Brazilian Pepper Management Plan for Florida

Edited by Amy Ferriter

A report from
The Florida Exotic Pest Plant Council's
Brazilian Pepper Task Force
Dan Clark, Chairman
July, 1997

Brazilian Pepper Management Plan for Florida

Recommendations from
the Brazilian Pepper Task Force
Florida Exotic Pest Plant Council

July, 1997

Amy Ferriter, Editor
Dan Clark, Brazilian Pepper Task Force Chairman

The Brazilian Pepper Management Plan was developed to provide criteria to make recommendations for the integrated management of Brazilian pepper in Florida. This is the first edition of the Brazilian Pepper management Plan for Florida. It should be periodically updated to reflect changes in management philosophies and operational advancements.

Mention of a trade name or a proprietary product does not constitute a guarantee or warranty of the product by the Brazilian Pepper Task Force or the Florida Exotic Pest Plant Council. There is no express or implied warranty as to the fitness of any product discussed. Any product trade names that are listed are for the benefit of the reader and the list may not contain all products available due to changes in the market.

Table of Contents

Brazilian Pepper Task Force Members

Dan Clark, Chair
City of Sanibel,
Natural Resources Department
800 Dunlop Road
Sanibel, FL 33957
(941) 472-3700

Gordon Baker
South Florida Water
Management District

Dean Barber
Florida Department of
Environmental Protection

Doug Devries
Everglades National Park

Amy Ferriter
South Florida Water
Management District

Dr. Dale Habeck
University of Florida

David Jones
Everglades National Park

Francois Laroche
South Florida Water
Management District

Todd Loadholtz
Brevard County

Thomas Medel
Sarasota County

Tony Pernas
Big Cypress National Preserve

Don Schmitz
Florida Department of
Environmental Protection

Jackie Smith
Florida Department
of Environmental Protection

Dan Thayer
South Florida Water
Management District

INTRO DUCTION

Invasive exotic pest-plants are a threat to Florida's natural areas. The problems associated with foreign aquatic infestations are well documented. Water hyacinth *(Eichhornia crassipes)* is notorious for restricting navigation and reducing water abatement in flood control canals. Navigation has been the primary concern for federal and/or state-sponsored nuisance plant control efforts. Unfortunately, many upland and wetland exotic plant management issues have been largely overlooked.

Without an organized forum to address invasive exotic plants in the state's natural areas, early control efforts were spotty at best. In 1982, concerned resource managers in Florida organized the Exotic Pest Plant Council (EPPC). The EPPC was established to unify the exchange of information between land management agencies, research scientists, industry and other interested groups that were concerned with the impacts of exotic plants in natural areas, and to serve as an advisory body to other groups or agencies. The EPPC has identified a list of Florida's Most Invasive Species. Brazilian pepper (*Schinus terebinthifolius* Raddi) is identified as a species that is widespread in Florida, and poses a significant threat to Florida's natural areas.

The Brazilian pepper Management Plan provides recommendations from the Brazilian Pepper Task Force (BPTF) – a working committee of the Exotic Pest Plant Council – for the integrated control of Brazilian pepper in Florida. The BPTF is an interagency group of professionals who either have direct experience in managing Brazilian pepper or have the technical knowledge required for an integrated management approach. It is the consensus opinion of the BPTF that the uncontrolled expansion of Brazilian pepper constitutes one of the most serious ecological threats to the biological integrity of Florida's natural systems.

Problem Statement

Brazilian pepper, native to Brazil, Argentina, and Paraguay (Mytinger, 1987), was introduced into the United States as an ornamental. This evergreen, dioecious, insect-pollinated tree belongs to the Anacardiaceae family (Loope and Dunevitz, 1981). It has bright red fruits and shiny green leaves which helped promote it as a popular holiday substitute for holly in Florida, quickly earning the misnomer Florida holly (Morton, 1969). Morton (1979) suggested that this plant was first introduced at the turn of the century by the Plant Introduction Service. However, Brazilian pepper was advertised in seed catalogs as early as 1832, over 60 years beforehand, in New York (Mack, 1991).

Brazilian pepper has been reported to have successfully naturalized in over 20 countries, now occurring in two sub-tropical belts (15-300 N and S) worldwide (Ewel *et al.*, 1982). In the United States, Brazilian pepper (either *S. terebinthifolius* or *S. molle)* is found in Florida, Louisiana, Texas, California, Hawaii, as well as the commonwealth of Puerto Rico. Although Brazilian pepper is an aggressive colonizer in Florida and Hawaii, it has not become widely naturalized in southern California and is, in fact, still a popular ornamental.

Brazilian pepper is a pioneer of disturbed sites such as highway, canal and powerline rights-of-way, fallow fields, and drained cypress stands, but it is also successful in many undisturbed natural environments (Woodall, 1982). Brazilian pepper successfully colonizes many native plant communities, including pine flatwoods, tropical hardwood hammocks, and mangrove forest (Loope and Dunevitz 1981, Ewel, *et al.*, 1982, Woodall 1982). The invasion of this aggressive, woody weed poses a serious threat to species diversity in many of Florida's native ecosystems, and is eliminating many indigenous sources of food for wildlife (Morton, 1979).

In addition to its threat to Florida's natural areas, Brazilian pepper also poses several health and safety problems. A relative of poison ivy *(Toxicodendron radicans),* direct contact with the sap can cause severe and persistent skin irritation. Airborne chemical emissions from the blooms can also cause sinus and nasal congestion, rhinitis, sneezing, headaches, and eye irritation in some individuals (Morton, 1979). Consumption of foliage by horses and cattle can cause hemorrhages, intestinal compaction, and fatal colic. Birds that feed excessively on the fruit have been known to become intoxicated and later die (Morton, 1978).

Several of its attributes have facilitated the spread of Brazilian pepper throughout Florida. Its fruits are commonly consumed by frugivorous birds. The dispersal of seeds by these birds, namely: mocking-birds, cedar-birds, and especially migrating robins has been responsible for the escape of this species into outlying, non-Brazilian pepper dominated ecosystems, especially those that include perches such as trees and utility lines (Ewel *et al.*, 1982).

Although specific introduction points are not clear, the popularization of Brazilian pepper in Florida can be attributed to plant enthusiast Dr. George Stone (Morton, 1978). In 1926, while residing in Punta Gorda on the west coast of Florida, he reportedly raised hundreds of plants. These seedlings were then distributed among his friends and many were planted along city streets (Morton, 1978).

It wasn't until after 1950 that Brazilian pepper became conspicuously dominant in Florida (Ewel *et al.*, 1982). Davis (1942) for example, did not remark on the presence of the species in his description of everglades vegetation. In 1969 however, biologists at Everglades National Park were expressing, with alarming concern, that Brazilian pepper had the potential to destroy many of South Florida's natural areas (Morton, 1979).

Brazilian pepper now covers hundreds of thousands of acres in south and central Florida, as well as many of the islands on the east and west coasts of the state (Bennett and Habeck, 1991). Biannual exotics surveys conducted by the South Florida Water Management District indicate that Brazilian pepper is the most widespread exotic plant in the state - occupying more than 700,000 acres (Ferriter, unpublished).

Goal

The goal of the Brazilian Pepper Task Force is to protect the integrity of Florida's natural ecosystems from the biological degradation caused by the invasion of Brazilian pepper.

Objective s

The Goal of the Brazilian Pepper Task Force can be achieved through the following objectives:

1. Eliminate Brazilian pepper from Florida's natural ecosystems.
2. Achieve an overall reduction of Brazilian pepper throughout Florida such that maintaining Florida's natural areas Brazilian pepper-free is economically feasible.
3. Implement an effective public information awareness and participation program that will encourage support for Brazilian pepper management issues.

Rec ommendations

The following are priority recommendations as suggested by the members of the BPTF.

1. **Secure funding for the continued evaluation and subsequent release of Brazilian pepper biological control agents into Florida.** The foundation of an effective control program for an aggressive pest-plant like Brazilian pepper requires the successful introduction of biological controls. Woody plant species such as Brazilian pepper require several different biocontrol agents.

2. **Seek additional funding for the construction, staffing, and operation of a quarantine facility in South Florida.** The total cost of building such a facility in South Florida has been estimated at $4,000,000. The U.S. Congress has authorized its construction and has allocated $1,250,000 to date. While the facility is being promoted as a way to accelerate the search for biological control agents for melaleuca, the facility would also be available for other environmental weeds such as Brazilian pepper.

3. **Encourage Brazilian pepper control programs for Florida's publicly-owned natural areas.**

4. **Enhance existing control programs through coordinated efforts to seek additional funding sources.**

5. **Seek partnerships with concerned citizen groups to participate in Brazilian pepper control programs.** Citizen groups like the "Pepper Busters" of Brevard and Hillsborough counties are examples of successful volunteer programs. Concerned residents are trained in the latest techniques for controlling Brazilian pepper on public lands and urban areas.

6. **Continue investigations into developing sound management options.**

7. **Use the support and resources of organizations such as the Exotic Pest Plant Council to organize a network of professionals to lobby the State Legislature and U.S. Congress to provide financial support and enact laws encouraging the management of Brazilian pepper and other exotic pest-plants.**

8. **Cooperate with agencies and organizations such as Florida's water management districts, the Florida Department of Environmental Protection, the Cooperative Extension Service, and the Native Plant Society in the production and dissemination of information intended to educate the public about the problems associated with the introduction of nuisance exotic plants such as Brazilian pepper.**

Brazilian pepper thrives on disturbed soils created by natural disruptions such as hurricanes.

TECHNICAL BACKGROUND

Biology of Brazilian Pepper

Vernacular Names

Brazilian pepper (tree), Christmas berry (tree), Florida holly (USA); Copal (Cuba); Pimienta de Brasil (Puerto Rico); NANI-O-HILO (Hawaii); Aroeira (Brazil); Chichita (Argentina); Faux poivrier or False pepper (French Riviera).

Taxonomy & Classification

Brazilian pepper belongs to the Anacardiaceae, the Cashew or Sumac family, which comprises approximately 600 species in 70 genera (actual numbers of taxa vary among authors, with genera ranging from 60 to 80, and species from 600 to 850). Members of this family are found primarily in tropical and subtropical regions of the world, but are also represented in the floras of the Mediterranean, and temperate Eurasia and North America. Three genera are indigenous to southeastern United States: Rhus (including *Toxicodendron;* Sumac, Poison ivy), *Metopium* (Poison wood), and *Cotinus* (Smoke tree) (Brizicky, 1962). A number of additional genera have been introduced and are cultivated for their edible fruits or seeds (*Mangifera,* Mango; *Pistacia,* Pistachio; *Spondias,* Hog plum), or ornamental qualities *(Schinus,* Pepper tree). In Florida, the family is represented by one to several species in each of the aforesaid genera, except *Cotinus*.

Members of the Anacardiaceae are readily characterized by the presence of resin (or sometimes latex) ducts, pinnately compound or trifoliolate leaves, typically 5-merous flowers with a nectary disc, and drupaceous fruits. The resin is often toxic and allergenic. In addition to their economic value as fruit and nut trees, and ornamentals, the family is recognized as a source of dyes, tannins, resins, oils and lacquers, waxes and varnishes, and commercial timber (Brizicky, 1962; Tomlinson, 1980). It is classified under the large plant order Sapindales, together with the Rutaceae (Citrus family), Meliaceae (Mahogany family), Aceraceae (Maple family), Sapindaceae (Soapberry family), and others.

Brazilian pepper joins approximately 29 other species in the genus *Schinus* L., a name given by the famous Swedish naturalist, Carolus Linnaeus, when he first established the genus in 1753. The name *Schinus* is derived from the word 'schinus', the Latin name for the Mastic tree *(Pistacia lentiscus* L.), also of the same family, which this genus resembles in its resinous juice (Correll & Correll, 1982). In a taxonomic revision of the genus, Barkley (1944) divided *Schinus* into two groups (subgenera) based on leaf and inflorescence characteristics. Brazilian pepper (together with about five other species, including *S. molle* L., California pepper) belongs to Subgenus *Euschinus* which is characterized by unarmed shrubs and trees having mostly pinnately compound leaves and large paniculate inflorescences. The remaining species are placed in Subgenus *Duvaua,* all of which possess simple leaves and mostly pseudoracemose inflorescences; the majority have armed branches.

Brazilian pepper, *Schinus terebinthifolius* Raddi, was first described in 1820 by the Italian, Giuseppe Raddi (1770-1829). The name *terebinthifolius* is derived from the Latin words 'terebinthus', the Latin name for the Terebinth tree (*Pistacia terebinthus* L.), and 'folium', leaf, in reference to the resinous leaves of this species, like those of Terebinth. Barkley (1944) recognized five varieties of *S. terebinthifolius,* three of which were known to occur (as introductions) in the United States prior to his publication and cited by him, namely var. *terebinthifolius* (reported from Florida and California), var. *acutifolius* Engl. (Michigan, Missouri, and California), and var. *raddianus* Engl. (Florida). The remaining two varieties, var. *pohlianus* Engl. and var. *rhoifolius* (Mart.) Engl., were not reported to occur here. Campbell *et. al.* (1980) comments on the possibility of hybridization occurring among the varieties established in Florida. *(See following section on "Vegetative & Reproductive Morphology" for characterization of varieties)*

Schinus terebinthifolius has been referred to by other names (synonyms) in the past, including *S. mucronulata* Mart. (in reference to the pointed leaf tip or mucro) and *S. antiarthriticus* Mart. (in reference to the supposed anti-arthritic action of its resin).

Vegetative & Reproductive Morphology

Habit Brazilian pepper is an evergreen shrub or small tree, 3-7 meters tall or more. Its trunk is often multiple-stemmed. Multiple-stemmed trees originate in one of two ways: from sprouting due to damaged trunks and crowns, and from germination of several fruits at the same point, e.g., from seeds dispersed in animal scat. When growing in open areas, the crowns of these trees are broad and rounded and comprise numerous, long, arching, leafy branches which often reach the ground. Ewel *et. al.* (1982) noted that these branches do not easily self-prune and "remain attached to the tree, forming an impenetrable tangle that surrounds the tree to ground level". The crowns of trees growing in dense, closed stands, on the other hand, differ in having the foliage concentrated at the top of the canopy, leaving the lower (understory) branches relatively leafless.

Figure 1 Schinus terebinthifolius, shoot morphology. a. Habit with fruit; b. habit with flower; c. fruiting branch; d. node with 2 serial axillary buds. (Tomlinson, 1980)

Vegetative Morphology The odd-pinnate (compound) leaves are alternately arranged on branches and range from 8 to 17 cm in length *(Fig. 1a)*. Each leaf is composed of usually 4 or 6 (or sometimes more) lateral leaflets, arranged in pairs along a narrowly winged leaf axis (rachis), and a single, terminal leaflet. The short petiole (to 3 cm long) is unwinged, and each leaflet is attached to the rachis by a very small stalk (subsessile). The leaf petioles and racheae (as well as the expanding leaf blades and shoot apices) are often tinged red. The leaflets are oblong-elliptic to obovate in shape, to 10 cm long by 4.5 cm wide, with blunt or rounded to pointed tips, tapering, sometimes asymmetric, bases, and toothed to subentire margins *(Fig. 2a)*. The leaflet blades are thinly leathery, and glossy, dark green above and dull, pale green below. Each blade is conspicuously veined above (less conspicuous below), with 10-12 lateral nerves on each side of the midrib. When crushed, the leaves produce a pungent aroma that has been variously described, from "peppery" to "turpentine-like". In the axils of the leaves are found one or two buds. If occurring singly, the bud will remain dormant. If occurring in pairs, i.e., serial buds *(Fig. 1d),* the uppermost bud has the potential to develop into a flowering shoot (Tomlinson, 1980). The description above applies to typical Brazilian pepper, var. *terebinthifolius*. There are a number of vegetative differences between it and the other four recognized varieties, mainly in leaf length, number of leaflets, and leaflet shape and margins. These differences are noted below (after Barkley, 1944; Campbell *et. al.,* 1980):

- var. *acutifolius* - leaves 7-22 cm long; leaflets 7-15, lanceolate in shape, margins obscurely toothed to smooth (entire), tips pointed, sessile; petiole to 4 cm long.
- var. *pohlianus* - leaves 7-19 cm long; leaflets 5-17, oval to obovate in shape; petiole to 4 cm long; rachis broadly winged; stems and leaves velvety-hairy.
- var. *raddianus* - leaves 7-16 cm long; leaflets 3-9, obovate in shape, terminal leaflet larger than laterals, margins toothed to nearly entire, tips rounded.
- var. *rhoifolius* - leaves 5-17 cm long; leaflets 3-7, oval to obovate in shape, terminal leaflet larger than laterals, margins mostly entire, tips rounded.

Campbell *et. al.* (1980) noted that Brazilian pepper is extremely variable in Brazil (and to a lesser degree in Florida), and that many exceptions to the general morphological descriptions can be expected. Due to difficulty in separating the varieties, *e.g.,* morphological characters often overlap in the field, southern Florida populations have not been adequately characterized or classified to the varietal level.

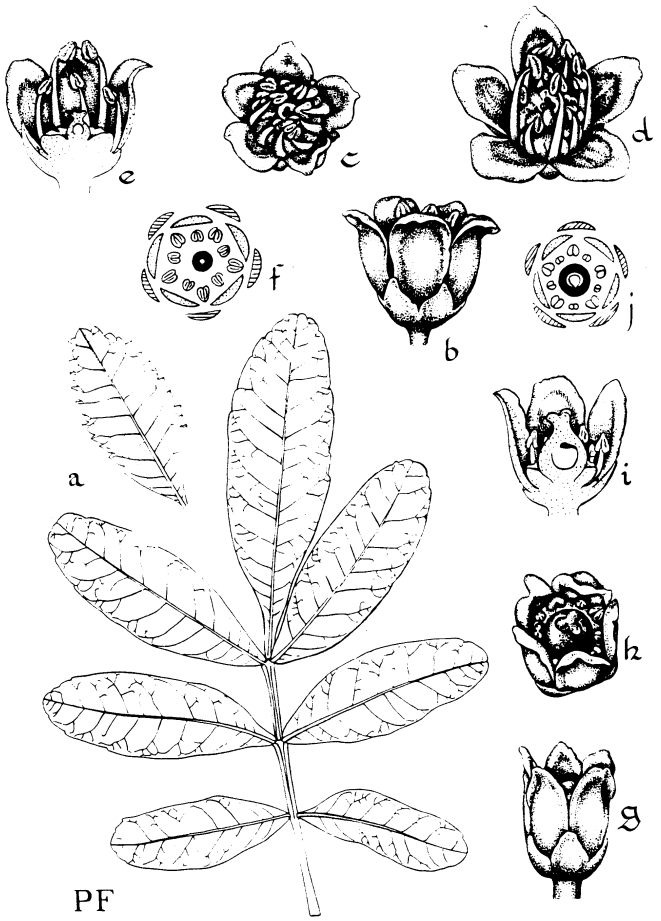


Figure 2 Schinus terebinthifolius, leaf and flowers. *a.* Leaf outline; toothed leaflet above; *b-f.* male flower, *b.* from the side, *c.* from above, early stage, *d.* from above, late stage, *e.* in longitudinal section, *f.* floral diagram; *g-i.* female flower, *g.* from the side, *h.* from above, *i.* in longitudinal section; *j.* floral diagram. (Tomlinson, 1980)

Reproductive Morphology Brazilian pepper is largely a dioecious plant which means that the flowers are all unisexual, *i.e.,* either male (staminate) or female (pistillate), and the sexes are physically separated, *i.e.,* occur on male and female trees. Ewel *et. al.* (1982), however, observed that a small number of trees in a population produce bisexual ("complete") flowers or are monoecious, *i.e.,* unisexual flowers occur on the same individual. The flowers are produced in showy, branched inflorescences (panicles), 2-11 cm long, which arise from the axils of leaves near the ends of stems *(Fig. 1b)*. In addition to flowers, the inflorescences also bear triangular to lanceolate, leaf-like bracts with ciliate margins. Both male and female flowers *(Fig. 2b-j)* occur on stalks (pedicels) 1 mm long and essentially have the same structure: 5 small, green, triangular sepals with ciliate margins; 5 small, white, glabrous, ovate petals; 10 stamens concentrically arranged in 2 series of 5, the outer series being longer; a lobed disc at the base of the stamens; and a single-chambered (unilocular) ovary with 3 short styles. However, in male flowers,

the ovary (pistillode) is non-functional, and in female flowers, the stamens (staminodes) are sterile. On female trees, flowering is followed by the production of bright red, fleshy, spherical drupes ("berries"), each 5-6 mm in diameter and containing a single seed *(Fig. 1c)*.

The description above applies to typical Brazilian pepper, var. *terebinthifolius*. There are a number of morphological differences between it and the other four recognized varieties, mainly in inflorescence and pedicel lengths, sepal, petal and fruit characters, and hairiness (pubescence). These differences are noted below (after Barkley, 1944):

- var. *acutifolius* - inflorescences 3-15 cm long, sparsely hairy, bracts ciliate; pedicels 1.5-2 mm long; sepals triangular-ovate, margins ciliate; petals lanceolate, mostly glabrous; fruits pink, 5 mm in diameter.
- var. *pohlianus* - inflorescences 2-8 cm long, soft-hairy, bracts triangular; sepals triangular-ovate; petals lanceolate.
- var. *raddianus* - inflorescence bracts triangular, sparsely glandular; sepals triangular- ovate; petals lanceolate.
- var. rhoifolius - inflorescences 1-9 cm long, bracts triangular; pedicels 1 mm long; sepals triangular-ovate; petals lanceolate to narrowly ovate.

Reproductive Biology, Phenology, and Growth

Although occurring sporadically throughout the year, flowering and fruiting phenomena in Brazilian pepper shows distinct periodicity. The main flowering period, September to October, is marked by the production of copious flowers from axillary inflorescences developing at the ends of leafy branches. A second flowering period (March-May) occurs in less than 10% of the population (Ewel *et. al.,* 1982). Observations by Ewel *et. al.* (1982) reveal that Brazilian pepper is pollinated by diurnal insects, including a number of dipterans (especially a syrphid fly, Palpada vinetorum), hymenopterans, and lepidopterans. Male and female flowers supply nectar (secreted by the floral disc) and/or pollen to the foraging insects. Pollen availability and nectar secretion in Brazilian pepper flowers is apparently timed to maximize pollination success, although Ewel *et. al.* (1982) suggested this is unnecessary in southern Florida due to the diversity of local insect pollinators (many of which are considered to be nectar and pollen "thieves") and good fruit set. Plants appear to be out-crossers, although the rare occurrence of fruits (under experimental conditions) developing from unisexual flowers has not been adequately explained.

Fruit production occurs during the winter (November to February), at which time the branches of female trees are heavily laden with red fruits while male trees remain barren. Ewel *et. al.* (1982) observed that ripe fruits are retained on a tree for up to 8 months, and all will be dispersed before the next flowering season. The attractive fruits are readily eaten and transported by birds and mammals, with water and gravity serving as less important dispersal agents. Seed dispersal by native and exotic birds, *e.g.,* catbird, mockingbird, American robin, red-whiskered bulbul, accounts for the presence of Brazilian pepper in almost every terrestrial plant habitat in southern Florida (Austin, 1978; Ewel *et. al.,* 1982; Ewel, 1986). Robins, when they are present, are believed to consume and transport more Schinus seed than all other dispersal agents combined. Raccoons and possibly possums are known to ingest the fruits, their stool providing additional nutrients for seed germination and seedling growth (Ewel *et. al.,* 1982). The fact that very little else is fruiting during the winter months when *Schinus* seeds are dispersed

Male and Female flowers supply nectar (secreted by the floral disk) and/or pollen to foraging insects.

has been suggested as a possible explanation for the success of Brazilian pepper in southern Florida (Ewel 1986).

Greenhouse experiments carried out by Ewel *et. al.* (1982) on Brazilian pepper indicate a germination rate of 20-60% (compared to 1-30% in the field), with most germination occurring within the first 20 days. The germination period ranges from November to April (and sometimes to as late as July!), with the highest activity occurring during January-February. Seeds are generally not viable after 5 months following dispersal. However, Ewel (1979) reported seed germination in late fall, under certain conditions; seeds apparently retain their viability during the wet season floods and germinate when water levels drop late in the year.

Water availability, especially rapid changes in water levels, determines to a great extent seedling success: seedlings are especially susceptible at the end of the dry season (May-June), which corresponds to the period of greatest germination activity, and during the wet season (July-September), where prolonged submergence may result in increased seedling mortality (Ewel *et. al.,* 1982). Its lack of success in southern California has, in fact, been attributed to the short period of sufficient soil moisture needed for germination and root establishment (Nilsen and Muller, 1980). Other density-dependent and density-independent factors may also influence patterns of success and mortality in Brazilian pepper seedlings in southern Florida.

Ewel *et. al.* (1982) discussed seedling survivorship in some detail and concluded that the tenacity and growth plasticity of Brazilian pepper seedlings is unusual and makes this species especially difficult to manage. Seedlings grow very slowly and can survive under the dense shade of mature stands, while exhibiting vigorous growth when the canopy is opened after a disturbance. In exposed, open areas, such as young successional communities, their rates of growth are among the highest, *i.e.,* 0.3-0.5 m per year.

Vegetative growth in Brazilian pepper undergoes a cycle of dormancy in winter (October-December), when flowering occurs, followed by shoot renewal and extension growth (evidenced by the production of long, drooping branches) more or less continuously throughout the rest of the year (Tomlinson, 1980; Ewel *et. al.,* 1982). While there is no general relationship between vegetative growth and reproductive development, *i.e.,* inflorescence initiation and growth, branches can terminate all subsequent vegetative growth (in other words, become determinate) if flowering is prolific (Tomlinson 1980).

Like many hardwood species, Brazilian pepper has the capability of resprouting from above-ground stems and root crowns, under certain conditions, *e.g.,* cutting to a stump, bark girdling, fire (if it girdles a stem), herbicide application (Woodall, 1979). Resprouting is often profuse and the growth rates of the sprouts, which originate from dormant and adventitious buds, are very high. Brazilian pepper's generally shallow root system (because of high water tables) also favors the production of underground root suckers. Root suckers form without evidence of damage to a tree or its root system and can develop into another individual. The clumping of *Schinus* often seen during the early stages of invasion can be explained by this suckering mechanism (Woodall, 1979).

Ewel (1979) summarized the many characteristics of Brazilian pepper which make it the successful weedy species that it is, including : (1) fast growth, (2) prolific seed production, (3) near continuous shoot extension and leaf renewal, (4) vigorous resprouting, and (5) tolerance of a wide range of growing conditions *(see next section)*. It is unique among weed species, however, in possessing a number of traits more typical of mature ecosystem species, including: (1) synchronous flowering and fruiting within a short time period, (2) male and female flowers produced on separate individuals, *i.e.,* dioecious, (3) pollination by insects, (4) large, animal-dispersed seeds, (5) large cotyledons (important for seedling success), and (6) shade tolerant seedlings.

Ch em i s try and To xicity

Phytochemical studies carried out during the 1960-70's revealed the presence of a number of diverse chemical compounds, including triterpene alcohols, ketones, acids, monoterpenes, and sesquiterpenes, in the bark, leaves and fruits of Brazilian pepper (Lloyd *et. al.,* 1977; Morton, 1978). The high concentration of volatile (and aromatic) monoterpenes has been suggested to be a probable cause of the respiratory problems associated with crushed fruits. The fact that widespread respiratory ailments have occurred when the tree is in bloom suggests that these same volatile compounds may also be produced by the flowers (Lloyd *et. al.,* 1977). Morton (1969, 1978) reports that persons sitting or playing beneath Brazilian pepper trees exhibited flu-like symptoms, and sneezing, sinus congestion, chest pains and acute headache were among the possible inhalant effects. It is of interest to note that the pollen from its flowers appears not to be a significant source of irritation or allergies, as it is sticky and not easily carried by wind (Morton, 1978).

Campello & Marsaioli (1974) noted in a paper on triterpenes that the ingested fruits have a "paralyzing effect" on birds. The narcotic and toxic effects on birds and other wildlife has also been noted by others, *e.g.,* Bureau of Aquatic Plant Management. Workman (1979) refers to the "hypnotic action" of fruit extracts, containing the triterpenes terebinthone and schinol, on chicks and mice. *The AMA Handbook of Poisonous and Injurious Plants* (Lampe & McCann, 1985) reports that the tripterpenes found in the fruits can result in irritation of the throat, gastroenteritis, diarrhea, and vomiting in man.

Like most other members of the Anacardiaceae, Brazilian pepper contains active alkenyl phenols, *e.g.,* urushiol, cardol, which can cause contact dermatitis and inflammation in sensitive individuals (Lampe & Fagerstrom, 1968; Tomlinson, 1980). Contact with the "sap" from a cut or bruised tree can result in rash, lesions, oozing sores, severe itching, reddening and swelling (especially of the eyes), and welts (Morton, 1978). Grazing animals, such as horses and cattle, are also susceptible to its toxic effects, and ingestion of leaves and/or fruits has been known to be fatal.

Of taxonomic interest is the observation that the chemistry of Brazilian pepper, specifically certain compounds extracted from the leaves and bark, is more similar to species of the related genus *Pistacia* than it is to other members of its own genus *Schinus* (Campello & Marsaioli, 1975).

Economic Uses

Before Brazilian pepper attained its present status (in southern Florida) as a serious pest plant, it was widely planted along city streets and in home gardens because of its ornamental qualities and for shade (Morton, 1969). Its decorative fruiting branches were particularly valued at Christmas, and the clusters of fruits were used to make leis and adorn hats (Morton, 1978). It has been successfully grown indoors: Graf (1982) provides information on its cultivation requirements ("a large container and plentiful watering") and propagation ("from cuttings and seeds").

As its vernacular name suggests, the dried fruits of Brazilian pepper are used as a spice and sold in the United States as "pink peppercorn". With regard to this, Bell & Taylor (1982) noted that "due to its toxic properties, its use in this way is inappropriate and potentially dangerous." In areas of South America where it occurs naturally, the plant is considered tonic and astringent, and the stems are the source of a resin called Balsamo de Misiones (Uphof, 1968). In Brazil, the plant is considered medicinal (Campbell *et al.,* 1980; Morton, 1978) and used in remedies for ulcers, respiratory problems, wounds, rheumatism, gout, tumors, diarrhea, skin ailments, and arthritis. Brazilians also value the bark for tanning where it is sold in fishing equipment shops and used to preserve fishing lines and nets (Mors & Rizzini, 1966; Morton, 1978). Campbell *et. al.* (1980) reports that Brazilian children play with the leaves by igniting them and watching them "pop and sparkle." Morton (1978) described several products made from Brazilian pepper: toothpicks from its twigs, posts, stakes and construction materials from its wood, and honey from its copious nectar. It is recognized as an important nectar and pollen source by the bee industry in Hawai'i (Yoshioka and Markin, 1991).

A number of economic uses are reported for other members of the genus as well. The fruits of California pepper, or Peruvian mastic, *Schinus molle* L., said to contain an essential oil, are pulverized and used to make refreshing drinks known as "horchatas" or "atoles," while gum from the trunk is reportedly used in varnishes and medicines, and for chewing (Uphof,

Economic uses for Brazilian pepper include honey and gourmet "pink peppercorns."

1968; Williams, 1981). Altschul (1973) reports that this species is used in the treatment of rheumatism in Mexico. In Peru, it is employed in the preparation of a mildly alcoholic drink (Rehm & Espig, 1991). Like Brazilian pepper, its dried fruits, exported from Peru and Ecuador to the United States, are used like pepper (or even to adulterate it!), and the essential oils from its leaves and fruits are used as an aromatic (Rehm & Epsig, 1991). The bark is used for tanning animal skins (Graf, 1982), and when powdered, it serves as a purgative for domestic animals (Uphof, 1968). A wine is reportedly made from small twigs (Hedrick, 1972). Mabberley (1987) notes its use as a fertility control agent in Uruguay.

Another species, *S. polygamus* (Cav.) Cabrera (= *S. dependens* Orteg.), is used in Chile to treat rheumatism, and a red wine is prepared from its 'berries'. The fruits of *S. latifolius* (Gillies) Engl. are used by Chilean indians to make an intoxicating liquor (Uphof, 1968; Hedrick, 1972).

Distribution, Ecology and Economic Impact

Distribution and Ecology

The genus *Schinus* occurs naturally in South America, with one species (*S. molle* L.) ranging as far north as Mexico. Brazilian pepper is indigenous to subtropical Brazil, Paraguay, and Argentina, and has been introduced to various subtropical regions of the world including other parts of South America, Central America, the Bahama Islands, the Caribbean Islands, the United States, Mediterranean Europe, northern and South Africa, China, southern and southeastern Asia, Australia, and the Pacific Islands (Morton, 1978; Campbell *et. al.,* 1980).

In its natural range, it is reported to occur as scattered individuals in a variety of habitats, from sea level to over 700 m elevation (Ewel *et. al.,* 1982). It never dominates the landscape as it does in southern Florida (Campbell *et. al.,* 1980; Ewel, 1986), where it grows on a broad range of moist to mesic sites, sometimes forming nearly monotypic stands, including tropical hardwood hammocks, bay heads, pine rocklands, sawgrass marshes, *Muhlenbergia* prairies, and the salt marsh-mangrove transition zone. In this region, it thrives on disturbed soils created by natural disruptions, *e.g.,* hurricanes, and is especially invasive in areas affected by human activities, particularly the newly created habitats resulting from agriculture and drainage, e.g. abandoned farmlands, roadsides, canal banks (Ewel, 1986).

Brazilian pepper does not become established in deeper wetland communities and rarely grows on sites inundated longer than three to six months. In Everglades National Park, for example, it is absent from marshes and prairies with hydroperiods exceeding six months as well as from tree islands with closed canopies (LaRosa *et. al.,* 1992).

Preliminary investigations on *Schinus* invasibility (employing seed introduction and seedling transplant experiments) in both native (undisturbed) and successional (disturbed) plant communities in southern Florida were carried out by Ewel *et. al.* (1982). Young successional communities were found to be more susceptible to invasion than older ones, and all successional communities were more susceptible than undisturbed, native communities. Of the three native "ecosystems" investigated, the pinelands were more susceptible to *Schinus* seed germination, followed by wet prairies ("glades") and hammocks. Successful invasion appears to be a function of both seed access to an area and the ability of introduced seeds to germinate and seedlings to survive (Ewel *et. al.,* 1982).

Concern over the occurrence of *Schinus* in salt-tolerant plant communities, *e.g.,* mangrove forest, in southern Florida, especially in Everglades National Park, led Mytinger and Williamson (1987) to investigate the tolerance of *Schinus* to saline conditions. Seed germination and transplanted seedlings did not succeed at salinities of 5 ppt or greater, which would largely exclude it from becoming established in mangrove forest. *Schinus* invasion of saline communities can occur, however, if salinity declines due to changes in drainage patterns resulting from natural phenomena or human activities.

The ability of Brazilian pepper to invade disturbed, successional habitats in particular, *e.g.,* abandoned agricultural fields formerly rock-plowed, is due to the enhanced conditions created by an altered substrate, *i.e.,* the soil is deeper, better drained, better aerated, and possibly more nutrient-rich (Ewel *et. al.,* 1982). This promotes the growth of mycorrhizal fungi in association with *Schinus*, allowing them to colonize areas that they would otherwise be unable to grow in.

The stages of secondary plant succession in abandoned, rock-plowed farmlands, leading to nearly pure stands of Brazilian pepper, have been well-documented in studies carried out in the Hole-in-the-Donut area of Everglades National Park utilizing *Schinus* tree and stem inventories, seedling density data, and forest understory characteristics (Loope and Dunevitz, 1981a; Ewel *et. al.,* 1982; Krauss, 1987). The general course for secondary succession (and *Schinus* invasion) on these rock-plowed farmlands is summarized in Doren and Whiteaker (1990): the process progresses (on sites < 10 years old) from low

density and reproduction in *Schinus* in a matrix of grasses and herbs, through (on sites 10-20 years old) a stage of rapid reproduction and increased density, to (on sites > 20 years old) dense stands of nearly pure *Schinus* that are "self-maintaining." The conclusion is that monotypic Brazilian pepper forests represent the final stage in secondary plant succession on abandoned farmlands. The use of repeated fires as a management tool for controlling successional growth *Schinus* in these areas has been investigated by Doren *et. al*. 1991. Although repeated burnings may slow down the invasion rate, it does not exclude its establishment; *Schinus* invasion progresses with or without the occurrence of fire.

Brazilian pepper forest structure in the Hole-in-the-Donut region of Everglades National Park was documented by Ewel *et. al*. (1982) and revealed stands containing from 200 to more than 2500 *Schinus* trees per hectare. The understory of even the densest stands contains ferns and shrubs, such as the exotic *Ardisia elliptica*. A number of native and exotic trees *(Myrsine floridana, Persea borbonia, Ilex cassine, Nectandra coriacea, Psidium guajava)* are also known to successfully invade, and establish small populations of individuals within, *Schinus* stands. Gogue *et. al*. (1974) have suggested that Brazilian pepper has the ability to inhibit the growth of competing vegetation through the production of allelopathic substances.

Brazilian pepper stands provide relatively poor wildlife habitat. In a study on the utilization of a mature Brazilian pepper stand by the native avifauna, Curnutt (1989) found that avian species diversity and total population density declined when compared to native pinelands and forest-edge habitats. Such results, expected when a species-rich habitat is replaced by one which is biologically less diverse, stress the need to protect native habitats from exotic pest plant encroachment.

A few native amphibian and reptile species were collected (though rarely) in Brazilian pepper forest habitats in the Long Key-Paradise Key region of the Everglades National Park, whereas two nonindigenous species, Cuban tree frogs *(Osteopilus septentrionallis)* and brown anole lizards *(Anolis sagrei),* were most common (Dalrymple, 1988). Dalrymple (1988) believes that most of the herptofauna in Brazilian pepper forests in this area was responding to basic microhabitat requirements and not the species composition of the vegetation. The herptofauna of Brazilian pepper forests is similar in species numbers and foraging guilds to those of southern Florida's hammock communities, probably because of the closed canopy conditions. and soil development found in both (G. Dalrymple, pers. comm). In Everglades National Park, anecdotal evidence suggests Brazilian pepper spread is threatening the nesting habitat of the gopher tortoise *(Gopherus polyphemus),* a species threatened in Florida.

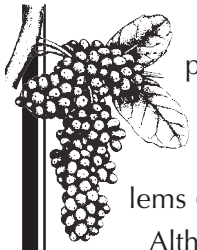
Of interest is the experimental evidence that the native wax myrtle *(Myrica cerifera)* is allelopathic and inhibitory to Brazilian pepper germination and seedling establishment (Dunevitz and Ewel, 1981). In previously farmed pinelands where wax myrtle has become dominant, Brazilian pepper has been observed to have slower growth rates and poorly developed seedlings. Their reduced vigor under these conditions suggests a possible use of wax myrtle in Brazilian pepper management practices (Dunevitz and Ewel, 1981).

Ec o n om ic Im pa ct

Sanford (1987) lists Brazilian pepper as one of Florida's best nectar-producing plants and commented that "the honey has a distinct peppery taste and is not considered by many to be of table grade, but is accepted well locally." It was estimated in 1989 that beekeepers sold from 6 to 8 million pounds of honey from Brazilian pepper per year in Florida (Schmitz, 1989). In addition, Brazilian pepper is considered to be important in bee maintenance during the winter months (Schmitz, 1989). However, the African honey bee *(Apis mellifera scutellata),* expected to arrive in Florida during the 1990s, may have a much greater impact on the state's bee industry (Office of Technology Assessment, 1993) than Brazilian pepper control efforts.

Because Brazilian pepper grows low to the ground and contains many crooked branches, it precludes economical harvesting by any conventional means for wood utilization (Morton, 1978). Morton (1978) also reports the strength characteristics would rank Brazilian pepper with the poorest of native hardwoods, and the extractive could pose a serious processing problem. The possibility of using Brazilian pepper for pulpwood has been tentatively explored. Morton (1978) found the species cannot be debarked using conventional equipment. However, the pulp yield is comparable to that from other hardwood pulps. It has been suggested it could be used for many paper grades such as printing, tissue paper and corrugating board.

In Brazil, the crushed, dried leaves of Brazilian pepper are applied as an antiseptic on skin ulcers; are eaten to relieve bronchitis and other respiratory ailments; and are considered to be a remedy for gout, muscular agony, pain of arthritis, diarrhea, intestinal weakness, and inertia of human reproductive organs (Morton, 1978). In Florida, it is doubtful that many



people use Brazilian pepper for medicinal purposes. Anecdotal evidence suggests Brazilian pepper can cause human contact dermatitis, allergies, and respiratory problems (Office of Technology Assessment, 1993).

Although once extensively sold as a landscape ornamental (one Central Florida nursery, Royal Palm Nurseries, Onceco, in 1937 advertised it as "one of our most worthwhile plants for general landscape purposes, as it makes a fine subject for mass planting and succeeds well along the beach, standing quite a lot of salt spray") from the 1920s through the 1960s, it was banned for commercial use in 1990. The banning of Brazilian pepper in 1990 as a landscape ornamental had no economic impact on the wholesale and retail industry (Schmitz, 1989) because the plant was no longer considered to have ornamental value.

Brazilian pepper may ultimately negatively impact Florida's tourist industry. Many visitors come to Florida to enjoy Florida's unique landscape and pay millions of dollars each year to gain admission to Everglades National Park and other preserved natural habitats (Schmitz, 1989). Any minimization of the spread of Brazilian peppers in these areas would maintain the interests of such visitors and the extent of their expenditures, including park or preserve admission, purchases of food, gasoline, and supplies and all the related permit fees and taxes. For example, tourist development taxes in Broward, Dade, Lee, Monroe, and Palm Beach counties were worth nearly $23 million in 1987 (Schmitz, 1989).

Manag eme nt Te chn iqu es

Biolo gica l Co ntrol

Classical biological control involves moving host-specific natural enemies from the native range of the weed to its introduced range. The goal is to reduce weed abundance to a level that can be tolerated. Biological control does not eradicate weeds. It simply restores a natural balance between the weed and its enemies. Biological control can be self-regulating since the introduced natural enemies often become part of the ecosystem.

Biological control is not a quick fix. The period of time between initiation of a weed biocontrol program and when the first natural enemy is released is measured in years. Release must be approved by both state and federal agencies. Releases require propagation of large numbers and distribution in the field followed by monitoring to determine whether establishment has occurred and how effective the natural enemies are.

In Florida there are many insects associated with Brazilian pepper (Cassani 1986, Cassani, *et al.* 1989), but only one, the phytophagous seed wasp *(Megastigmus transvaalensis)* was abundant enough to cause significant seed reduction (Habeck *et al* 1989). Infestation rates of seeds are usually less than 5 percent, but can be as high as 30 percent in some localities.

In 1986, the Department of Entomology and Nematology of the Institute of Food and Agricultural Sciences (IFAS) initiated a biological control agreement with the University of Sao Paulo in Brazil. This included short duration surveys in southern Brazil to determine the range of Brazilian pepper's natural enemies and to determine the insect fauna on the plant in Florida. To date, more than 200 insect species have been found associated with Brazilian pepper in Brazil (Bennett and Habeck 1991 and Bennett *et al* 1990). Several of these insects were selected as potential biological control candidates for further study. Permission was obtained to bring some of them into quarantine in Florida for host specificity and biological studies.

The two insects that have received the most attention are the Brazilian peppertree sawfly *(Heteroperryia hubrichi)* Hustache (Pergidae: Hymenoptera); a defoliator, and Brazilian peppertree thrips *(Liothrips ichini)* Hood (Phlaeothripidae: Thysanoptera). The thrips was studied by Garcia (1977) who considered it likely to be host-specific to Brazilian pepper since he never found it on any other plant species. This insect is usually found as adults on newly unfolding and as nymphs on young stems. They damage the plant with their rasping-sucking mouthparts and frequently kill the new shoot. They also attack flowers causing them to abort. This restricts the vigor and growth rate of young plants and if established in Florida could remove the competitive advantage that Brazilian pepper currently holds over the native Florida vegetation.

In Brazil the larvae of the thrips are parasitized by a small wasp that limits its impact on Brazilian pepper. This wasp would be eliminated during the standard quarantine procedures required to clear biological control agents for field release. In the absence of this wasp, the thrips should have a more devastating impact on the growth rate of Brazilian pepper. The Brazilian peppertree sawfly is a primitive wasp that does not sting. Caterpillar-like larvae feed in groups, defoliating the plant. The immature stages (Larvae) are almost an inch long when mature. While this insect is also believed to be host-specific, it is proving difficult to rear in quarantine.

Other insects of interest found during preliminary studies include a bruchid beetle *(Lithraeus atronotatus)* whose larvae feed in and destroy fruit, a stem-tip gall maker *(Crasimorpha infuscata),* a

flower feeding casebearer *(Coleophora sp.)* and unidentified flower-infesting gall midge, several leaf tiers and several weevils. The seed bruchid, one leaf tier and the stem tip gall maker were introduced into Hawaii to control Brazilian pepper but only the first two became established in the field. The leaf tier has had no appreciable impact on Brazilian pepper whereas the infestation rate of seeds by the bruchid increased to about 10 percent. It later dropped to a negligible level following the appearance of the phytophagous wasp *(M. transvaalensis)* that now infests 10 - 15 percent of the seeds (Yoshioka and Markin 1991).

The goal of this biological control program is to select and introduce natural enemies that will restrict seed production and reduce the vigor and growth rate of seedlings and young plants.

M e chan ica l Co ntrol

Mechanical control of Brazilian pepper is accomplished through the use of heavy equipment such as bulldozers, front end loaders, root rakes and other specialized equipment. The use of heavy equipment is sometimes not suitable in natural areas. Once undisturbed soils have been unsettled, they are succeptable to invasion by invasive exotic pest-plants. Mechanical control is accepted along ditch banks, utility rights-of-way and other disturbed areas. As followup, a herbicide application is highly recommended to prevent regrowth from the remaining stumps. Stumps that fail to be chemically treated will resprout and continue to infest natural areas and wetlands.

A chainsaw may be used for the removal of single trees or small clumps of trees. Once the vegetation has been cut and treated the remaining foliage may be burnt, left to decay or taken to a local landfill for proper disposal. It is not recommended to mulch Brazilian pepper trees for use in landscapes unless the tree is male or not in seed. Local foresters can provide information on burning permits and other local laws. Brazilian pepper belongs to the Anacardiaceae family; therefore the sap and smoke from the burning may irritate or cause an allergic reaction to sensitive individuals.

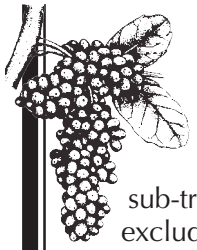
As with any control method, followup is important. Treatment areas must be checked periodically for new infestations or recurring growth from remaining stumps.

Ph y s ica l Co ntrol

Plants can be stressed, or even killed, by the physical environment. Temperature and salinity variations, water level fluctuations, and the presence or absence of fire are examples of physical conditions that can dictate vegetation patterns. Land managers use many of these natural limiting factors to manipulate the environment for vegetation management. More often than not, however, nature controls these physical changes and the land manager is forced to take a side seat and observe the changes.

Although fire may affect Brazilian pepper seeds, seedlings and saplings, it provides little control for mature trees.

Although fire may effect Brazilian pepper seeds, seedlings, and saplings, it provides little control for mature trees. Research conducted by Nielson and Muller (1980) in southern California has shown that Brazilian pepper seeds are killed by fire. Brazilian pepper trees less than one meter in height which are found in limestone rockland pine forests in southern Florida have an increased mortality rate when subjected to five year fire intervals (Loope and Dunevitz, 1981). Everglades National Park has maintained rockland pine forested areas largely free of Brazilian pepper by maintaining fire management programs that kill seedlings before reaching fire-resistant heights (David Jones, Pers. comm.). Brazilian pepper found in other habitat types may persist with a similar fire regime due to water levels and plant growth rates. Research and personal observation have proven that fire is not an effective control method for mature Brazilian stands.



Brazilian pepper occurs naturally in sub-tropical South America and has been introduced to various regions of the world with similar climates. As with many tropical and sub-tropical plant species, Brazilian pepper is excluded from more temperate regions by temperature. It is unknown if any attempts have been made to control Brazilian pepper in situ by lowering temperature. Potential non-target damage and logistical implications of such a task are obvious.

The salt tolerance of Brazilian pepper is relatively low. Mytinger and Williamson (1987) investigated the tolerance of Brazilian pepper to saline conditions and found that seed germination and transplanted seedlings failed at salinities of five ppt or greater. This intolerance is supported by the stressed phenotype found in salt terns, and the relative exclusion of Brazilian pepper from intact, undisturbed mangrove forests. It is apparent in South Florida that many natural and manmade hydrological alterations, such as ditching, impoundments, or flooding, have the ability to change salinities enough to allow Brazilian pepper to invade. The use of salt or a saline solution to control Brazilian pepper again raises the questions of logistics and potential non-target damage.

Recent evidence has shown that flooding Brazilian pepper may stress, or in some cases, kill mature trees and seedlings. Brazilian pepper is absent from marshes and prairies with hydroperiods exceeding six months at Everglades National Park (LaRosa *et. al.,* 1992). Experimental results from a project on Sanibel Island *(See Sanibel Island case study)* illustrate the effects of flooding.

H erbicida l Co ntrol

Brazilian Pepper, like other woody plant species, can be controlled with herbicides applied in a variety of ways. The most common application methods are foliar spray, stump treatment, basal soil treatment, and basal bark application. In foliar treatments the herbicides are pre-mixed with diluent and sprayed onto the foliage of the plant. Usually the leaves are "sprayed-to-wet" which means applying only enough solution to begin running off the leaf surface. Basal soil treatments can be used with either liquid or dry formulations. The material is broadcast onto the soil under the canopy of the tree. Rainfall carries the herbicide into the root zone of the plant where it is absorbed by the roots. The basal bark application consists of the herbicide solution being applied, most commonly by back-pack sprayer, in a wide band on the stems of the plants near the base. The material is absorbed into the plant and translocated throughout the plant. Another technique is to treat the stump with a herbicide solution immediately after cutting the tree at or near ground level. There are other application methods such as the "frill and girdle", and various direct injection techniques for the control of exotic species. However, these methods are not practical for controlling Brazilian pepper. Aerial application of herbicides can be used in areas that are remote or where there are large monotypic stands.

Since the 1960s, various agencies have used available products to manage the growth and spread of Brazilian pepper. Prior to the establishment of the United States Environmental Protection Agency (EPA) this plant was controlled using SILVEX (2,4,5-TP) applied as a foliar treatment from truck-mounted sprayers. This was a chlorinated phenoxy herbicide in the same group of chemicals as 2,4-D. By the time EPA suspended all uses of SILVEX, circa 1976, the Velsicol Chemical Company had registered another phenoxy-type compound known as BANVEL 720 (dicamba plus 2,4-D) for use on woody species. In the early 1980s other compounds such as triclopyr, glyphosate, hexazinone, tebuthiuron, and imazapyr were being developed for managing vegetation on rights-of-way. The South Florida Water Management District (SFWMD) provided field trial sites for these compounds during and after their development process. Although data collected from these trials were not published, most of these products provided 95% - 100% control of Brazilian Pepper when applied in accordance with label directions.

In the early 1980s, several studies were done to determine which herbicides and rates are most effective for Brazilian pepper infestations. Woodall (1982), working at the USDA Southeastern Forest Experiment Station, tested eight herbicides at various rates in both greenhouse and field studies. He found that DED-WEED (2,4,5-TP), HYVAR (bromacil), KARMEX (diuron), TORDON (picloram plus 2,4-D), and VELPAR (hexazinone) provided 100% control of seedlings in the greenhouse study. AMMATE X (ammonium-sulfate), BANVEL (dicamba) and ROUNDUP (glyphosate) did not provide significant seedling control. In the field study basal soil treatments using HYVAR and VELPAR were effective in controlling Brazilian pepper trees. Results of foliar applications using DED-WEED, BANVEL, VELPAR, and AMMATE X (ammonium-sulfamate) proved variable at best *(Table 1)*.

Ewel *et al*. (1982) chose five products for field trials at Everglades National Park following an initial screening of potential herbicides. These included BANVEL 720, BANVEL 5G (dicamba), ROUNDUP, VELPAR and GARLON (triclopyr). Herbicides were applied in February and March. Results indicate that Brazilian pepper can be killed with a foliar application of triclopyr and glyphosate at high rates, basal

bark treatments with triclopyr, and basal soil treatments with hexazinone. The two dicamba formulations were not effective *(Table 2)*. Ewel noted two reasons for a springtime application. First, low water levels increased accessibility and reduced environmental hazards associated with introducing herbicides to flooded soil. Second, herbicide uptake is greatest if applied when a plant is metabolically active. Male trees produce new leaves after the end of autumn flowering in November. Female trees do not resume new leaf production until fruit fall is completed in February/March. It should be noted that Woodall's study was conducted in late summer to late autumn as compared to Ewell's study which was conducted in February and March. Based on later studies (Vandiver, 1993, personal communication), it is likely that timing of application is very important.

In studies conducted at Everglades National Park, Doren and Whiteaker (1990) showed that the basal bark application of GARLON 4 (triclopyr) at a 2% solution provided 94% control and that higher concentrations did not provide any significant increase in the amount of control obtained *(Table 3)*.

Laroche and Baker (1994) evaluated several herbicides and application techniques. Application techniques included foliar, basal bark, basal soil, and direct tree injection with E-Z-JECT capsules and FICSAN plugs. The established treatment plots were heavily infested with Brazilian pepper, generally very dense and consisting of numerous individual trees which were multi-stemmed. The corresponding treatment number of E-Z-JECT capsules were injected into the bark of each stem. The E-Z-JECT system uses a five-foot long, spring-loaded, telescoping barrel to inject 22-caliber cartridges into the bark of the tree. Each capsule is filled with a waxy formulation of herbicide which slowly melts with increased temperatures and is absorbed by the tree. In another treatment, FICSAN plugs were placed in small openings, created with a hollow-core tipped hammer, around the circumference of each stem. These plugs are made of plastic and are specially designed to rupture from the inside when hammered into the opening, releasing herbicide into the tree (Laroche, 1992). Foliar applications were made with a truck mounted sprayer. The appropriate amount of each herbicide was diluted in 50 gallons of water and the resulting solution was sprayed over the foliage with a handgun. Foliar applications were directed to each individual tree in each plot to minimize damage to non-target vegetation. Basal soil treatments were made with a backpack sprayer by applying the appropriate amount of undiluted herbicide on the soil around the base of each stem. SPIKE 40P (tebuthiuron) was also applied by hand-throwing the appropriate amount of pellets around the base of each tree. Basal bark applications were made with a backpack sprayer by applying the appropriate amount of herbicide directly onto the bark around the circumference of each stem. The herbicide was diluted in diesel oil to facilitate penetration of the bark. All treatments were applied in March. The plots were evaluated one year post treatment and percent mortality or defoliation was used to determine the effect of each treatment *(Table 4)*.

Neither the E-Z-JECT or FISCAN plug treatments produced acceptable control levels. Herbicide symptoms were apparent in these treatments but none of the trees were defoliated. In addition these application techniques were cumbersome and difficult to use due to the density of the understory and multiple-stem growth habit of the trees. Foliar application of GARLON 3A and ARSENAL (imazapyr) resulted in greater than 90% control at both rates. RODEO (glyphosate), even at the higher rate, resulted in defoliation of only 32% of the trees. According to Vandiver (1993, personal communication) RODEO tends to be more effective on Brazilian pepper when applied in December in South Florida. Basal soil application of VELPAR and SPIKE were very effective. Basal bark application of GARLON 4 in an oil based solution is also very effective. The results of this study showed that site conditions and seasonal timing of application will determine the most effective combination of herbicide and method necessary to achieve good control of this pest plant. Since this study was done, VELPAR has lost its registration for use in wetland areas and can only be used in upland terrestrial sites and SPIKE is no longer registered in Florida. This is due to their persistence in the soil and potential for contamination of groundwater.

These studies indicate that several herbicides can effectively control Brazilian pepper. Generally, site conditions will often determine what combination of herbicide and method of application to use for the control of this pest plant in South Florida. Additionally more research is necessary to further understand the relationship between herbicide effectiveness and time of application.

See appendix on page 27 for detailed information on herbicide control techniques.

Table 1 Results of herbicide trials on Brazilian pepper conducted by Woodall (1982).

Herbicide	Rate	Method	❑ Cont.	Summary
AMMATE	.46kg a.i./Liter	Stump	43%	Stump treatments are suitable only when tops are required to be removed from the site. They give temporary control and are labor intensive.
BANVEL	.06kg a.i./Liter	Stump	90%	
DED-WEED	.06kg a.i./Liter	Stump	92%	
VELPAR	4.5 kg a.i./ha	Broadcast-soil	95%	New seedling developed within 9 months, possibly originating from stored seeds as well as a new seed crop.
AMMATE	65kg a.i./1000 L	Foliar	0%	Due to the fact that foliar applications are a physiologically indirect means of killing root systems, the probability for long lasting success with this method is low – Brazilian Pepper is a vigorous, easily sprouting species.
BANVEL	1.2kg a.i. /1000 L	Foliar	52%	
DED-WEED	4.8kg a.i. /1000 L	Foliar	82%	
VELPAR	4.8kg a.i. /1000 L	Foliar	75%	
VELPAR	8ml/ 5cm s.b.d.	Basal-soil	98%	For widely scattered bushes where access to the main stem is difficult, basal spot is easy, effective and selective.
HYVAR	8ml/ 5cm s.b.d.	Basal-soil	98%	

Table 2 Results of herbicide trials on Brazilian pepper conducted by Ewell *et al.,* (1982)

Herbicide	Rate	Method	❑ Cont.	Summary
BANVEL 720 Liq.	5%	Foliar	58%	Malformed epicormic and basal sprouts were observed after defoliation following application, but most of these sprouts later died
BANVEL 720 Liq.	2.5%	Foliar	77%	
BANVEL 720 Invert	3.5%	Foliar	73%	
BANVEL 720 Invert	1.8%	Foliar	62%	
BANVEL 5G	48ml/m crown dm.	Soil	18%	Results were not readily visible until at least 2 months after application. This treatment was not effective even after 9 months following application.
BANVEL 5G	8ml/m crown dm.	Soil	8%	
ROUNDUP	1.7%	Foliar	54%	Recommended for large numbers of small individuals, as in the understory of a stand.
ROUNDUP	.8%	Foliar	100%	
VELPAR	24 g/L water	Foliar	100%	Killed >75% of the neighboring shrubs and vines, most of them were still dead 9 months post treatment.
VELPAR	12g/L water	Foliar	100%	
GARLON (M-4021)	.8%	Foliar	92%	Recommended for large numbers of small individuals, as in the understory of a stand.
GARLON (M-4021)	.3%	Foliar	77%	
GARLON (M-4021)	1.5%	Basal-Bark	100%	Had little long-term impact on understory plants. Recommended for killing large trees.
GARLON (M-4021)	.5%	Basal-Bark	100%	

Table 3 Results of herbicide trials on Brazilian pepper conducted by Doren and Whiteaker (1990).

Herbicide	Rate	Method	❑ Cont.	Summary
GARLON 4	2%	Basal Bark	94%	Very little difference in treatment effectiveness between the two concentrations.
GARLON 4	4%	Basal Bark	96%	See above.

Table 4 Results of herbicide trials on Brazilian pepper conducted by Laroche and Baker (1994).

Method[1]	Herbicide	Rate	❑ Control
EZJECT	RODEO	1 capsule @ 2″ intervals	0%
	RODEO	1 capsule @ 4″ intervals	0%
	RODEO	1 capsule @ 8″ intervals	0%
FISCAN	SPIKE	1 capsule @ 3″ intervals	0%
	SPIKE	1 capsule @ 6″ intervals	0%
	SPIKE	1 capsule @ 12″ intervals	0%
	VELPAR	1 capsule @ 3″ intervals	0%
	VELPAR	1 capsule @ 6″ intervals	0%
	VELPAR	1 capsule @ 12″ intervals	0%
Basal Soil	SPIKE	0.25 ounces / 6″ BSD[2]	98%
	SPIKE	0.5 ounces / 6″ BSD	95%
	SPIKE	1 ounce / 6″ BSD	97%
	VELPAR	2 milliliters / every 2″ BSD	40%
	VELPAR	4 milliliters / every 2″ BSD	84%
	VELPAR	8 milliliters / every 2″ BSD	91%
Basal Bark	GARLON 4	1:4 oil @ 0.1 oz/ 1″ BSD	5%
	GARLON 4	1:4 oil @ 0.25 oz/ 1″ BSD	10%
	GARLON 4	1:4 oil @ 0.5 oz/ 1″ BSD	55%
Foliar	ARSENAL	0.5% solution[3]	95%
	ARSENAL	1.0% solution	98%
	GARLON 3A	1.5% solution	93%
	GARLON 3A	3.0% solution	97%
	RODEO	0.5% solution	0%
	RODEO	1.5% solution	55%

[1] EZJECT® Injection ammo is pre-formulated with an 83.5% formulation of Glyphosate, and FISCAN® Injection plugs are pre-formulated with a 90% formulation of hexazinone or an 80% formulation of the butiron.

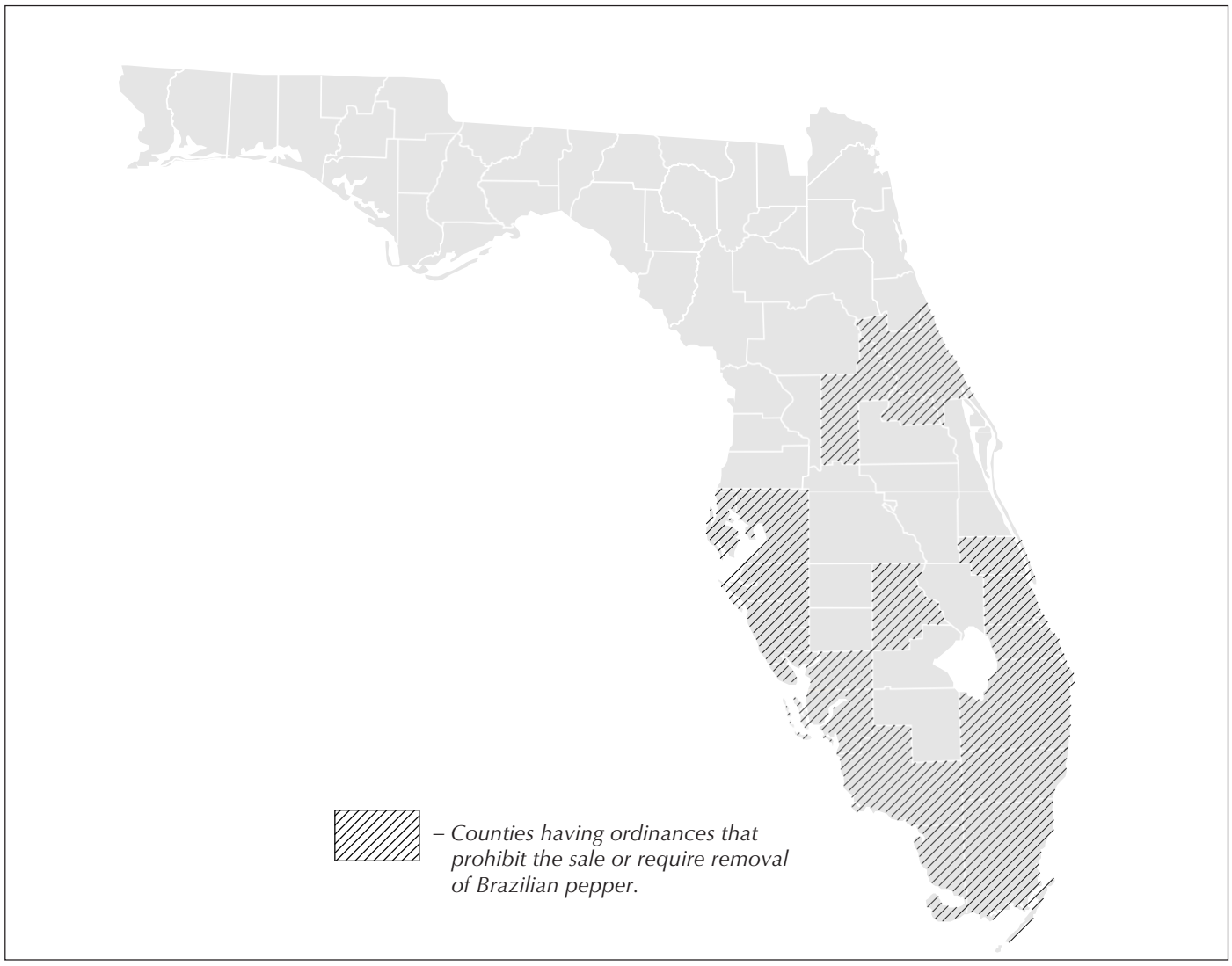
[2] BSD = Basal stem diameter

[3] Half a pint of X77 and 8 oz of submerge was added to each 50 gallon solution. Each Brazilian pepper tree was sprayed to wet.

Pro p ose d and Ena ct e d Law s

In Florida, widespread recognition of the severe threat posed by Brazilian pepper is evident in the many laws enacted throughout the state to prohibit the sale and cultivation of this plant. There is a state law prohibiting the sale, cultivation and transportation of Brazilian pepper. In 1990, section 369.251, was passed by the Florida legislature. In 1993, 16C-52, Florida Administrative Code, was amended putting Brazilian pepper on the state's prohibited plant list.

Several counties restrict the sale, transportation or cultivation of Brazilian pepper by law. Many of these counties also control it by omission from tree protection ordinances or require removal upon site development. Some counties have permitting requirements before removal is allowed. The following counties have ordinances that prohibit the sale or require the removal of Brazilian pepper: Broward, Charlotte, Collier, Dade, Highlands, Hillsboro, Indian River, Lake, Lee, Manatee, Martin, Monroe, Palm Beach, Pinellas, Sarasota, Seminole, St. Lucie, Volusia.



Resource Management Approach

The integrated management of Brazilian pepper requires a combination of control techniques to be effective. Essential elements of effective management include: biological, herbicidal, mechanical and physical control. Comprehensive descriptions for each of these management techniques are located in Section VI.

Prior to implementing Brazilian pepper controls the following factors must be considered and used in developing a site specific control plan:

1) Occurrence - extent of infestation, density, spatial distribution and other plant communities that are present.
2) Topography and soils - How does occurrence relate to elevation and soils? What are the characteristics of the soils - organic, sandy, hydric?
3) Hydrology - Has the site been impacted by drainage? Are there canals, agricultural fields, or wells nearby that may have caused a drawdown of the water table on the site?
4) Available management techniques - Which method of treatment or combination of methods is most suitable to the site being treated?
5) Economic factors - How much will it cost to exert initial control and then provide a long term follow up? What are sources of funding, grants, mitigation? Will the work be done by agency staff or by a contractor?
6) Public perception - Will public reaction cause bad publicity? What can be done to educate the public to avoid negative reaction?
7) Work schedule - Determine a reasonable time schedule as a goal for initial treatment and plan for routine maintenance control.

The key to an effective and long-lasting management program for Brazilian pepper is the introduction of biological control agents. Without biological control, Brazilian pepper elimination will be much more expensive and will not be truly integrated. The current investigation into biological organisms will most likely result in the introduction of defoliators and sprout inhibitors. Once introduced, several years are generally required for populations to build effective levels. In the interim, and throughout the biocontrol introduction phase, herbicidal and mechanical controls will be required to reduce current infestations and prevent spread into uninfested areas. Manual removal of seedlings in combination with single tree herbicide applications is the most conservative approach in natural areas. However, individual tree treatments are costly. Thus, less costly

The integrated management of Brazilian pepper requires a combination of control techniques to be effective.

methods of herbicide application are currently being investigated. Direct herbicide application can still result in non-target damage, as much as a year after treatment, depending on the herbicide used. Aerial application of herbicides may result in less herbicide being used on a site and in some situations may lower the cost of initial treatment. Manual removal of seedlings may not be advisable in all situations due to the percentage of roots broken below the ground surface. In addition, the soil disturbance that results may stimulate more seeds to germinate. mechanical removal using heavy equipment is best suited for rights-of-way and other areas where routine maintenance follows and site disturbance is not a concern.

Case Studies

Big Cypress National Preserve

Brazilian pepper is one of the most problematic exotic species in the Preserve. Brazilian pepper quickly invades disturbed, well-drained sites such as roadside soil banks, levees, oil well pads, old farm fields, and abandoned homesites, with the largest monotypic stands occurring on filled sites. In addition, scattered trees and small stands can be found in hardwood hammocks, as an understory plant in pinelands, and as an epiphyte on stumps and cypress knees.

Brazilian pepper control has been ongoing since the creation of the Preserve in 1974. Primary treatment methods have been basal treatments with 15% Garlon 4® using diesel fuel as a carrier or stump treatments using 100% Garlon 3A®. In 1994, a 150 gallon spray tank was purchased and a foliar spray program was initiated using Garlon 4® herbicide (2.5% solution) with water and Kinetic® added as a surfactant. This program was designed to reduce the seed source in an effort to minimize Brazilian pepper recruitment into surrounding natural areas.

Another facet of the National Park Service effort to eradicate Brazilian pepper from the Preserve relies on the use of heavy equipment. Prior to federal acquisition, lands within the Preserve were often used for activities that resulted in disturbance to the natural landscape. These lands were subject to rock mining, homesteads, farming, and road and canal construction. These human-caused changes to the landscape often resulted in the filling of wetlands. These filled areas are almost always heavily infested with Brazilian pepper.

The strategy for eradicating the Brazilian pepper focused on its intolerance to extended inundation (Hilsenbeck, 1972, as cited in Duever, *et al.*, 1986). Based on this premise, the plan for eradicating the Brazilian pepper from these areas focused on extending the hydroperiod by restoring the areas' elevations to predisturbance conditions.

Brazilian pepper was mechanically removed from the areas utilizing a bulldozer with a root rake. With the use of a track-hoe and bulldozer, the fill material was excavated and disposed of. The final elevations were determined by the presence of cap rock and/or the elevations of the surrounding areas. Monitoring of these sites has revealed no re-establishment by Brazilian pepper. To date, over 250 acres of Brazilian pepper have been removed.

Biscayne National Park

Brazilian pepper is less problematic on the islands of Biscayne National Park than other invasive pest plants such as *Colubrina asiatica* (Lather leaf), *Thespesia populnea* (Seaside mahoe) and *Schaevola taccada*. However, on the mainland, especially around Convoy Point, Brazilian pepper is becoming

Brazilian pepper growing as an epiphyte on a palm trunk.

more widespread, particularly after Hurricane Andrew. A possible reason for this is the transport of copious seed material from the islands to the mainland by hurricane winds. The plant quickly colonized disturbed sites and, once established, spread to new areas. The areal extent of Brazilian pepper coverage in Biscayne National Park today is unknown, and a mapping project is planned to provide this information.

Since Hurricane Andrew, exotic plant control in Biscayne National Park has not been performed with any regularity. The resource managers are formulating an exotic plant management plan and hope to implement a major initiative soon. Documentation of control efforts will be required under the new plan.

The main method used for the treatment of Brazilian pepper is cut and spray using Garlon 3A. Basal bark treatments using Garlon 4 are being planned. The latter treatment will be used on Brazilian pepper in remote areas, while the cut and spray method will be applied on trees in high profile areas.

De Soto National Memorial

Brazilian pepper is one of the most problematic exotic species in DESO Park. It is found in the Park's dense mangroves and in isolated areas adjacent to the Park. Mechanical removal has been used in appropriate areas.

The herbicidal control involves applying triclopyr (Garlon 3A) to fresh cut stumps 4" to 6" in length. It is applied with a hand pressure sprayer. Product use rate is applied at an undiluted or 1:1 mixture applied to the cambium. The DESO Brazilian pepper control program was initiated as of January 1994.

Everglades National Park

Schinus terebinthifolius was first reported growing in a farmed area of the Park known a Hole-in-the-Donut in 1959 (Alexander & Crook, 1974) but probably became established there in the 1940's (Olmsted & Johnson, 1983). It began to spread throughout this area as these farmlands were abandoned. In the early 1960's, Craighead reported that Brazilian pepper had advanced around Everglades City. In 1972, after Hurricane Donna, Hilsenbeck found that the plant had invaded *Muhlenbergia* prairie and the mangrove zone near West Lake. Brazilian pepper distribution was mapped by Park resource management personnel in 1976 and found to have spread to parts of the pinelands, the Flamingo area, the coastal area around Madeira and Little Madeira Bays, and north of Park headquarters along the eastern Park boundary. An unpublished report by Koepp (1978) on the occurrence of *Casuarina* in the southeastern corner of the Park indicated its presence there as well.

A 1982 survey of Brazilian pepper in mangrove areas found that plants were discontinuously distributed and occurred in patches with certain habitats; i.e., low mangrove areas, being more susceptible to invasion than others (Olmsted & Johnson, 1983). The most recent information on Brazilian pepper distribution in the Park is derived from a Park mapping project using 1987 aerial photographs. This distribution map reveals an areal extent of Brazilian pepper in excess of 105,000 acres, 95% of which lies in the mangrove zone along the west and northwest coasts. Details on the mapping procedure are found in Rose (1988). Recent, cursory surveys in the East Everglades indicate that a number of tree islands; *e.g.,* bayheads in Shark Slough, particularly those disturbed by dry season wildfires and, more recently, by Hurricane Andrew, are supporting increasing numbers of Brazilian pepper.

The size and extent of Brazilian pepper populations in the Park defy control methods by available resources. The majority of the control effort—surveying, treatment, and monitoring, is carried out by rangers in the various districts of the Park. They are guided by annual "action plans" developed by district backcountry rangers in cooperation with Park resource managers. The control work carried out varies among the districts and is a reflection of differences in personnel, funding, and other work assignments.

Recent control efforts have concentrated on maintaining areas treated in past years. Flamingo District rangers have treated and maintained the area along the main Park road between West Lake and Mahogany Hammock and between East and Northwest Cape. Pine Island District rangers, with assistance from seasonal work crews, have maintained the Anhinga Trail at Royal Palm. Northwest District rangers (at Everglades City) have treated and maintained several backcountry campsites. The time devoted to Brazilian pepper control is limited by the treatment of other Category I exotic pest plants including *Casuarina spp.* and *Colubrina asiatica* which have established populations on the islands and shores of Florida Bay and the Gulf Coast.

The herbicidal control of Brazilian pepper in the Park is accomplished by applying trichlopyr (Garlon) as a basal bark or cut stump treatment. The basal bark formulation contains 4% - 8% mineral oil, while the cut stump formulation contains 50% water. Follow-up treatments are necessary to treat regrowth (sprouts). Small plants are pulled by hand or treated with a foliar application of Arsenal where the dilution

and rate of application vary depending upon the formulation used.The mechanical removal of mature Brazilian pepper from 3.5 acres on an upland site at Chekika Hammock in the East Everglades Acquisition Area was carried out in the fall of 1993 as part of a mitigation and restoration project. The Brazilian pepper trees were uprooted using heavy equipment, piled into heaps, and mechanically mulched. The mulch was laced around the bases of native trees left standing in the cleared area; *i.e., Bursera simaruba* and *Ficus aurea,* creating a series of low maintenance beds 18 - 24 inches deep. Brazilian pepper recruitment in these beds is easily controlled by hand pulling.

The cleared area, however, consisting of three zones with varying elevational and hydroperiod patterns, necessitated that a different Brazilian pepper management strategy be used for each zone. One zone (shallow soil on higher ground) is managed to control the re-establishment of Brazilian pepper by regular mowing, thus hindering the establishment of woody vegetation. A second zone (long hydroperiod marsh) is revegetating naturally with typical wetland species; Brazilian pepper is controlled by the hand pulling of seedlings.

The third zone (intermediate in elevation and hydroperiod) was regarded as being most susceptible to Brazilian pepper colonization and was covered with sod (St. Augustine grass) as a temporary ground cover and weed deterrent. Brazilian pepper has not yet been found in this zone. This area will eventually be planted with subtropical hardwood species similar to those found in the adjacent hammock.

Hole-in-the-Donut Mitigation Project

Situated within the boundaries of Everglades National Park, the Hole-in-the-Donut (HID) comprises approximately 4,000 ha of previously farmed land. One-half of the area was rock-plowed, and, after its abandonment in the mid-1970's, the area has been invaded by Brazilian pepper The remaining 2,000 ha of non-rock plowed land, abandoned from 1930 through the early 1960's, has returned primarily to native vegetation with only a small portion dominated by Brazilian pepper (Ewel, *et al.*, 1982).

When the Park acquired the HID in 1975, farming ceased, and restoration of the area was addressed. Several studies were carried out in the Park to examine old field succession. (See Doren, *et al.*, 1990, for a summary.) However, the rapid spread and establishment of Brazilian pepper in the area, estimated at increasing by as much as twenty times its population density per year (Loope & Dunevitz, 1981), proved too overwhelming for successful restoration.

During the late 1970's and 1980's, several methods were tested to eliminate Brazilian pepper, including bulldozing, burning, mowing, and planting and seeding of native species, and all failed. However, one method, the complete removal of disturbed substrate, resulted in the recolonization of previously rock-plowed sites by native vegetation to the exclusion of Brazilian pepper. This has been attributed to the removal of the effects of the disturbed substrate and subsequent increase in hydroperiod (Doren, *et al.*, 1990).

In 1989, through an off-site, compensatory mitigation project, funding was provided for a pilot project involving the experimental removal of the disturbed substrate on approximately 24 ha of degraded (previously rock-plowed) wetlands within the HID. On 18 ha of the site, Brazilian pepper was mechanically removed and the soil removed to bedrock, while on the remaining 6 ha, part of the soil was left after Brazilian pepper removal. Continuous monitoring has revealed that the larger site has successfully eliminated Brazilian pepper (and other pest plants) and restored native wetland species, while *Schinus* has recolonized the entire area of partial soil removal. This study and data from several other sites in Dade County indicate that the restoration of Brazilian pepper-dominated, rock-plowed wetlands are dependent upon the complete removal of the fundamental substrate; i.e., the artificially created substrate with concomitant hydrological improvements. Details of the pilot study are given in Doren, *et al.* (1990).

The apparent success of the pilot project has encouraged the Park to expand the work on a larger scale and reclaim all the remaining Brazilian pepper-dominated, rock-plowed wetlands within the HID. The Park has applied for a Federal Clean Water Act, Section 404, dredge and fill permit and a State of Florida wetland regulatory permit to establish a regional mitigation bank. It is estimated that the mechanical removal of Brazilian pepper (and subsequent substrate removal) from the entire 2,000 ha in the HID will take up to 20 years to complete.

Myakka River State Park

Opened to the public in 1942, Myakka River State Park encompasses 28,875 acres. Oak and cabbage palm hammocks, grassy marshes and sloughs surround both the upper and lower Myakka Lakes. Vast expanses of dry prairie and pine flatwoods help make Myakka River State Park one of the largest and most biologically diverse parks in the state.

Its proximity to the coast and limited surrounding developments have helped to restrict the level of Brazilian pepper infestation within the park. Following resource management guidelines set by the Florida park service and the unit management plan specifically outlined for the park, an average of 100 Brazilian pepper trees are reported and removed from the park each year. An aggressive monitoring program by park staff requires exotic species to be reported. Location information is logged, and the trees are slated for removal.

Volunteers and various community organizations, including community service workers, are used to help park staff in Brazilian pepper removal. Early detection allows workers to hand pull young seedlings and saplings. Larger trees (up to 3" caliper) are removed (including the root systems) by hand digging. When hand removal becomes impractical due to size or location, Garlon 4 (mixed with JLB oil) is applied as a basal bark treatment

Sanibel Island - Sanibel-Captiva Conservation Foundation

Results from an experiment conducted by the Sanibel-Captiva Conservation Foundation (SCCF) on Sanibel Island, Florida (1990-1991), and the effects of a substantial rainfall in 1995 suggest that Brazilian pepper can be stressed or killed by flooding.

In both cases, Brazilian pepper did not exhibit the adaptations generally found in wetland species of woody plants in response to flooding. These adaptations include adventitious rooting and lentical enlargement (Kozlowski, 1984), both of which were observed in buttonwood trees immediately adjacent to the stressed Brazilian pepper.

Inundation produced stress to varying degrees including leaf chlorosis, wilting and abscission. Trees that lost all of their leaves eventually died. Dead trees took approximately 1.5 years to decompose.

The following are results of the SCCF 1990-1991 experiment that involved the artificial flooding by periodic pumping of a 4.5 acre Brazilian pepper-infested impoundment of varying grade elevations. The average water level in the impoundment for 77 days (September 19-December 4) was 3.2 feet NGVD, with a high of 3.9 feet NGVD. Trees flooded by an average of 9.5 to 15 inches of water showed varying degrees of stress; some lost all of their leaves, and died, while others recovered from leaf chlorosis, wilting and partial leaf abscission. Flooding levels of less than 9.5 inches of water created little or no stress. Trees with lateral roots which could reach areas of decreased inundation exhibited less stress than would be indicated by the inundation level of the main trunk. Soils in the lower areas (15 to 22 inches of inundation) tended to be more organic in nature and may have been more conducive to creating an anaerobic state which caused severe root stress. Other encroaching plant species which were stressed include wax myrtle *(Myrica cerifera)* and saltbush *(Baccharis halimifolia)*.

Similar results were observed on a larger scale in 1995. In the Spring of this year, a new water control structure was completed on Sanibel Island. The crest elevation is 3.2 NGVD. The capacity of the structure to release water through the opening of gates was offset by the ability to hold water 0.7 feet (8.4 inches) higher than previously possible. This allowed for higher water levels in Brazilian pepper-infested interior wetlands in the western half of the island. Brazilian pepper exhibited signs of severe stress in areas of low elevations. During periods of high summer rains (July 18-October 29), water levels averaged 3.1 feet NGVD with a high of 3.7 feet and a low of 2.6 feet.

Two significant impacts were observed: stress on hardwood vegetation, predominantly Brazilian pepper in low-lying areas, and the restoration of open water sites, especially in areas where prescribed burns were performed in early June 1995. Brazilian pepper stress ranged from total leaf loss and death in low-lying areas, to partial leaf loss in transition zones, to leaf yellowing in lower ridge areas. Other encroaching plant species that were stressed include wax myrtle *(Myrica cerifera)* and saltbush *(Baccharis halimifolia)*.

Literature Cited

Alexander, T.R. and A.G. Crook. 1974. Recent Vegetational Changes in Southern Florida. In: "Environments of South Florida: Present and Past II." P.J. Gleason (ed.) Miami Geological Soc., Coral Gables, Florida.

Altschul, S.R. 1973. *Drugs and Foods from Little-Known Plants - Notes in Harvard University Herbarium*. Harvard University Press, Cambridge.

Austin D.F. 1978. Exotic plants and their effects in southeastern Florida. *Environ. Conserv.* 5: 25-34.

Barkley, F.A. 1944. *Schinus* L. *Brittonia* 5: 160-198.

Bell, C.R. and B.J. Taylor. 1982. *Florida Wildflowers and Roadside Plants*. Laurel Hill Press, Chapel Hill.

Big Cypress National Preserve. 1992. *Big Cypress National Preserve General Management Plan and Environmental Impact Statement*. National Park Service, Washington, D.C.

Brizicky, G.K. 1962. The genera of Anacardiaceae in the southeastern United States. *J. Arn. Arb.* 43: 359-375.

Campbell, G.R., J.W. Campbell and A.L. Winterbotham. 1980. *The First Fund for Animals, Inc. Schinus terebinthifolius Brazil Expedition, July 1980 - Interim Report.* [Unpublished]

Campello, J.P. and A.J. Marsaioli. 1974. Triterpenes of *Schinus terebinthifolius*. *Phytochem.* 13: 659-660.

Campello, J.P. and A.J. Marsaioli. 1975. Terebenthifolic acid and bauerenone. *Phytochem.* 14: 2300-2302.

Correll, D.S. and H.B. Correll. 1982. *Flora of the Bahama Archipelago*. J. Cramer, Vaduz.

Curnutt, J.L. 1989. Breeding bird use of a mature stand of Brazilian pepper. *Fl. Ornithol. Soc.* 17: 53-76.

Doren, R.F., L.D. Whiteaker, G. Molnar and D. Sylvia. 1990. Restoration of Former Wetlands Within the Hole-in-the-Donut in Everglades National Park. In: F.J. Webb (ed.). *Proc. 7th Annual Conference on Wetlands Restoration and Creation.* Hillsborough Comm. Coll., Tampa.

Doren, R.F. and L.D. Whiteaker. 1990. Comparison of economic feasibility of chemical control strategies on differing age and density classes of *Schinus terebinthifolius*. *Nat. Areas Journ.* 10: 28-34.

Doren, R.F., L.D. Whiteaker, and A.M. LaRosa. 1991. Evaluation of fire as a management tool for controlling *Schinus terebinthifolius* as secondary successional growth on abandoned agricultural land. *Environ. Management* 15: 121-129.

Duever, M.J., Calson, J., Meeder, J., Duever, L., Gunderson, L., Riopell, L. Alexander, T., Myers, R. and Spangler, D. 1986. *The Big Cypress National Preserve.* National Audubon Society Research Center Report No. 8. New York, New York.

Dunevitz, V. and J. Ewel. 1981. Allelopathy of wax myrtle *(Myrica cerifera)* on *Schinus terebinthifolius*. *Fl. Sci.* 44: 13-20.

Ewel, J.J. 1979. Ecology of *Schinus*. *In:* Workman, R. (ed.). *Schinus - Technical Proceedings of Techniques for Control of Schinus in South Florida: A Workshop for Natural Area Managers.* The Sanibel-Captiva Conservation Foundation, Inc., Sanibel. pp. 7-21.

Ewel, J.J., D.S. Ojima, D.A. Karl, and W.F. DeBusk. 1982. *Schinus in Successional Ecosystems of Everglades National Park*. South Florida Research Center Report T-676, Everglades National Park. 141 pp.

Ewel, J.J. 1986. Invasibility: Lessons from South Florida. *In:* Mooney, H.A. and J.A. Drake (eds). *Ecology of Biological Invasions of North America and Hawaii*. Springer-Verlag, New York. pp. 214-230.

Ferriter, A.P. (1997) Biological monitoring of exotic pest-plants in South Florida. (Unpublished)

Gleason (ed.). 1984. *Environments of South Florida: Present and Past*. Miami Geol. Soc. Mem. 2: 61-72.

Gogue, G.J., C.J. Hurst, and L. Bancroft. 1974. Growth inhibition by *Schinus terebinthifolius*. *Amer. Soc. Hort. Sci.* 9: 45.

Graf, A.B. 1982. *Exotica 4 International*. Roehrs Co., East Rutherford.

Gunderson, L.H. 1983. *Status of Exotic Woody Species in Big Cypress National Preserve.* South Florida Research Center Report SFRC-83/07. Everglades National Park, Homestead, Florida.

Hedrick, U.P. 1972. *Sturtevant's Edible Plants of the World*. Dover Publications, New York.

Koepp, W.P. 1978. *Summary of Casuarina Project - South East Corner*. Resource Management Report, Everglades National Park. [Unpublished]

Krauss, P. 1987. *Old Field Succession in Everglades National Park.* Report SFRC-87/03, South Florida Research Center. Everglades National Park, Homestead.

Lampe, K.F. and R. Fagerstrom. 1968. *Plant Toxicity and Dermatitis.* Williams & Wilkins Co., Baltimore.

Lampe, K.F. and M.A. McCann. 1985. *AMA Handbook of Poisonous and Injurious Plants.* American Medical Association, Chicago.

Langeland, K. A. 1990. Exotic Woody Plant Control. Florida Cooperative Extension Service / Institute of Food and Agricultural Sciences University of Florida and Exotic Pest Plant Council, Circular 868 16 pp.

Laroche, F. B. 1992. Evaluation of the FISCAN Plug for Melaleuca control. *Aquatics*. Vol. 15, No. 2.

Laroche, F. B. and G. E. Baker. 1994. Evaluation of several Herbicides and Application Techniques for the Control of Brazilian Pepper. *Aquatics* 16 (1):18-20.

LaRosa, A.M., R.F. Doren and L. Gunderson. 1992. Alien plant management in Everglades National Park: An historical perspective. In: Stone, C.P., C.W. Smith and J.T. Tunison (eds.). *Alien Plant Invasions in Native Ecosystems of Hawai'i: Management and Research*. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu. pp. 47-63.

Lloyd, H.A., T.M. Jaouni, S.L. Evans and J.F. Morton. 1977. Terpenes of *Schinus terebinthifolius*. *Phytochem*. 16: 1301-1302.

Loope, L.L. and V.L. Dunevitz. 1981. *Investigations of Early Plant Succession on Abandoned Farmland in Everglades National Park*. South Florida Research Center Report T-644, Everglades National Park. 65 pp.

Loope, L.L. and V.L. Dunevitz. 1981. *Impact of Fire Exclusion and Invasion on Schinus terebinthifolius on Limestone Rockland Pine Forests of Southeastern Florida*. Report T-645, South Florida Research Center. Everglades National Park, Homestead.

Mabberley, D.J. 1987. *The Plant Book*. Cambridge University Press, Cambridge.

Mors, W.B. and C.T. Rizzini. 1966. *Useful Plants of Brazil*. Holden-Day Inc., San Francisco.

Morton, J.F. 1969. Some ornamental plants excreting respiratory irritants. *Proc. Fl. St. Hort. Soc.* 82: 415-421.

Morton, J.F. 1978. Brazilian pepper - Its impact on people, animals and the environment. *Econ. Bot.* 32: 353-359.

Mytinger, L. and G.B. Williamson. 1987. The invasion of *Schinus* into saline communities of Everglades National Park. Fl. Sci. 50: 7-12.

Nilsen, E. and W. Muller. 1980. A comparison of the relative naturalization ability of two *Schinus* species in southern California. I. Seed germination. *Bull. Torrey Bot. Club* 107: 51-56.

Olmsted, I. and J. Johnson. 1983. Status of Exotic Woody Species in South Florida National Parks, *Part I: Everglades National Park. South Florida Research Center, Everglades National Park*. 43 pp. (Unpublished)

Rehm, S. and G. Espig. 1991. *The Cultivated Plants of the Tropics and Subtropics - Cultivation, Economic Value, Utilization*. Verlag Josef Margraf.

Rose, M. 1988. *Procedures: Exotic Tree Species Mapping From Aerial Photographs at Everglades National Park*. South Florida Research Center, Everglades National Park. 12 pp. [Unpublished]

Tomlinson, P.B. 1980. *The Biology of Trees Native to Tropical Florida*. Harvard University Printing Office, Allston.

Uphof, J.C. 1968. *Dictionary of Economic Plants*. Verlag von J. Cramer, Lehre.

Williams, L.O. 1981. *The Useful Plants of Central America*. Escuela Agricola Panamericana, Honduras.

Woodall, S. 1979. Physiology of *Schinus*. In: Workman, R. (ed.). *Schinus - Technical Proceedings of Techniques for Control of Schinus in South Florida: A Workshop for Natural Area Managers*. The Sanibel-Captiva Conservation Foundation, Inc., Sanibel. pp. 3-6.

Woodall, S. L. 1982. Herbicide tests for control of Brazilian-Pepper and Melaleuca in Florida. Southeastern Forest Experiment Station, Asheville, N. C. USDA Forest Service Research Note SE 314. 10 pp.

Workman, R. 1979. History of *Schinus* in Florida. *In:* Workman, R. (ed.). *Schinus* - Technical *Proceedings of Techniques for Control of Schinus in South Florida: A Workshop for Natural Area Managers*. The Sanibel-Captiva Conservation Foundation, Inc., Sanibel. pp. 3-6.

Yoshioka, E.R. and G.P. Markin. 1991. Efforts of biological control of Christmas berry (*Schinus terebinthifolius)* in Hawaii. In: Center, T.D. *et al*. (eds.). *Proceedings of the Symposium on Exotic Pest Plants*. Technical Report NPS/NREVER/NRTR-91/06. National Park Service, Washington, D.C. pp. 377-387.