Brazilian Peppertree

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S. D. Hight - United States Department of Agriculture, Agricultural Research Service, Center for Biological Control, Tallahassee, Florida, USA,
J.P. Cuda - Department of Entomology and Nematology, University of Florida, Gainesville, Florida, USA,
J. C. Medal - Department of Entomology and Nematology, University of Florida, Gainesville, Florida, USA.

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Pest Status of Weed

Schinus terebinthifolius Raddi, commonly called Brazilian peppertree in North America, is an introduced perennial plant that has become well established and invasive throughout central and southern Florida (Ferriter, 1997; Medal *et al.*, 1999). This species is native to Argentina, Brazil, and Paraguay (Barkley, 1944, 1957) and was brought to Florida as an ornamental in the 1840s (Ferriter, 1997; Mack, 1991). The plant is a dioecious, evergreen shrub-to-tree that has compound, shiny leaves. Flowers of both male and female trees are white and the female plant is a prolific producer of bright red fruits (Fig. 1). Although the plant is still grown as an ornamental in California, Texas, and Arizona, *S. terebinthifolius* is classified as a state noxious weed in Florida and Hawaii (Ferriter, 1997; Habeck *et al.*, 1994; Morton, 1978).

Figure 1. Fruit clusters on plant of *Schinus terebinthifolius*. (Photograph by S. Hight.)

Nature of Damage

Economic damage. As a member of the Anacardiaceae, *S. terebinthifolius* has allergen-causing properties, as do other members of the family. While not affecting as many people as poison ivy (*Toxicodendron radicans* [L.] Kuntze), poison oak (*T. toxicarium* [Salisb.] Gillis), or poison sumac (*T. vernix* [L.] Kuntze), all of which are in the Anacardiaceae, the sap of Brazilian peppertree can cause dermatitis and edema in sensitive people (Morton, 1978). Resin in the bark, leaves, and fruits is sometimes toxic to humans, mammals, and birds (Ferriter, 1997; Morton 1978). Even the odors of the flowers of *S. terebinthifolius* can induce allergic reactions (Morton, 1978). Abundant growth of this poisonous plant may damage the multi-billion dollar tourist industry in Florida. The value of wildlife-related recreational activities in Florida has been estimated at $5.5 billion (UF-IFAS, 1999). Visitors sensitive to *S. terebinthifolius* who would otherwise come to Florida for such activities may decide to vacation elsewhere rather than risk exposure to this toxic weed. Wood of Brazilian peppertree is of little value due to its low quality, multiple, low-growing stems, and poisonous resin (Morton, 1978).

Ecological damage. In Florida, *S. terebinthifolius* is an aggressive, rapidly spreading weed that displaces native vegetation by forming dense monocultures (Fig. 2). These thickets reduce the biological diversity of native plants and animals (Bennett *et al.*, 1990; Medal *et al.*, 1999). As early as 1969, *S. terebinthifolius* was recognized as an important invader in Everglades National Park (Morton, 1978). The Florida Department of Agriculture and Consumer Services recognizes the plant as a noxious weed (Morton, 1978) and in 1990 the sale of *S. terebinthifolius* was prohibited by the Florida Department of Environmental Protection (Langeland, 1998). Conservation organizations consider *S. terebinthifolius* a high priority target because it is already widespread and has great potential to increase its range even further (Randall, 1993). The U.S. Fish and Wildlife Service (1998) identified *S. terebinthifolius* as one of the most significant non-indigenous species currently threatening federally-listed threatened and endangered native plants throughout the Hawaiian islands. In Florida *S. terebinthifolius* is considered one of the worst invasive species by the Florida Exotic Pest Plant Council, and is recognized as the most widespread exotic plant in the state; infesting nearly 300,000 ha and found in all the terrestrial ecosystems of central and southern Florida (Habeck, 1995; Ferriter, 1997).

Figure 2. Dense stand of *Schinus terebinthifolius* trees in Everglades National Park. (Photograph by J. Cuda and J. Medal.)

In southern and central Florida, *S. terebinthifolius* colonizes disturbed sites such as highways, canals, powerline rights-of-ways, fallow fields, and drained wetlands. It also is able to establish in many undisturbed natural environments (Woodall, 1982), including pine flatwoods, tropical hardwood hammocks, and mangrove forests (Loope and Dunevitz, 1981; Ewel *et al.*, 1982; Woodall, 1982). The invasion of this aggressive, woody plant poses a serious threat to biodiversity in many of Florida's native ecosystems, and is eliminating many indigenous food sources for wildlife (Morton, 1978). Attributes of the plant that contribute to its invasiveness include a large number of fruits produced per female plant, an effective mechanism of dispersal by birds (Panetta and McKee, 1997), and tolerance to shade (Ewel, 1978), fire (Doren *et al.*, 1991), and drought (Nilsen and Muller, 1980).

Extent of losses. Direct losses have not been quantified due to lack of long-term monitoring programs and data collection and analysis.

Geographical Distribution

Schinus terebinthifolius is native to Argentina, Brazil, and Paraguay (Barkley, 1944, 1957). The plant was spread around the world as an ornamental, beginning in the mid to late 1800s (Barkley, 1944; Mack, 1991). Naturalization of *S. terebinthifolius* has occurred in more than 20 countries worldwide throughout subtropical areas (15 to 30°N or S latitudes) (Ewel *et al.*, 1982). In the United States, the plant occurs in Hawaii, California, Arizona, Texas, and Florida (Habeck *et al.*, 1994; Ferriter, 1997). In Hawaii, the plant is commonly called Christmasberry due to its attractive green foliage and red fruits present in December. The plant is sensitive to cold temperatures (Langeland, 1998). Its distribution in eastern North America is limited to central and southern Florida, although along the Florida coast, plants can be found as far north as Levy and St. Johns Counties (ca. 29°N).

Background Information On The Pest Plant

Taxonomy

The order Sapindales, one of the eighteen orders within the subclass Rosidae, contains fifteen families and about 5,400 species. More than half of the species belong to only two families, the Sapindaceae and Rutaceae, each with nearly 1,500 species. The Anacardiaceae is a small but well known family, consisting of 60 to 80 genera and about 600 species (Cronquist, 1981). The family is primarily pantropical, but some species occur in temperate regions. Species of Anacardiaceae, which may be trees, shrubs, or woody vines, are characterized by well developed resin ducts or latex channels throughout most plant parts. Leaves of these plants are typically alternate and either pinnately compound or trifoliolate. Flowers are usually unisexual, with parts in groups of five. Nectary disks are five-lobed and fruits are typically drupes (Cronquist, 1981). The genus *Schinus* has 28 species and its center of distribution is northern Argentina (Barkley, 1944, 1957). *Schinus* species are native to Argentina, southern Brazil, Uruguay, Paraguay, Chile, Bolivia, and Peru (Barkley, 1944, 1957). Barkley (1944) recognized five varieties of *S. terebinthifolius*. Differences between the varieties are based on leaf length, leaflet number and shape, and the form of leaflet margins (Barkley, 1944). Two varieties of *S. terebinthifolius* have been introduced into Florida, but the most abundant is *S. terebinthifolius* var. *radianus* (M. Vitorino, pers. comm.).

Biology

The main flowering period of *S. terebinthifolius* in Florida is September through October, with a much-reduced bloom from March to May. Small, white flowers occur in dense axillary panicles near the end of branches. The flowers are insect pollinated and successful fertilization leads to the production of prolific numbers of bright red fruits from November to February. A small fruit set occurs from June to August. Fruits are eaten and dispersed by birds and mammals. In fact, fruits have a near-obligate requirement for ingestion before seeds can germinate, as seeds within fruits that have not passed through the digestive tract have little chance of germinating before they loose viability (Panetta and McKee, 1997). Seeds remain viable in soil for six or nine months, in Florida and Australia, respectively (Ewel *et al.*, 1982; Panetta and McKee, 1997). Removal of the seed from the fruit by ingestion and excretion or mechanical means promotes seed germination, and germination rates do not differ between bird-ingested seeds or mechanically cleaned seeds (Panetta and McKee, 1997). Water extracts of *S. terebinthifolius* fruits inhibit germination of *S. terebinthifolius* seed as well as other plant species, presumably due to the presence of phenolic acid compounds (Nilsen and Muller, 1980).

Leaves are present on *S. terebinthifolius* plants throughout the year. However, vegetative growth ceases in winter (October to December), corresponding to the flowering period. Growth and extension of the shoot tips occurs more or less continuously throughout the rest of the year (Tomlinson, 1980; Ewel *et al.*, 1982).

Similar to many hardwood species, *S. terebinthifolius* is capable of resprouting from above-ground stems and crowns after damage from cutting, fire, or herbicide treatment. In addition, root sprouts form from trees with or without evidence of damage and can develop into new individuals. Resprouting and suckering is often profuse and the growth rates of the sprouts are high, leading to the formation of dense clumps (Ferriter, 1997; Woodall, 1979).

Analysis of Related Native Plants in the Eastern United States

The order Sapindales includes fifteen families, of which ten (Staphyleaceae, Sapindaceae, Hippocastanaceae, Aceraceae, Burseraceae, Anacardiaceae, Simaroubaceae, Meliaceae, Rutaceae, and Zygophyllaceae) have native members in eastern North America. Nine of these ten families have native species within the range of *S. terebinthifolius* in Florida. The tenth family, Staphyleaceae, has a species that occurs in northern Florida. The Rutaceae includes important fruit crops grown in subtropical Florida (*Citrus* spp.). Four genera of Anacardiaceae are indigenous to eastern North America: *Rhus*, *Toxicodendron*, *Metopium*, and *Cotinus* (Brizicky, 1962; Gleason and Cronquist, 1963). Except for *Cotinus*, the above genera are each represented by several species in Florida that overlap in range with *S. terebinthifolius* (Ferriter, 1997). A number of additional species of Anacardiaceae have been introduced and are currently cultivated in Florida for their edible fruits or seeds, including *Mangifera indica* L. (mango), *Pistacia* spp. (pistachio), and *Spondias* spp. (purple mombin).

History of Biological Control Efforts in the Eastern United States

Area of Origin of Weed

The center of distribution of the genus *Schinus* is northern Argentina, and its natural distribution is in South America (Argentina, southern Brazil, Uruguay, Paraguay, Chile, Bolivia, and Perú) (Barkley, 1944, 1957). Only the species *Schinus molle* L. historically extended north into Mexico (Barkley, 1944, 1957). However, Barkley (1957) believed that even *S. molle* was originally from warm temperate regions of South America and has been introduced throughout Central America where it became readily established. Barkley (1944, 1957) lists the South American distribution of the five varieties of Brazilian peppertree as follows: *S. terebinthifolius* var. *terebinthifolius* Raddi – from Venezuela to Argentina; *S. terebinthifolius* var. *acutifolius* Engl. – southern Brazil and Paraguay to Missiones, Argentina; *S. terebinthifolius* var. *pohlianus* Engl. (the most common variety of the species) – southern Brazil, Paraguay, and northern Argentina; *S. terebinthifolius* var. *raddianus* Engl. – south-central Brazil; and *S. terebinthifolius* var. *rhoifolius* (Mart.) Engl. – south-central Brazil.

Areas Surveyed for Natural Enemies

Natural enemies associated with *S. terebinthifolius* have been evaluated in Florida (Cassani, 1986) and Hawaii (Hight, unpub.). During a 14-month survey in Florida, 115 arthropods were recorded. Even though 40% of the arthropods were phytophagous on *S. terebinthifolius*, they did not cause significant damage to the plant (Cassani, 1986). Collections that occurred over approximately one year in Hawaii revealed only 34 insect species feeding inconsequentially on introduced *S. terebinthifolius*. Occasional outbreaks of an introduced polyphagous noctuid caterpillar, *Achaea janata* L., have occurred in Hawaii. Although the caterpillars may defoliate large stands of *S. terebinthifolius*, outbreaks tend to last only one generation and occur sporadically at various locations on the island of Hawaii, having no effect on populations of *S. terebinthifolius* (Yoshioka and Markin, 1994; Hight, unpub.).

Surveys were conducted in South America (primarily Brazil) for potential biological control agents by researchers from Hawaii in the 1950s (Krauss, 1962, 1963) and by Florida researchers in the late 1980s to 1990s (Bennett *et al.*, 1990; Bennett and Habeck, 1991; Medal *et al.*, 1999). Krauss (1963) provided an annotated list of 33 insect species that he collected from Schinus species, many of which were undescribed. Exploratory surveys in southern Brazil conducted by Floridian researchers identified at least 200 species of arthropods associated with *S. terebinthifolius* (Bennett *et al.*, 1990; Bennett and Habeck, 1991).

Natural Enemies Found

Surveys of *S. terebinthifolius* in both Hawaii and Florida revealed only one species that was potentially damaging to this plant. The seed-feeding wasp *Megastigmus transvaalensis* (Hussey) (Hymenoptera: Torymidae), originally from South Africa, was accidentally introduced into both Hawaii (Beardsley, 1971) and Florida (Habeck *et al.*, 1989). The original host plants of this insect were four South African *Rhus* species (Grissell and Hobbs, 2000). In Florida and Hawaii, this wasp has been found only in *S. terebinthifolius* fruits (Wheeler *et al.*, 2001; Hight, unpub.). Overall mortality of *S. terebinthifolius* seeds caused by this wasp was reported to be as high as 76% in Florida (Wheeler *et al.*, 2001) and 80% in Hawaii (Hight, unpub.). Given that seedling survival is low (Ewel, 1986), wasp damage may contribute significantly to reducing the spread of this weed species.

Based on the Hawaiian surveys for natural enemies in South America, three insect species native to Brazil were released into Hawaii: a seed-feeding beetle, *Lithraeus* (=*Bruchus*) *atronotatus* Pic (Coleoptera: Bruchidae), in 1960 (Davis, 1961; Krauss, 1963); a leaf-rolling moth, *Episimus utilis* Zimmerman (Lepidoptera: Tortricidae), in 1954 to 1956 (Beardsley, 1959; Davis, 1959; Krauss, 1963); and a stem-galling moth, *Crasimorpha infuscata* Hodges (Lepidoptera: Gelechiidae), in 1961 and 1962 (Davis and Krauss, 1962; Krauss, 1963). The first two species became established but cause only minor damage (Clausen, 1978; Yoshioka and Markin, 1991).

Based on surveys in Brazil by Florida scientists, two insect species were selected as initial biological control agents to undergo host specificity studies – the sawfly *Heteroperreyia hubrichi* Malaise (Hymenoptera: Pergidae) and the thrips *Pseudophilothrips ichini* Hood (Thysanoptera: Phlaeothripidae). The sawfly was introduced into the Gainesville quarantine facility in 1994 and underwent host specificity tests from March 1995 to June 1998 (Medal *et al.*, 1999). An additional plant species (*Rhus michauxii* Sargent) was tested at the request of the U.S. Fish and Wildlife Service in 1999 (Cuda and Medal, unpub.). Host specificity testing of the thrips began in the Gainesville quarantine in 1995, and is expected to be completed in 2002.

Host Range Tests and Results

No-choice, larval development tests were conducted with the sawfly *H. hubrichi* on 34 plant species in 14 families at the Gainesville quarantine facility and 12 species in seven families in Brazil (Table 1) (Medal *et al.*, 1999). None of these plants were used successfully as hosts by this insect. Hight *et al.* (2002) conducted no-choice, host specificity tests in Hawaiian quarantine on 20 plant species in 10 families. The Hawaiian analysis included both larval development tests and female oviposition tests. While only three of the Hawaiian test plants had been evaluated in Florida, 17 plant species were tested for the first time (Table 1).

Table 1. Plants Used in Host Specificity Tests at Various Locations with *Heteroperreyia hubrichi* for Biological Control of *Schinus terebinthifolius*[1].

Taxon	Plant Species	Hawaii	Florida	Brazil
MAGNOLIOPHYTA				
Magnoliopsida				
Rosidae				
Sapindales				
Anacardiaceae	*Schinus terebinthifolius* Raddi	X	X	X
	Schinus molle L.		X	X
	Rhus copallina L.		X	
	Rhus michauxii Sargent			X
	Rhus sandwicensis A. Gray	X		
	Mangifera indica L.	X	X	X
	Anacardium occidentale L.		X	
	Cotinus coggygria Scop.		X	
	Toxicodendron radicans (L.) Kuntze		X	
	Toxicodendron toxicarium (Salisb.) Gillis		X	
	Toxicodendron vernix (L.) Kuntze		X	
	Metopium toxiferum (L.) Krug & Urb.		X	
	Spondias dulcis Parkinson		X	
	Spondias purpurea L.		X	
	Pistacia chinensis Bunge		X	
Sapindaceae	*Dodonaea viscosa* Jacq.	X		
	Sapindus saponaria L.	X		
	Litchi chinensis Sonn.	X		
	Euphoria longan Lam.	X		
	Alectryon subcinereum Gaertn.	X		
	Nephelium mutabile L.	X		

Rutaceae	*Melicope hawaiensis* (Wawra) T. Hartley & B. Stone	X		
	Citrus sinensis (L.) Osbeck	X	X	X
Aceraceae	*Acer rubrum* (L.)		X	
Apiales				
Araliaceae	*Reynoldsia sandwicensis* A. Gray	X		
Apiaceae	*Daucus carota* L.		X	
Myrtales				
Myrtaceae	*Metrosideros polymorpha* Gaud.	X		
	Eucalyptus grandis Hill ex Maiden			X
	Eucalyptus uniflora L.			X
Fabales				
Fabaceae	*Acacia koa* A. Gray	X		
	Sophora chrysophylla (Salisb.) Seem.	X		
	Arachis hypogaea L.		X	
	Phaseolus vulgaris L.		X	
	Vigna unguiculata (L.) Walp.		X	
Capparales				
Caricaceae	*Carica papaya* L.		X	
Asteridae				
Scrophulariales				
Myoporaceae	*Myoporum sandwicense* A. Gray	X		
Proteales				
Proteaceae	*Macadamia integrifolia* Maiden & Betche	X		
Rubiales				
Rubiaceae	*Coffea arabica* L.	X		
Solanales				
Convolvaceae	*Ipomoea batatas* (L.) Lam.		X	X
	Ipomoea indica (J. Burm.) Merr.	X		
Solanaceae	*Capsicum annuum* L.		X	X
	Solanum tuberosum L.		X	X
	Lycopersicon esculentum Mill.		X	X
Capparales				
Brassicaceae	*Brassica oleracea* L. (broccoli)		X	
	Brassica oleracea L. (cauliflower)		X	
Malvales				
Malvaceae	*Gossypium hirsutum* L.		X	
	Abelmoschus esculentus (L.) Moench		X	
Laurales				
Lauraceae	*Persea americana* Mill.		X	X
Fagales				
Fagaceae	*Quercus virginiana* Mill.		X	
Juglandales				
Juglandaceae	*Carya glabra* (Mill.) Sweet		X	

Liliopsida				
Cyperales				
Poaceae	*Zea mays* L.		X	
	Oryza sativa L.		X	
	Saccharum officinarum L.		X	X
Pterodophyta				
Dicksoniaceae	*Cibotium glaucum* (Sm.) Hook & Arnott	X		

[1] List of plant species are arranged in phylogenetic order with regards to their degree of relationship to the target weed, i.e., plants at the beginning of the list are more closely related to *S. terebinthifolius* than plants at the end of the list.

A petition to release the schinus sawfly into the Florida environment was submitted to the Technical Advisory Group (TAG), USDA, APHIS in 1996. TAG reviewed the petition and considered the sawfly sufficiently host specific for introduction into Florida. An Environmental Assessment (EA) was prepared by APHIS and submitted for public comment. The U.S. Fish and Wildlife Service requested host specificity tests be conducted on *R. michauxii*, a federally-listed endangered species that was not on the original test plant list. Tests indicated that *R. michauxii* was not an acceptable host plant of the sawfly, and the information was sent to APHIS. Field observations in Brazil and laboratory feeding trials indicated *H. hubrichi* to be highly host specific to *S. terebinthifolius*. This insect was able to feed, develop, and become a reproductively mature adult only on *S. terebinthifolius* (Medal *et al.*, 1999).

The potential host range in Hawaii appears to be slightly broader than that identified in Florida and Brazil. Tests in Florida evaluated two North American species of sumac (*Rhus copallina* L. and *R. michauxii*) and found them unsuitable for *H. hubrichi* oviposition and incapable of supporting larval development (Medal *et al.*, 1999). Hawaiian tests indicated that the Hawaiian sumac (*Rhus sandwicensis* A. Gray) did support larval development and was highly attractive to the female for oviposition. Chemicals still present in ancestral, continental species that deter herbivorous insects may have been lost over time in the Hawaiian sumac. Of the five varieties of *S. terebinthifolius* recognized in South America (Barkley, 1944), *H. hubrichi* prefers the most pubescent varieties (*S. t. rhoifolius* and *S. t. pohlianus*) (M. Vitorino, pers. comm.). The dense pubescent nature of *R. sandwicensis* may stimulate female oviposition regardless of the quality of the plant for larval development. Both *S. terebinthifolius* and *R. sandwicensis* were comparable in their acceptability to ovipositing females as measured by the proportion of females that oviposited on the test plant and the number of eggs that a female laid. But *R. sandwicensis* was a dramatically poor host for *H. hubrichi* larvae in both performance characteristics of larval survival (1%) and development time (30% longer) (Hight *et al.*, , 2002).

Field surveys of plants in Brazil indicated that *P. ichini* is probably host specific to *S. terebinthifolius* (Garcia, 1977). Larval feeding and adult oviposition tests for *P. ichini* were completed and a petition for field release in Florida was submitted to the TAG in October 2002. The test plant list is the same as that approved by TAG for *H. hubrichi* with the addition of the native plant *R. michauxii*. The results of field surveys in Brazil and host specificity tests indicated that *P. ichini* can reproduce only on *S. terebinthifolius* and *S. molle* (Cuda, unpub.).

Releases Made

To date, no biological control agents have been purposefully introduced in Florida against *S. terebinthifolius*. A decision to release the sawfly in Florida has been delayed pending a finding of no significant impact of the vertebrate toxins lophyrotomin and pergidin discovered in the larvae of *H. hubrichi* (Cuda, unpub.; see also p. 125).

Biology and Ecology of Key Natural Enemies

Heteroperreyia hubrichi Malaise (Hymenoptera: Pergidae)

Adults of the leaf-feeding sawfly are generally black in color with yellow legs (Fig. 3). The life cycle begins when females emerge from pupal cases in soil near the base of *S. terebinthifolius* trees and search for well-developed, non-woody young stems in which to oviposit. A female and male *H. hubrichi* mate on the surface of the soil or on plants, although females do not need to mate for oviposition to occur. Each female inserts a single egg mass shallowly into non-woody stems. Eggs are arranged in rows and the female "guards" her eggs until she dies, just before the eggs hatch (Fig. 3). Eggs hatch in 14 days. Neonate larvae feed gregariously on both surfaces of young leaflets at the tip of shoots (Fig. 4). As they grow they move as a group onto new leaflets and larger leaves until the third to fourth instar when they disperse throughout the plant and feed individually. Larvae are green with red spots and black legs. After reaching the seventh instar, larvae move into soil and pupate. Insects reared on *S. terebinthifolius* took 26 to 42 days from egg hatch to pupation. The pupal stage lasts from 2 to 7 months (Medal *et al.*, 1999; Hight *et al.*, , 2002).

Figure 3. Adult female *Heteroperreyia nubrichi* guarding her eggs. (Photograph by S. Hight.)

Figure 4. Gregarious larvae of *Heteroperreyia hubrichi* feeding on leaf of *Schinus terebinthifolius*. (Photograph by S. Hight.)

Pseudophilothrips ichini **Hood (Thysanoptera: Phlaeothripidae)**

Adult and larval meristem-sucking thrips are generally red and black in color (Figs. 5 and 6). Adults are usually found on new unfolding leaves of *S. terebinthifolius* while immatures occur on stems of young shoots (Cuda *et al.*, 1999). Both immature and adult stages consume plant juices with their rasping-sucking mouthparts, often killing new shoots. Eggs are laid singly or in small groups at the base of leaves or within terminal shoots and hatch in seven to eight days. Eggs from unmated females produce male offspring whereas eggs from mated females give rise to female offspring. The nymphal stage lasts about 25 days and females need a five to 15 day period before they begin oviposition. A new generation of *P. ichini* can occur every 38 days (Cuda *et al.*, 1999).

Figure 5. Adult *Pseudophilothrips ichini* on young shoot of *Schinus terebinthifolius*. (Photograph by J. Cuda and J. Medal.)

Figure 6. Larval *Pseudophilothrips ichini* on yound shoot of *Schinus terebinthifolius*. (Photograph by J. Cuda and J. Medal.)

Evaluation of Project Outcomes

Establishment and Spread of Agents

No classical biological control agents have yet been purposefully introduced into Florida against *S. terebinthifolius*. However, plans are being developed to evaluate the establishment and spread of *H. hubrichi* in Florida once the insect has been approved for field release (Cuda, unpub.). At least three study sites will be established in Florida throughout the geographical range of *S. terebinthifolius*. Releases of *H. hubrichi* will be made in cages. A series of annual photographs from fixed locations will be taken at each release site to document vegetation changes. Solar powered remote weather stations will be placed at each release site to monitor and identify environmental conditions that may lead to *H. hubrichi* establishment. Weather data also will be used to separate effects of *H. hubrichi* on *S. terebinthifolius* from annual variations in plant growth due to abrupt differences in weather patterns. Effects of this insect on *S. terebinthifolius* and non-target plants will be evaluated in release cages. Annual productivity of *S. terebinthifolius* and dominant native vegetation will be compared between cages with and without *H. hubrichi*. To monitor changes and effects on vegetation over a landscape scale, a remote sensing project is being developed that will allow automated computer recognition of various vegetation components and monitor changes in vegetation over time. Finally, conventional vegetation analysis techniques will be used to evaluate the effect of *H. hubrichi* on the target and non-target plants.

Recommendations for Future Work

Additional surveys for phytophagous insects of *S. terebinthifolius* need to be conducted in northern Argentina, the most likely center of origin of this species (Barkley, 1944). Virtually all previous South American explorations by workers from Hawaii (Krauss, 1962, 1963) or Florida (Bennett *et al.*, 1990; Bennett and Habeck, 1991) have taken place in southern Brazil. Although this work has identified several promising biological control candidates, surveys might be more successful in Argentina. For example, on a 10-day survey in January 2000 of *S. terebinthifolius* natural enemies in the state of Missiones, Argentina, two species of stem-boring cerambycids and a bark-girdling buprestid were collected (Hight, unpub.). Identifications of these insect species are pending. No stem-boring or bark-girdling insects were identified from Brazilian surveys.

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