

LIPP, C. C.:

1994. *Ecophysiological and community-level constraints to the invasion of* Myrica faya*, an alien tree in Hawai'i Volcanoes National Park.* Ph.D. dissertation, Department of Botany, University of Hawai'i at Manoa, Honolulu.

LUTZOW-FELLING, C., D. E. GARDNER, G. P. MARKIN, & C. W. SMITH:

1995. Myrica faya: *Review of the biology, ecology, distribution, and control, including an annotated bibliography.* Technical Report 94. University of Hawai'i Cooperative National Park Resources Studies Unit, Honolulu.

MARKIN, G. P., & L. SILVA:

this volume. The insect fauna associated with *Myrica faya* in the Atlantic Islands and on mainland Portugal.

SILVA, L., AND J. TAVARES:

this volume. Phenological cycles of *Myrica faya* Aiton (Myricaceae) in the Açores Islands: Preliminary results.

SKOLMEN, R.:

1979. Plantings in the forest reserves of Hawai'i 1910-1960. Manuscript on file, Institute of Pacific Islands Forestry, Pacific Southwest Forest and Range Experiment Station, USDA Forest Service, Honolulu.

SMITH, C. W.:

1985. Impact of alien plants in Hawai'i's native biota. Pp. 180-250 In: C. P. Stone and J. M. Scott , eds., *Hawai'i's terrestrial ecosystems: Preservation and management.* University of Hawai'i Cooperative National Park Studies Unit, Honolulu.

VITOUSEK, P. M.:

1986. *Biological invasions and ecosystem properties: Can species make a difference?* Pp. 163 -176 In: H. A. Mooney and J. A. Drake, eds., *Ecology of biological invasions of North America and Hawai'i.* Springer-Verlag, New York.

1990. Biological invasions and ecosystem processes: Towards an integration of population biology and ecosystem studies. *Oikos*, **57**: 7-13.

1992. Effects of alien plants on native ecosystems. Pp. 29-41 In: C. P. Stone, C. W. Smith, and J. T. Tunison, eds., *Alien plant invasions in native ecosystems of Hawai'i: Management and research.* University of Hawai'i Press, Honolulu.

VITOUSEK, P. M., & L. R. WALKER:

1989. Biological invasion by *Myrica faya* in Hawai'i: Plant demography, nitrogen fixation, and ecosystem effects. *Ecological Monographs* **59**: 247-265.

VITOUSEK, P. M., L. R. WALKER, L. D. WHITEAKER, D. MUELLER-DOMBOIS, & P. A. MATSON:

1987. Biological invasion by *Myrica faya* alters ecosystem development in Hawai'i. Science **238**: 802-804.

WALKER, L. R.:

1990. Germination of an invading tree species (*Myrica faya*) in Hawai'i. *Biotropica* **22**: 140-145.

WALKER, L. R., AND P. M. VITOUSEK:

1991. An invader alters germination and growth of a native dominant tree in Hawai'i. *Ecology* **72**: 1449-1455.

WALKER, L. R., P. M. VITOUSEK, L. D. WHITEAKER, AND D. MUELLER-DOMBOIS:

1986. The effect of an introduced nitrogen-fixer (*Myrica faya*) on primary succession on volcanic cinder. (Abstr.) P. 98 In: C. W. Smith, ed., *Proceedings of the Sixth Conference in Natural Sciences, Hawai'i Volcanoes National Park*. University of Hawai'i Cooperative National Park Studies Unit, Honolulu.

WHITE, F.:

1993. African Myricaceae and the history of the Afromontane flora. *Opera Botanica* **121**: 173-188.

WHITEAKER, L. D., AND D. E. GARDNER:

1987. *The phenology and stand structure of* Myrica faya *Ait. in Hawai'i.* Technical Report 62. University of Hawai'i Cooperative National Park Studies Unit, Honolulu. 20 pp.

1992. Firetree (*Myrica faya*) distribution in Hawai'i. Pp. 225-240 In: C. P. Stone, C. W. Smith, and J. T. Tunison, eds., *Alien plant invasions in native ecosystems of Hawai'i: Management and research.* University of Hawai'i Press, Honolulu.

WOODWARD, S. A., P. M. VITOUSEK, K. MATSON, F. HUGHES, K. BENVENUTO, AND P. A. MATSON:

1990. Use of the exotic tree *Myrica faya* by native and exotic birds in Hawai'i Volcanoes National Park. *Pacific Science* **44**:88-93.

YAMAYOSHI, H. T.:

1954. *Myrica faya* survey, District of Hamakua, Hawai'i. Unpublished report. Board of Commissioners of Agriculture and Forestry, Territory of Hawai'i, Hilo. 3 pp.