Current Biocontrol Investigations: Exploration for Control Agents in the Native Habitats of Firetree, and Evaluation of Rust Diseases of Rubus spp. in the Southeastern U. S.

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Firetree (*Myrica faya* Ait.) has long been recognized as one of the most seriously disruptive and widely encroaching alien species in Hawaii Volcanoes National Park (HAVO). In management efforts to control firetree, tens of thousands of firetrees have been removed from HAVO environments in past years, but the population continues to increase. Former exploratory trips by Hawaiian entomologists to the native regions of this species have indicated that both diseases and insects worthy of consideration in a biocontrol program may exist. One such disease-causing fungus, identified as *Dothiorella berengeriana* Sacc., showed initial promise but in subsequent tests was found to be insufficiently specific in host range to be useful in Hawaii (Fred Bianchi, copies of unpublished correspondence). Other potential agents have been observed but not tested conclusively for biocontrol purposes. It was desirable for investigators to return to the native regions of firetree: The Azores, Madeira, and the Canary Islands, to further observe this species in its original environments. Since firetree is not considered aggressive in its native habitats, it was necessary to assess the effects of any previously observed or newly discovered biological agents in limiting this species and maintaining it in balance.

The current exploratory trip was made by Dr. Charles Hodges, a U. S. Forest Service senior forest pathologist, and Dr. Donald Gardner, a National Park Service plant pathologist. Enroute to the above-named North Atlantic islands, we visited the USDA Plant Disease Research Laboratory at Fort Detrick in Frederick, Maryland. This laboratory maintains microbiologically (as distinct from entomologically) secure greenhouse and laboratory quarantine facilities suitable for research work involving foreign pathogenic organisms prior to their release into the environment for biocontrol purposes. We also traveled to the Commonwealth Mycological Institute at Kew Botanical Gardens near London, England to establish and renew contacts and to search herbarium records for references to *Myrica faya* and any fungi reported to attack this species. From England we traveled to Lisbon, Portugal where we visited the laboratory of Dr. Natalina Azevedo, the plant pathologist who had been commissioned by the Hawaii Board of Agriculture and Forestry to test the pathogenicity and host range of *Dothiorella berengeriana* following its discovery in the Azores by Mr. Bianchi. Dr. Azevedo's results provided the basis for rejection of the fungus as a candidate biocontrol agent for firetree in Hawaii, as documented in a letter to her from Alan Thistle in 1957 (copies of unpublished correspondence).

We arrived in the Azores during the latter part of April, 1984, and visited four of the nine islands of the Portuguese archipelago: San Miguel, Terceira, Faial, and Pico. We traveled from the Azores to Madeira, also a Portuguese possession, in mid-May, visiting the main island of Madeira, which is the only island of the group having firetrees. From Madeira we traveled to the Canary Islands, possessions of Spain, during the latter part of May. We visited three of the seven islands of that archipelago: Gran Canaria, Tenerife, and La Gomera.

Although in general much of the land at lower elevations of all islands visited is under cultivation, native forests in upper elevations are still plentiful and firetree is abundant and readily accessible. This is particularly true of Terceira, Faial, and Pico of the Azores, where firetree not only constitutes an important component of forests, sometimes growing in pure stands, but also occurs in cultivated areas along hedge and fence rows, in fields and pastures, and along roadsides. Firetrees planted as windbreaks around vineyards and garden plots are common. When used as windbreaks and border plantings, the trees are closely spaced and are often evenly trimmed on each side. Firetrees are also occasionally used as ornamentals in parks and near buildings, where they may also be pruned to specified shapes.

In the Azores and the central mountainous and northern coast regions of Madeira firetree occurs both in natural stands and around cultivated areas from sea level to several hundred meters elevation, depending on the particular location.

Firetree typically appears limited in the Canary Islands to upper elevations, above approximately 400 meters. The climate of the Canaries was found to be considerably drier than that of either the Azores or Madeira, presumably limiting Myrica faya to the upper, forested regions where this species occurs as an abundant and an important component of the flora of Tenerife, La Gomera, and reportedly La Palma also, although we did not visit the latter island. We observed firetree only in a botanical garden on the island of Gran Canaria and were informed that plants of this species were scattered and would be difficult to locate in a limited time on Gran Canaria, as well as on the other eastern islands of the Canaries.

Flowering and fruiting states throughout the islands were variable and difficult to predict, but appeared roughly correlated with elevation. Depending on the location, pistillate trees were observed in preflowering or in early to late stages of flowering and immature fruit development. Staminate trees were particularly variable in flowering stages, and newly developing flowers to those with old, dehiscent anthers were observed often in the same sites. Flushing of new growth may also have been dependent on the elevation and most notably on the size or age of the individual tree. Small trees and sprouts from older cut stumps exhibited vigorous production of new growth, contrasting with larger adjacent trees which were often conspicuously flowering (usually staminate) but which were producing no current year's growth.

Firetrees were found to assume various growth forms depending on the site in which they occur. Trees in dense forests develop tall, more or less straight, unbranched trunks and small crowns similar to the growth forms of associated species; whereas trees in pastures or other open areas assume a branched, bushy form such as that more commonly found in and around HAVO. We observed many large, apparently very old trees with trunks 24 to 30 inches in diameter and approximately 60 feet tall. In forests on Tenerife the crowns of large firetrees sometimes could be observed overstorying other tree species and firetrees could be identified in forest crowns from a distance by this characteristic. Large, old more or less isolated firetrees observed in the Azores and Madeira may be remnants of old forests which have since been converted to pasture land or they may have survived in fence or hedge rows near cultivated areas. We were informed in Madeira, however, that Myrica faya is more typically considered a substory forest component.

Firetree seedlings and saplings were abundant at some sites, and in areas with recent volcanic activity, such as on the Azores island of Faial, young trees were observed colonizing a'a lava flows. Firetrees occupying sea cliffs and other exposed, harsh environments were often rooted in rock or in extremely rocky soil and were severely stunted and wind-pruned such that they assumed a short, shrub-like growth form. Furthermore, trees near the sea coast showed some damage from salt water spray, but were nevertheless able to survive this exposure. The soil of many Myrica faya sites was obviously rocky and poor and less suitable for cultivation. We noted in the Azores in particular that the better sites had been converted to agricultural uses or forest plantations, usually of Japanese cedar (Cryptomeria japonica (L.f.) D. Don), and less useful plant species, including firetree, were left to occupy poorer sites to which they are apparently adapted.

As a general observation, firetree is abundant in its native habitats and must be considered a healthy, prominent component of the flora of the Azores, Madeira, and the Canary Islands, although locally it is found more frequently in some areas than others. We had little difficulty locating sufficient numbers of plants to adequately observe representative populations in all of its habitats. Sufficient firetree material occurs on the Azores island of Pico alone to support an extended, indepth study of the species in a particular location of its native range should this be desirable.

Firetree did not appear to be significantly limited in spread or abundance in its native regions by particular insects or diseases. Instead, climatic and ecological conditions such as rainfall and competition with other native and alien species, including the widespread alien tree Pittosporum undulatum Vent. which itself is often considered a problem in forests, may be of more importance in maintaining firetree in balance in forest situations. Human activities such as land clearing for cultivation, and mechanical removal of invading individual plants of this as well as other woody species from pastures and fields, are reportedly sufficient to maintain cultivated areas without further concern. Firetree is reportedly preferred as a source of firewood in the Azores and Madeira, but we did not observe evidence of harvesting for this purpose and such removal probably exerts little overall influence on the dynamics or structure of Myrica faya populations in these regions.

Notwithstanding the apparent general health of firetree in its original environments, we noted particular diseases and insects attacking this plant, some of which we believe to be worthy of further consideration. Throughout its range, firetree was infected with a canker disease of the main trunks, branches, and smaller twigs. This disease was typified by severe bark disruptions, sometimes exposing the inner wood. On large stems the cankers were about 12 inches long and contrasted strikingly with surrounding areas of normal bark. Many cankers sometimes occurred on the stem and branches of single trees. It was frequently possible to identify firetrees in dense, mixed forests by the presence of the conspicuous cankers on stems of this species in contrast to the lack of such symptoms on all other associated trees. This is probably the same canker disease referred to by Mr. Bianchi (copies of unpublished correspondence) during his earlier exploration of these regions. Mr. Bianchi reported that the cause of these cankers was never discovered, despite extensive efforts to do this.

Our observations showed the cankers to be consistently associated with fruiting bodies of Nectria sp. Fungi of this genus typically cause cankers similar to those observed in other woody host species. Although we have not yet conducted inoculation tests to prove pathogenicity, we have little doubt that these may be considered Nectria cankers. This disease appeared capable of killing trees and branches in some locations, and also of interfering with normal growth, but the presence of large cankers on stems of large, apparently old firetrees indicates that trees may be capable of coexisting with the disease. The degree of host specificity of the pathogen, as well as its specific identity, remain to be determined.

Branch and twig galls of older trees, sometimes in frequencies of hundreds per tree, were also observed. The cause of these galls, which caused little apparent damage to affected trees, was less obvious than was that of the cankers; however, we observed some evidence that Nectria may also be associated with the galls.

A second widespread disease which was observed on all islands we visited except Gran Canaria and was often locally common, resulted in curling, blackening, and death of young shoots. What we assume to be this disease was also observed by Mr. Bianchi who associated it with Dothiorella dieback but also recognized differences between the two diseases according to the descriptions in his correspondence. Mr. Bianchi reported that the blackened tissue of shoots killed by this disease differed from Dothiorella dieback by producing white flocculose fungal growth, which we have also observed, on the tissue surface.

In his subsequent exploratory investigations to the native habitats of firetree, Krauss (1964) reported a similar disease caused by the fungus Ramularia destructiva Phillips & Plowright. We consider this to be the disease which we observed and confirm Mr. Bianchi's intimation that two distinct dieback-type diseases may be present. The Ramularia disease must likewise be tested to determine its host-specificity and other suitable characteristics for biocontrol purposes in Hawaii. The disease was not observed on plants other than firetree. A disease of staminate flowers, probably caused by the same fungus, was observed particularly on the island of Terceira in the Azores. The disease appeared to be associated with premature drop of the flowers. Ramularia also appeared to be associated with a leaf spot disease of firetree. Our observations indicated the leaf spot and the flower disease to be much more limited in distribution than was the shoot dieback, however, and therefore not as damaging.

A branch dieback associated with Dothiorella was observed on firetree on Madeira. We assume this disease to be the one reported by Mr. Bianchi and tested in Portugal by Dr. Azevedo as discussed above. Branches were killed back and blackened approximately 1 foot from the tips, in contrast to the symptoms of the Ramularia shoot dieback which affected only newly developing shoots. At the time of our observation, however, Dothiorella dieback appeared to be restricted in distribution to only a few plants in localized areas. The potential effectiveness of this disease was emphasized by Mr. Bianchi, but, as discussed above, this fungus was declared unsuitable for biocontrol purposes unless a virulent, host-specific strain could be found.

We found a single firetree declining as a result of infection by Armillaria mellea (Vahl.:Fr.) Kummer, a common root-rotting fungus also of wide distribution and host range. This pathogen presently occurs in Hawaii, where it attacks a number of species, including Acacia koa Gray, and would not be suitable as a biocontrol agent.

Other leaf spot diseases of unknown origin were observed, sometimes common in local areas but rare in other locations. The occurrence of leaf spots on former years' foliage which remained on the trees indicates that these infections were usually of insufficient severity to cause defoliation.

We observed a phenomenon unusual for firetree, typically an evergreen species, on the island of San Miguel. At elevations above 600 m plants of this species, which form low, thicket-like stands in that environment, were defoliated. We were informed by local forest service personnel that firetree is normally deciduous at such higher elevations. We found some of the branches and twigs themselves to be dead, however, and little tendency toward refoliation was observed among these plants at the time of our visit to this area in late April. We question whether the reported deciduous nature of these trees is in fact part of a normal phenological cycle. On the other hand, we were not able to immediately determine any abnormal environmental influences, including pathogenicity, which would account for this condition. This defoliation was not observed elsewhere among the islands at similar elevations. Extended seasonal observation would more fully establish the nature of this reported deciduous cycle.

Krauss (1964) reported a number of insect species associated with firetree. Several of these were sent to Hawaii in conjunction with his investigations, but only one moth species was reported to have been released and become established. The small caterpillars of Carposina sp., possibly C. atlanticella Rebel, were found by Krauss boring into green fruits of Myrica faya and destroying the seed at Ribeira Frio, Madeira. Although many lots of infested fruits were sent to Honolulu for propagation and further investigation, the stock died out before conclusive results could be obtained.

We likewise observed caterpillars of most probably the same species on Madeira feeding in a similar manner in the interior of green fruits, consuming the seed. Caterpillars could often be found inside fruits with no apparent exterior damage or entry point, whereas other fruits were obviously damaged and frass was evident on clusters of infested fruit. We estimated that as many as 90% of the fruits were entered and the seed destroyed at local sites where heavy infestation occurred.

Caterpillars similar in description to the fruit and seed feeding species were found boring into young firetree shoots through the apex. This feeding activity resulted in a hollowing of the shoot and caused shoot death which resembled in some respects the shoot blight caused by Ramularia discussed above. Like the Ramularia disease, shoot destruction caused by the caterpillars was readily apparent and locally common. This insect was not found in the Canary Islands, but is nevertheless considered one of the more destructive agents of firetree we observed. We did not observe feeding activity by this insect on any plant species associated with firetree. Since the adult stages of the Myrica faya insects are required for positive identity to be established, we initiated arrangements with local entomologists to investigate the life cycle of the insect and further characterize it.

We observed other insects and insect feeding injury on firetree, some of which was probably also observed and reported by Bianchi and Krauss. The insects included a weevil, small beetles, leaf binding caterpillars, and lygus bugs. We observed two species of scale insects of rather widespread distribution throughout the islands, although the occurrence of these insects on other plants indicated that they were not specific. They never occurred in sufficient numbers to cause visible damage. Occasionally firetrees were found with leaf damage apparently resulting from phytophagous activity of larger insects which we were unable to locate.

In summary of the firetree investigations, our observations indicate that Myrica faya is generally abundant and healthy in its native habitats and that biological agents were apparently not important limiting factors of this species in those regions during the time of our visit. We did discover at least two diseases and two insects (or one insect that causes two types of damage) which should be further investigated in a biocontrol program for Hawaii.

Since State of Hawaii permit applications for the importation of foreign microorganisms are required to bear the scientific names of organisms to be brought into the state, we were not able to obtain such permits prior to our departure. We did obtain open permits to bring cultures of pathogenic organisms into the mainland U. S. to be deposited and maintained at the Frederick, Maryland laboratory, however, until further testing can be conducted.

Biocontrol of Rubus

Alien Rubus species are among the most disruptive plants in and around Hawaiian national parks. Past attempts by the State Department of Agriculture at biocontrol of R. penetrans Bailey (known as R. argutus Link in the southeastern U. S., where it is native), the most widespread Rubus species in Hawaii, have been partially successful (see Gardner and Davis, 1982). Gardner and Hodges (1983) reported a rust fungus disease of R. penetrans in Hawaii which was investigated to determine its present effectiveness in limiting R. penetrans and in attacking other alien Rubus species as well as the two endemic species R. hawaiiensis Gray and R. macraei Gray.

The rust fungus Kuehneola uredinis (Lk.) Arth. is also known to occur in the Southeast where it may infect R. argutus stems, as well as leaves. Such systemic infection has not been observed in Hawaii. Dr. Hodges and I are cooperating in a study to determine the pathogenicity or virulence of southeastern isolates of K. uredinis on native and nonnative Rubus species from Hawaii.

A second systemic rust species of southeastern Rubus species, Gymnoconia nitens (Schw.) Kern & Thur. (Kunkelia nitens) (Schw.) Arth. is likewise being tested on Rubus species from Hawaii. We began this work at North Carolina State University to which we traveled in conjunction with our trip to the native regions of firetree.

Cuttings of *Rubus penetrans*, *R. ellipticus* Sm., *R. glaucus* Barth., *R. rosaefolius* Sm., *R. hawaiiensis*, and *R. macraei* had previously been sent to the Horticulture Department of North Carolina State University where they were rooted and established in the greenhouse by local departmental collaborators. At the time of our visit, plants of each *Rubus* species were healthy and growing vigorously. Dr. Homer Wells, of the University of Georgia, also collaborated by supplying large quantities of rust inoculum from Georgia which we used for inoculation. We inoculated by spraying the plants with a mist of spore-water suspension and covering the plants with plastic bags for 2 days to maintain high humidity. Inoculated plants remain under observation in the greenhouse.

Literature Cited

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