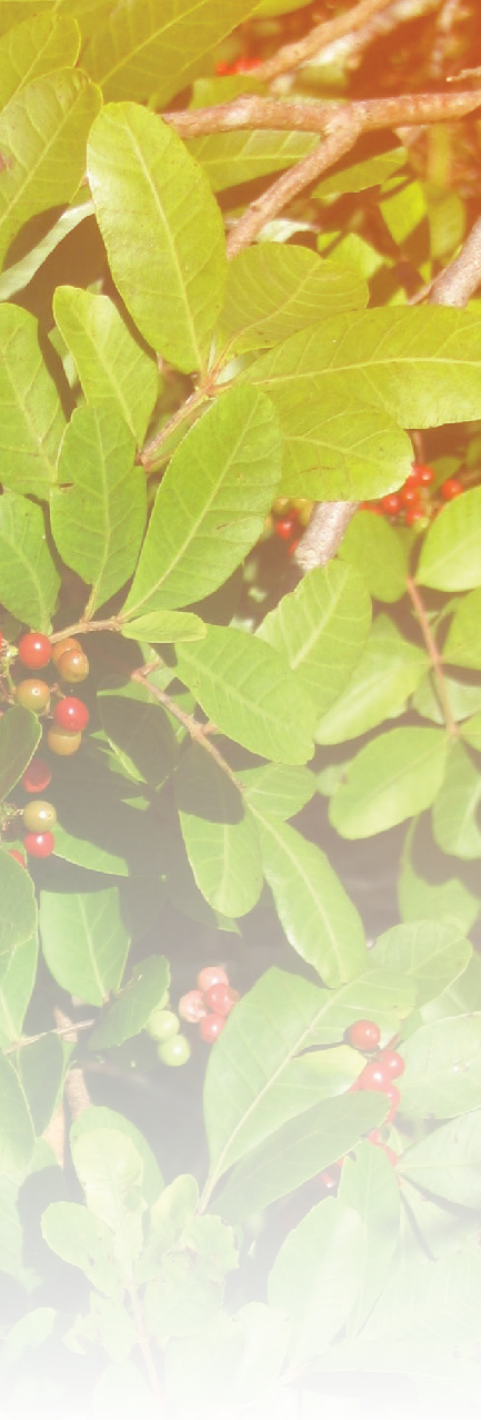
Brazilian Peppertree

Integrated Management Guide 2019

James P. Cuda[1], Stephen F. Enloe[2], Kenneth T. Gioeli[3], Carey R. Minteer[4], Patricia Prade[4]

[1]Entomology and Nematology Department, University of Florida, Gainesville, FL 32611-0620
[2]Agronomy Department, Center for Aquatic and Invasive Plants, Gainesville, FL 32653-0610
[3]UF/IFAS Extension, St. Lucie County, Ft. Pierce, FL 34945-3045
[4]UF/IFAS Indian River Research and Education Center, Ft. Pierce, FL 34945-3138



Contents


Photo credit: UF/IFAS

INTRODUCTION

About Brazilian Peppertree

Brazilian peppertree (*Schinus terebinthifolia Raddi, Anacardiaceae*) has become a 'poster child' for invasive plants in Florida landscapes. It was popularized as an ornamental following its introduction into Florida during the late 19th and early 20th centuries. The lag period between the introduction of Brazilian peppertree, and its aggressive spread is likely a result of hybridization, natural selection of well adapted genotypes, and release from natural enemies.

As its name would suggest, Brazilian peppertree is native to South America, where it is found in Brazil, Argentina and Paraguay. In the USA, Brazilian peppertree occurs in Florida, Texas, Alabama, California and Hawaii. Although it was introduced into Florida as an ornamental plant in the late-1800s, it was not until the 1950s that it was recognized as an environmental threat.

Much has been learned about Brazilian peppertree's ecology, genetics, distribution, and management since the 2nd edition of the Brazilian Peppertree Management Plan was published in 2006. New educational materials are being developed to help natural resource managers understand how state-of-the-art control tactics can fit into a Brazilian peppertree integrated pest management (IPM) plan including the use of biological control agents first approved by USDA in 2019. This new IPM guide includes up-to-date information on Brazilian peppertree's identification, biology, distribution, impacts and current management strategies.

Goals of Brazilian Peppertree Integrated Pest Management (IPM)

Large-scale management of Brazilian peppertree cannot be conducted effectively by any single approach. Prevention is no longer a viable option because the plant is so widespread. Long-term sustainable management

of Brazilian peppertree will require an integrated approach. Concepts like Integrated Weed Management, or Integrated Pest Management or Invasive Plant Management (IPM) have one thing in common. They all involve the coordinated use of weed and environmental information and all available control methods to prevent unacceptable levels of environmental damage by Brazilian peppertree using the most economical means available with the least possible hazard to people, property and the environment. (Source: IPM Florida: http://ipm.ifas.ufl.edu/)

A basic tenant of IPM is that the invaded plant communities are dynamic and will require the application of various technologies (e.g., chemical, cultural, and mechanical controls, as necessary) to enhance the natural processes and mechanisms that direct vegetation change. Where possible, natural controlling processes (e.g., biological control, plant competition, allelopathy) will be manipulated to increase management effectiveness. Prior to implementing Brazilian peppertree control measures, land managers should consider the following factors in developing a site-specific management plan:

1. Occurrence - Extent of infestation, density, spatial distribution and other plant communities that are present. Environmental sensitivity of the location should also factor into your management plan. For example, your management strategies are likely going to be different in hardwood hammocks and mangrove forests.
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 (biological, chemical, mechanical, physical) 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.
8. Time of Year – Brazilian peppertrees are likely to be more susceptible to herbicide management while flowering. Also, if you manage your trees while fruit is present, you risk spreading the seeds if you intend to cut and remove the trees.

In order to implement a site-specific IPM plan for Brazilian peppertree, the critical ecological processes that direct plant community dynamics to the detriment of Brazilian peppertree in that particular ecosystem

must be identified and manipulated. Those processes with the highest probability of causing change in the desired direction will be modified to produce predictable results. This approach, which is referred to as 'successional weed management', requires a basic understanding of the three general causes of plant succession: disturbance, colonization and species performance (Figures 1 and 2).

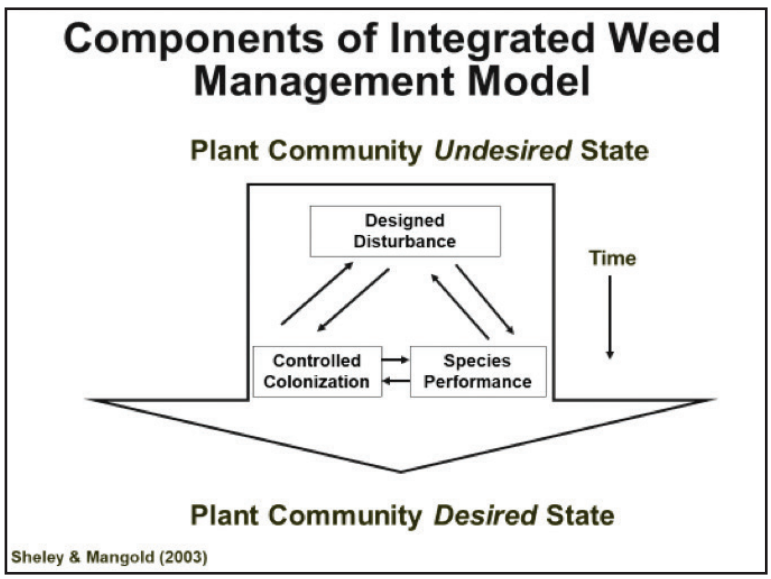


Figure 1. Key elements of a successional weed management model. This process is time dependent. (Credit: Sheley and Mangold (2003)

In Fig. 2, management objectives are aimed at increasing the production of native plants at the expense of Brazilian peppertree. Appropriate chemical, mechanical and physical control practices can be aggressively applied to remove the existing canopy with minimal impact to non-target native species because the Brazilian peppertree infestation is a virtual

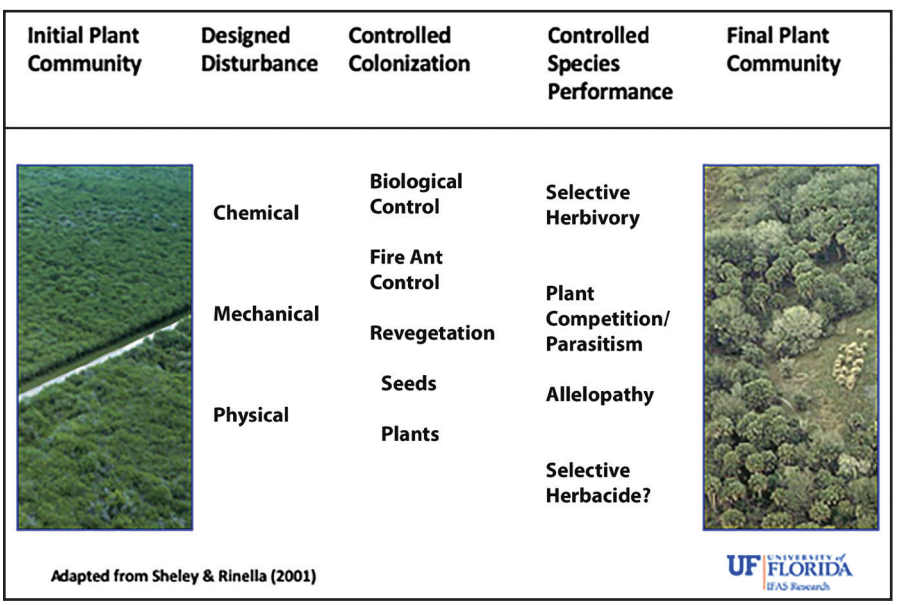


Figure 2. Successional management of Brazilian peppertree illustrating the different tactics that can be used for the designed disturbance, controlled colonization and species performance phases. The image on the left is a monoculture of Brazilian peppertree whereas the image on the right is a diverse plant community that is the desired outcome.

monoculture. Once the standing biomass is removed, the appropriate Brazilian peppertree biological control agents (e.g., leaf gallers and thrips) will be released to attack the understory regrowth and seedlings. An area-wide fire ant control program can be implemented, if necessary, during the biological control agent release phase to increase the likelihood of natural enemy establishment by minimizing ant predation. If seeds of native plants are lacking, a revegetation program may be implemented by broadcasting seeds or transplanting competitive native species. Wax myrtle (*Morella cerifera* L.) is one of the more valuable native species because of its demonstrated allelopathic effects on Brazilian peppertree and its tolerance to some foliar herbicides in upland and freshwater riparian areas. In this example, the process of plant succession to the desired state will be directed initially by aggressive mechanical/chemical control followed by release of herbivorous biocontrol agents and plant competition with an occasional herbicide spot treatment, if necessary.

Importance of Public Education

The Invasion Curve shown here should be the basis for prioritizing threats, control methods and costs for managing invasive species. It illustrates how the eradication of an invasive species is virtually impossible after the invader spreads over time. Brazilian peppertree occurs under the area of the curve labelled Resource Protection & Long-term Management. It is so widespread and abundant in the Florida peninsula that control costs are very high and dedicated resources are needed to address population reduction and long-term management. Long-term management only can be achieved through IPM.

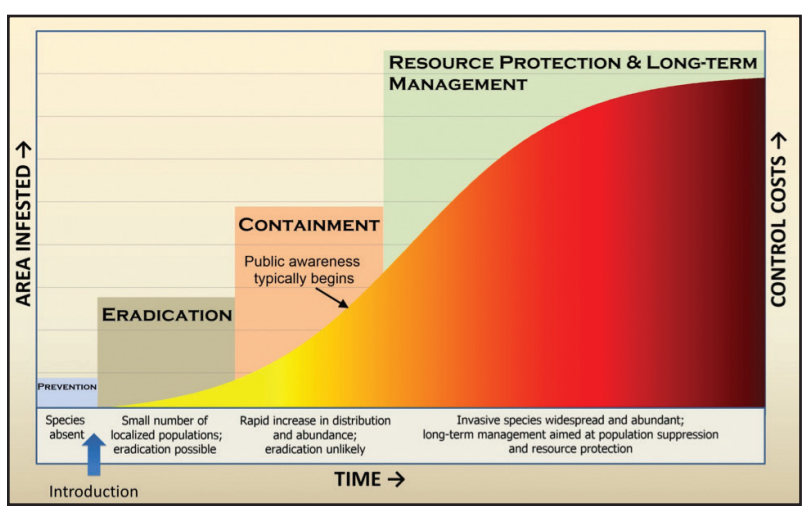


Figure 3. The invasion curve. Adapted from Invasive Plants and Animals Policy Framework, State of Victoria, Department of Primary Industries, 2010.

For more information about management of Brazilian peppertree, contact your local UF/IFAS Extension office.

Scan the QR code to find the contact information for the extension office in your county (https://sfyl.ifas.ufl.edu/find-your-local-office/)

IDENTIFICATION

How to Identify Brazilian Peppertree

Brazilian peppertree (Fig. 4) is a large dioecious (separate sexes) evergreen shrub or small tree, up to 10 m in height, with multi-stemmed branches that often form an impenetrable tangle. It has shiny alternate compound leaves that are highly aromatic, especially when crushed. Flowers of both male and female trees are small greenish white in color, have 5 petals and are borne in clusters. Fruits are small drupes, approximately 5 mm in diameter, green when immature and bright red when ripe.

Figure 4. Brazilian peppertree plant showing the compound leaves, flowers and fruits (Photo credit, Bryan Harry).

Look-Alikes

Brazilian peppertree is similar in appearance to coral ardisia, *Ardesia crenata* Sims and shoebutton ardisia, *Ardisia elliptica* Thunb. Like Brazilian peppertree, both *Ardisia* spp. are not native to the USA and also are highly invasive (FLEPPC Category I). However, coral ardisia is restricted to forest understories only whereas Brazilian peppertree and shoebutton ardisia are found in variety of habitats, ranging from mangrove areas to dry upland sites. The leaves of both *Ardisia* spp. are simple, not compound like Brazilian peppertree. Also, the flowers of *Ardisia* spp. are bisexual, not unisexual like Brazilian peppertree. The red fruits or berries of Brazilian peppertree drop to the ground when

Figure 5. Brazilian peppertree look a likes. *Ardesia crenata* on the left, and *Ardisia elliptica* on the right.

they reach maturity whereas they are retained year-round on *Ardisia* spp. The mature fruits of coral ardisia are red like Brazilian peppertree but those of shoebutton ardisia turn black when ripe.

BIOLOGY

Brazilian peppertree flowers produce large quantities of pollen and nectar and are primarily insect pollinated. Insect dispersal of pollen contributed to hybridization. Brazilian peppertree is a prolific seed producer that is capable of producing drupes at 3 years of age. Seeds are short-lived and remain viable in the soil only for 2-6 months; viability rate is between 30-60%. Germination and seedling growth rates of Brazilian peppertree are high compared to other species (66-100%), which contributes to the aggressiveness of this weed. In Florida, flowering occurs from September through November; a much-reduced bloom period occurs from March to May. Fruits are typically produced from November to February and are consumed and dispersed primarily by birds and mammals. Robins and other seed feeding animals like opossums and raccoons are considered the most important seed dispersers. They consume large quantities of seed and spread them to habitats that Brazilian peppertree would never otherwise reach. In addition, some seed dispersal occurs in flowing water. Brazilian peppertree also is capable of resprouting from above-ground stems, and root crowns after physical damage or improper treatment with herbicides.

It is noteworthy that one of the reasons Brazilian peppertree is so invasive is due to hybrid vigor. After two distinct genotypes were introduced into Florida, they hybridized. The crossing of the two parental plants over time produced the novel genotypes. Results of a recent common garden experiment showed that hybrids of these two introductions have higher survival, growth rates and produce more biomass in Florida than the parental genotypes.

DISTRIBUTION

US Distribution of Brazilian Peppertree

This map shows the current US distribution of Brazilian peppertree. In addition to Florida, Brazilian peppertree has been reported from Georgia, Alabama, Texas, California, and Hawaii. Dense populations occur in southern California, Florida, Hawaii, and south Texas. Data for this distribution map are based on voluntary reporting as of April 2019. The legend indicates the locations where Brazilian peppertree plants have been documented.

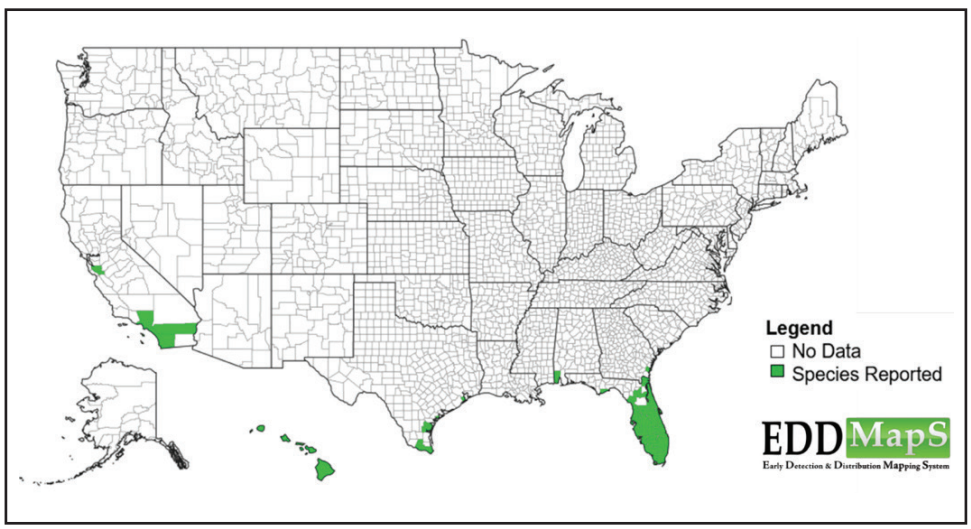


Figure 6. Distribution of Brazilian Peppertree in the United States. (Source, EDDMaps)

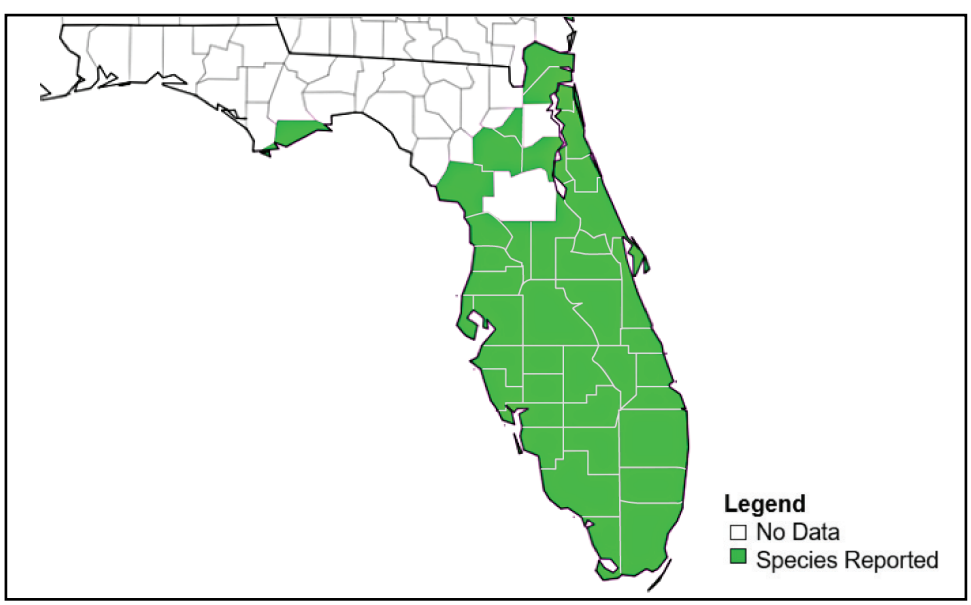


Figure 7. Distribution of Brazilian Peppertree in Florida. Brazilian peppertree has been reported from 42 of Florida's 67 counties (67%). (Source, EDDMaps)

IMPACTS

Economic. During FY2017-2018, three of Florida's Water Management Districts (SFWMD, SJRWMD, and SWFWMD) spent a combined total of $1.7 million controlling Brazilian peppertree on district owned/managed lands.

Environmental. Chemicals released from the foliage and roots of Brazilian peppertree have been shown to inhibit germination and growth of native plants. This phenomenon, which is referred to as allelopathy, gives Brazilian peppertree a competitive advantage over most native species except wax myrtle.

The invasion of Florida's natural shoreline habitats and saline communities of the Everglades National Park by Brazilian peppertree threatens rare federal and/or state listed native plants such as the Beach Jacquemontia, *Jacquemontia reclinata,* and the Beach Star, *Cyperus pedunculatus*. Also, the nesting habitat of the gopher tortoise is being encroached upon by Brazilian peppertree.

Health. Brazilian peppertree displays allergen-causing properties similar to those induced by poison ivy, poison oak, poisonwood, and poison sumac because they all belong to the same plant family Anacardiaceae. Direct contact with the plant sap or resin may result in a rash followed by intense itching in at-risk people. Ingesting the bark, leaves, and fruits can be toxic to humans, mammals, and birds.

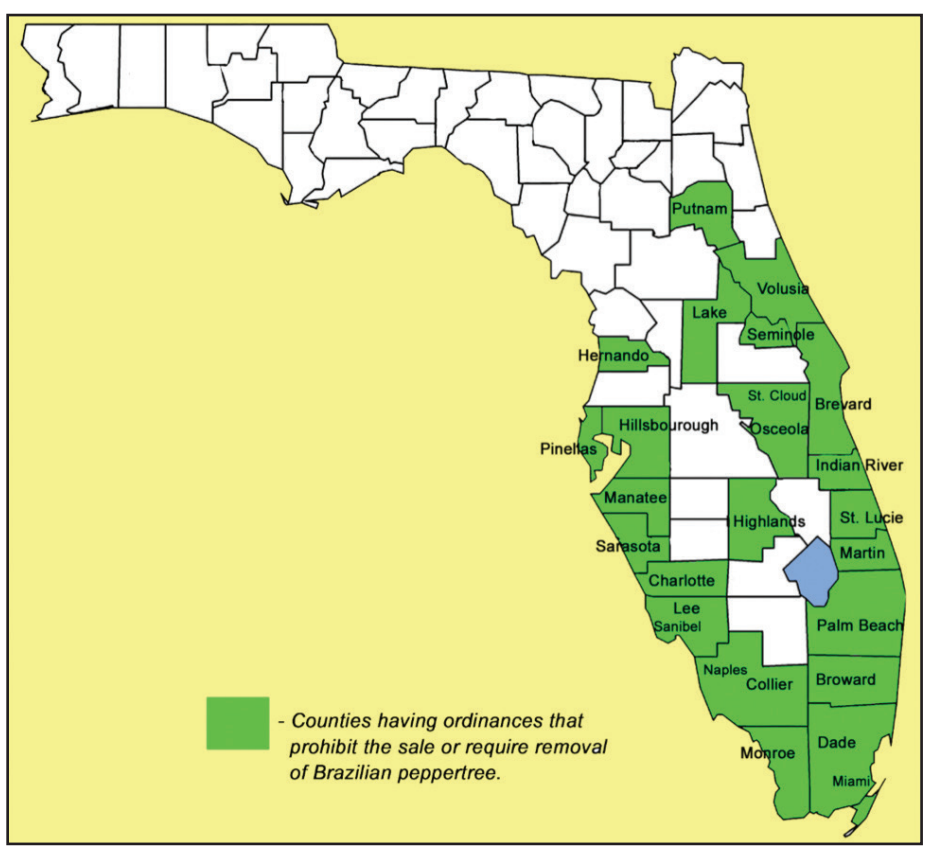


Figure 8. Florida counties that have enacted local ordinances requiring the removal of Brazilian peppetree. (Credit: M. Sanford)

REGULATORY AUTHORITY

Laws and Regulations

Florida law (F.S. 369.251) prohibits the sale, cultivation and transportation of Brazilian peppertree. To date, twenty-five Florida counties/municipalities have enacted local ordinances prohibiting the sale of Brazilian peppertree or require its removal (Fig. 8)

Brazilian Peppertree also is on the:

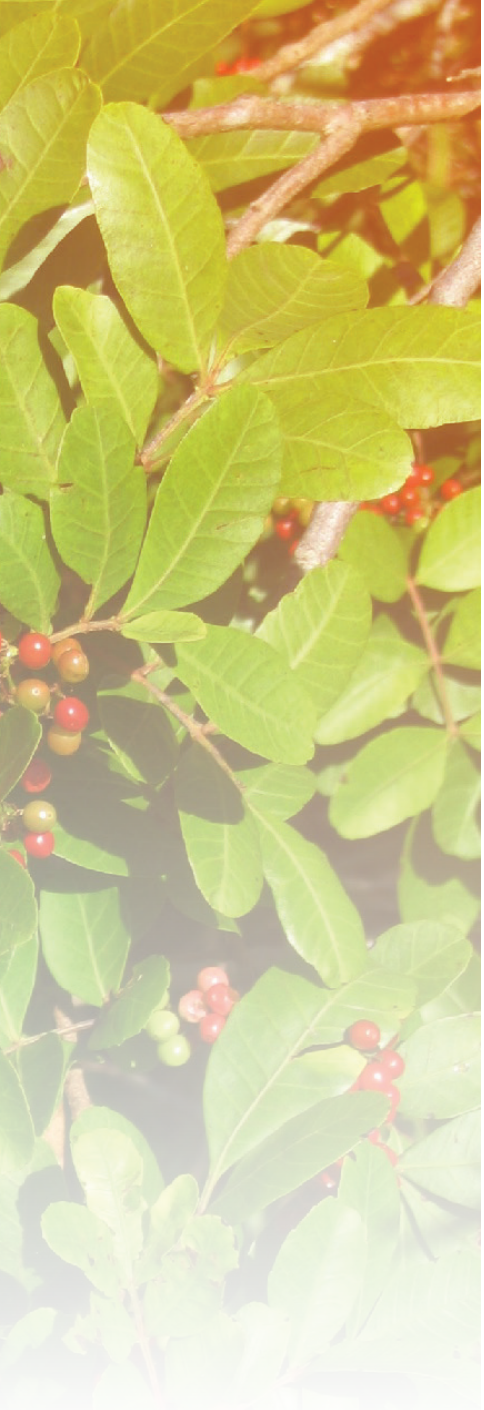
- California Invasive Plant Council List. https://www.cal-ipc.org/plants/inventory/
- Hawaii Ecosystems at Risk List. http://www.hear.org/plants/
- Texas Noxious Plants list http://texreg.sos.state.tx.us/public/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=4&pt=1&ch=19&rl=300
- State list of Noxious Weed in Florida https://www.flrules.org/Gateway/View_notice.asp?id=18358916
- Florida Prohibited Aquatic Plant List, Class 1 https://plants.ifas.ufl.edu/wp-content/uploads/files/5B-64.011_ProhibitedAquaticPlantsList_Feb2012.pdf
- Florida Exotic Pest Plant Council List, Category I* http://bugwoodcloud.org/CDN/fleppc/plantlists/2017/2017FLEPPCLIST-TRIFOLD-FINALAPPROVEDBYKEN-SUBMITTEDTOALTA.pdf

*Category I are "Invasive exotics that are altering native plant communities by displacing native species, changing community structures or ecological functions, or hybridizing with natives."

Scan the QR code to visit CAIP's website, where you can download the Florida lists and access legislative chapters

Early Detection and Rapid Response
Ive Got1 - https://www.eddmaps.org/florida/report/

How to Report a New Brazilian Peppertree Infestation:
EDDMaps (Early Detection & Distribution Mapping System)
https://www.eddmaps.org/distribution/usstate.cfm?sub=78819



MANAGEMENT OPTIONS

To date, management efforts in Florida to control Brazilian peppertree have focused on prohibiting the sale of the plants by the nursery trade, mechanical or physical removal, and chemical control. A combination of chemical and mechanical control measures has been used with some success in spite of plant's ability to recover from the effects of these conventional control practices. Chemical and mechanical controls, however, are unsuitable for some natural areas (e.g., mangrove forests) because they may have negative side effects on non-target species and the environment. In order to maintain the integrity of Florida's fragile ecosystems and natural resources, effective and sustainable control of Brazilian peppertree will require the integration of a variety of tactics including biological control.

Physical Control

Burning. Physical methods (e.g., burning) are routinely used for controlling existing Brazilian peppertree stands often in combination with herbicide applications. Prescribed burns cause significant mortality (30-45%) at low plant densities. Savannas with frequent fire regimes (natural or man-made) contain less Brazilian peppertree. However, fire is less effective when Brazilian peppertree densities are high.

Flooding. Exposing the roots with a high-pressure water hose is a technique referred to as hydrojecting (Figure 9), which can kill Brazilian peppertrees. Long periods of flooding also may stress or even kill Brazilian peppertree plants. Studies have shown that Brazilian peppertree seedlings are especially vulnerable to prolonged submergence. For instance, in the Everglades National Park, Brazilian peppertree is absent from marshes and prairies with hydroperiods exceeding 6 months.

Figure 9. Brazilian peppertree on a ditch bank in Hillsborough County being killed by exposing the roots with a high pressure water hose technique referred to as hydrojecting.
(Photo credit: Heather Faessler)

Mechanical Control

Bulldozers, front end loaders, root rakes and other specialized heavy equipment can remove Brazilian peppertrees. However, other control methods must be implemented after the existing stands are removed because disturbance of the soil usually creates favorable conditions for regrowth from the seedbank, resprouting, and recolonization by long distance avian seed dispersal. The use of heavy equipment is not suitable in sensitive natural areas such as mangrove communities where alternative control measures are required.

Figure 10. Front end loader in Port St. Lucie fitted with cutting/grinding attachment for removal of Brazilian peppertrees along roadside rights-of-way. (Photo credit: J. Dunton)

Biological Control

Biological control is the introduction of natural enemies into Florida from the native range (South America) that feed and reproduce only on Brazilian peppertree plants.. Also referred to as Classical Biological Control, this method should be the basis for an integrated approach for the management of Brazilian peppertree in Florida. In 2016, the Brazilian peppertree thrips *Pseudophilothrips ichini* (Fig. 11) and the yellow Brazilian peppertree leaf galler *Calophya latiforceps* (Fig. 12) were recommended for release in Florida because research by UF and USDA scientists showed these insects attack only Brazilian peppertree. The thrips was released in south Florida on 16 July 2019. Both insects can inhibit the growth and reproduction of Brazilian peppertree, but it is unlikely the thrips will persist in areas exposed to prolonged flooding because part of its life cycle occurs in the soil. For more information on these biological control agents, see Appendix Featured Creatures.

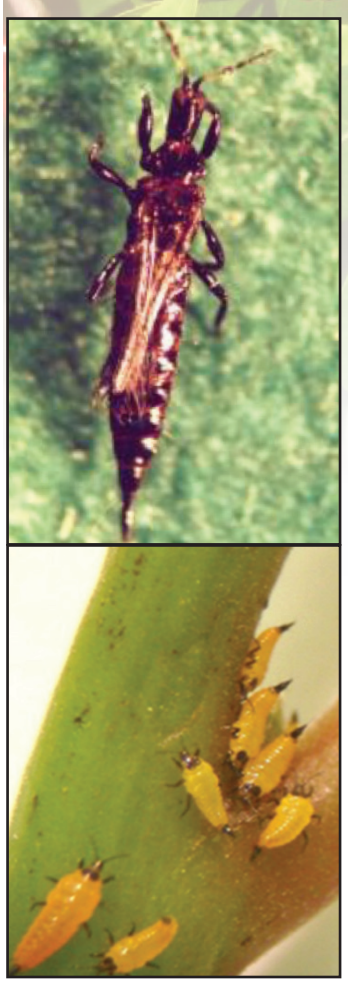
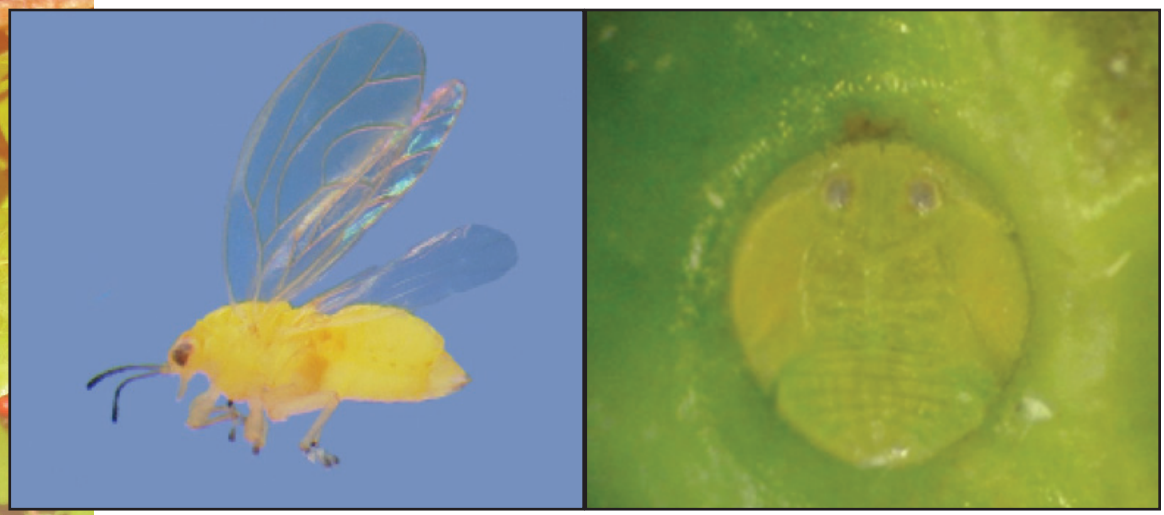


Figure 11. Brazilian peppertree thrips *Pseudophilothrips ichini*. (Photo credit: V. Manrique)



Figurew 12. Yellow Brazilian peppertree leaf galler *Calophya latiforces.* (Photo credit: R. Diaz)

Chemical (Herbicidal) Control

The use of herbicides is the most common and cost-effective method employed to date for controlling Brazilian peppertree (see Appendix, Brazilian Peppertree Control). Optimal performance of these herbicides depends on the application method (foliar, cut-stump, basal bark, and hack and squirt), the type of herbicide used, application rate and environmental conditions.

All herbicides MUST be applied according to label directions using appropriate protective gear. Glyphosate products are less effective when used alone in spring and early summer. In Florida, Brazilian peppertrees growing in aquatic systems should be treated only with glyphosate or imazapyr products approved for aquatic use.

Because only female plants produce seeds, the term "matricide" refers to selectively controlling reproductively mature female trees either chemically or mechanically. This approach focuses control efforts on stopping the production of new seeds, thus preventing seed dispersal by birds that are primarily responsible for spreading the plant. In situations where time, funds and availability of herbicides are limiting factors, treating only female plants is recommended.

Figure 13. Up to 98% control of Brazilian peppertree has been achieved with the herbicide imazapyr using a foliar application technique referred to as "lacing". This involves treating only half the foliage with a low volume sprayer. (Photo credit: E. Hanlon)

Figrure 14. Plants are cut down with a machete or chain saw and the stumps treated with one of several approved herbicides. It is essential to treat the cut stump within a few minutes of cutting. For a multi-stemmed species like Brazilian peppertree, all of the individual cut stumps must be treated for maximum effect. (Photo credit: S. Enloe)

Figure 15. The hack and squirt technique involves making a single hack per stem with a sharp machete and applying 0.5 or 1 ml of aminocyclopyrachlor to the cut. (Photo credit: S. Enloe)

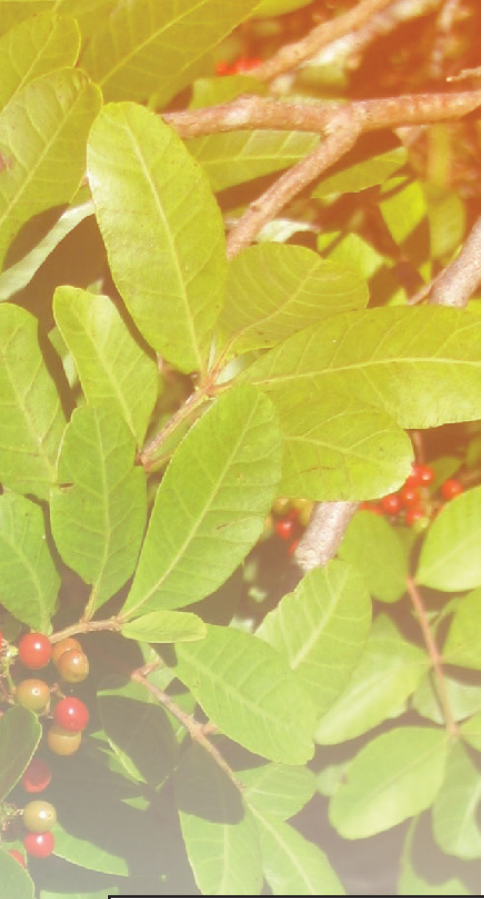


Figure 16. For the basal bark treatment, an oil soluble herbicide can be applied in an oil carrier to the entire circumference of each stem to a height of 12-18". Oil based products can weaken spray tank seals causing the equipment to fail to pressurize when not thoroughly cleaned. (Photo credit: S. Enloe)

GLOSSARY

Allelopathy	Chemical inhibition of one plant by another, due to the release into the environment of substances acting as germination or growth inhibitors.
Biocontrol	Use of living natural enemies to control pests.
Dioecious	Female and male flowers occur on different plants (i.e., there are separate male and separate female Brazilian peppertrees).
Distribution	Geographical range in which the plant occurs.
Herbicide	EPA approved chemical compounds that kill weeds.
Herbivore	An organism that feeds on plants.
Hybrid vigor	An increase in characteristics (size, growth rate, fertility, and yield) of a hybrid organism over those of its parents.
Integrated Pest Management (IPM)	An ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and nontarget organisms, and the environment (UC IPM definition).
Natural enemy	Collective term for parasitoids, pathogens, predators, and herbivores that inflict mortality on a population of a species.

ACKNOWLEDGEMENTS

We thank past and current members of the Brazilian Peppertree Task Force of the Florida Exotic Pest Plant Council for their valuable contributions to the integrated management of Brazilian peppertree. We also acknowledge the dedication and assistance of the faculty and staff of the University of Florida and collaborating research institutions in South America. Finally, we thank the South Florida Water Management District, the Florida Department of Environmental Protection, and the Florida Industrial and Phosphate Research institute for supporting the management of Brazilian peppertree in Florida.

FOOTNOTE

Regarding the use of glyphosate products in Florida, in December 2017 the EPA "concluded that glyphosate is not likely to be carcinogenic to humans". Therefore, UF/IFAS supports the safe use of glyphosate products until further review despite recent litigation efforts in California and elsewhere. EPA is scheduled to publish its proposed interim registration review for glyphosate in 2019.

RESOURCES FOR MORE INFORMATION

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- Sheley, R.L. and M.J. Pinella. 2001. Incorporating biological control into ecologically based weed management, pp. 211-228. In E. Wajnberg, J.K Scott and P.C. Quimby (eds.), Evaluating Indirect Ecological Effects of Biological Control.

The following are excerpts from UF IFAS Extension publications. They can be located online at:

- http://entnemdept.ufl.edu/creatures/beneficial/Calophya_latiforceps.htm
- http://entnemdept.ufl.edu/creatures/BENEFICIAL/Pseudophilothrips_ichini.html
- https://edis.ifas.ufl.edu/pdffiles/AA/AA21900.pdf

Common name: yellow Brazilian peppertree leaf-galler (suggested common name)
Scientific name: Calophya latiforceps Burckhardt (Insecta: Hemiptera: Calophyidae: Calophyinae)

Introduction

In the late 1970s, Brazilian peppertree, Schinus terebinthifolia Raddi (Sapindales: Anacardiaceae), was targeted for classical biological control in Florida because its invasive properties (see Host Plants) are consistent with escape from natural enemies (Williams 1954), and there are no native Schinus spp. in North America. The lack of native close relatives should minimize the risk of damage to non-target plants from introduced biological control agents (Pemberton 2000).

Several exploratory surveys for natural enemies of Brazilian peppertree have been conducted in South America (Hight et al. 2002, Cuda et al. 2006, McKay et al. 2009, Wheeler et al. 2016). In 2010, Calophya latiforceps Burckhardt, a new species of leaflet galling psyllid we are calling the yellow Brazilian peppertree leaf-galler **(Figure 1)**, was discovered attacking Brazilian peppertree in the northern state of Bahia, Brazil (Burckhardt et al. 2011).

Figure 1. Leaves of Brazilian peppertree, Schinus terebinthifolia, attacked by developing nymphs Calophya latiforceps Burckhardt. Photograph by Rodrigo Diaz, LSU AgCenter, Baton Rouge, LA.

The genus Calophya Löw is a predominantly New World, Oriental and East Palaearctic genus of 59 described species that are mostly associated with Anacardiaceae and other Sapindales. Among the psyllids developing on Schinus, there are 14 described Calophya species, which all induce galls (Burckhardt and Basset 2000). These authors showed that several Calophya spp. are monophagous, meaning they are restricted to a single host plant species.

Distribution

Calophya latiforceps has been collected from only a few localities in northeastern Brazil in the Bahia state. **(Figure 2)** (Burckhardt et al. 2011).

Figure 2. Distribution of *Calophya latiforceps* Burckhardt. Map produced by Abhishek Mukherjee, Indian Statistical Institute, Kolkata, India.

Description

Eggs: Eggs are laid along the margins and veins of new leaf flushes. Newly laid eggs are oblong in shape, white in color (< 3 days old) and turn black before nymphal hatching (Figure 3). Egg length is probably similar to that of Calophya terebinthifolii Burckhardt & Bassett, which is 0.212 ± 0.002 mm (Christ et al. 2013).

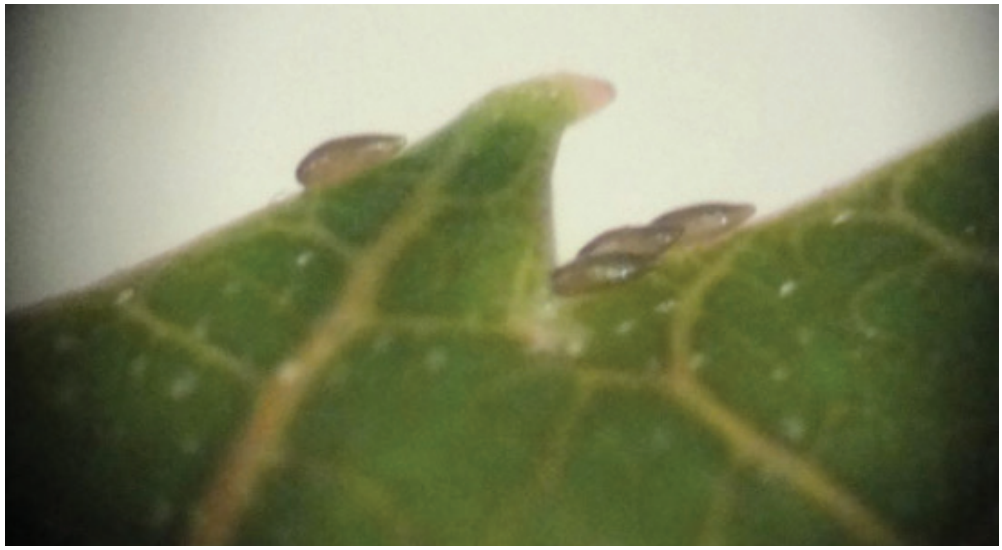

Figure 3. Eggs of *Calophya latiforceps* Burckhardt. Photograph by Rodrigo Diaz, LSU AgCenter, Baton Rouge, LA.

Nymphs: The first instar nymphs are often referred to as crawlers. Subsequent instars are not mobile, they are bright yellow and secrete waxy droplets **(Figures 4)**. When removed from the leaf, the fifth instar resembles a half-sphere. Length and width of the 5th instar are 0.82 mm and 0.79 mm, respectively.

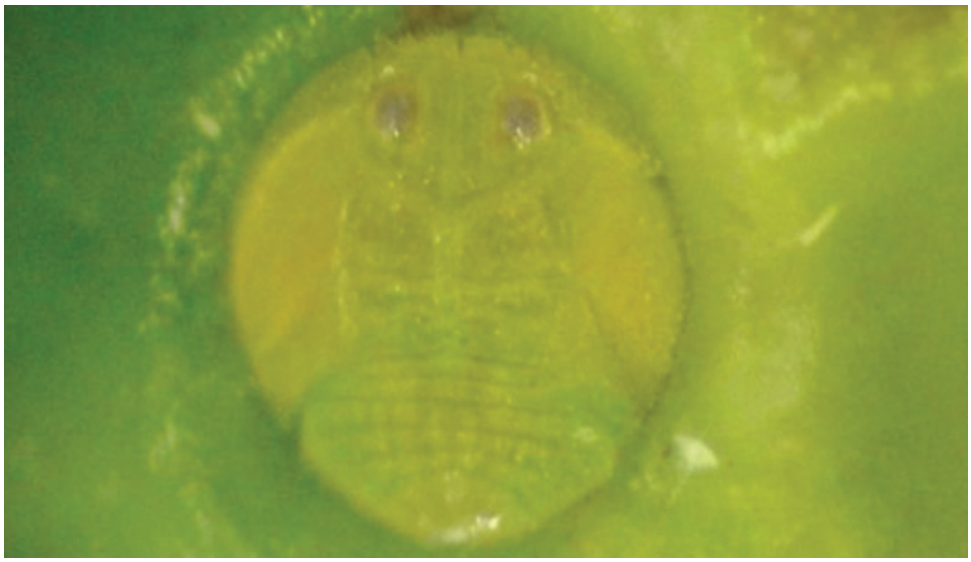

Figure 4. Late instar nymph of *Calophya latiforceps* Burckhardt. Photograph by Rodrigo Diaz, LSU AgCenter, Baton Rouge, LA.

Adults: Adults are bright yellow and are found on new flushes of Brazilian peppertree. Females are larger in size than males; 1.59 ± 0.01 mm in length compared to 1.48 ± 0.01 mm. The eyes are greyish in color. The antennae are dirty yellowish basally and gradually become darker towards the apex. The tibiae and tarsi are greyish brown. The forewing has yellow or light brown veins, and the membrane is colorless and transparent. The sex of the adults can be distinguished by the shape of the tip of the abdomen, which is pointed in females **(Figures 5 and 6).**

Figure 5. Male of *Calophya latiforceps* Burckhardt. Photograph by Rodrigo Diaz, LSU AgCenter, Baton Rouge, LA.

Figure 6. Female of *Calophya latiforceps* Burckhardt. Photograph by Rodrigo Diaz, LSU AgCenter, Baton Rouge, LA.

Life Cycle and Biology

According to Diaz et al. (2014a), newly emerged adults are pale green in color and remain inactive for ~30 minutes on the leaflet from which they emerged. Adults remain on the plant during the cooler hours of the morning or late evening. Adults are poor fliers and move < 30 cm in random jumps. Long distance dispersal is presumably aided by wind currents. Groups of adults feed and search for mates on new leaf flushes, and copulation occurs a few hours after emergence; mating lasts 3 to 5 min. Adults live on average 9.3 ± 0.6 d (range 6.3 to 12 days).

Females oviposit on new leaflets (<2 cm long); eggs are laid individually along the leaflet margins and veins as well as along leaf petioles. After eclosion, first instars (crawlers) walk slowly on the upper side of leaflets and settle after a couple of hours. Most of the crawlers settle on the same leaflet where the eggs were laid.

Twenty-four hours after settling, a yellow halo in the plant tissue appears around the nymphs. Susceptible plants respond to nymphal feeding by forming a slight depression whereas resistant plants respond by killing the plant cells at the point of feeding **(Figure 1)**. This hypersensitive response was noticeable two or three days after nymphs settled and resulted in 100% mortality of the psyllids (Diaz et al. 2014a). Surviving nymphs increase in size rapidly as they mature. There are five instars and total developmental time to the adult stage ranges from 35 to 53 days (average 38.6 days).

Host Plants

The only known host plant for *Calophya latiforceps* Burckhardt is Brazilian peppertree, Schinus terebinthifolia. Quarantine host range studies on 99 plant taxa (species, varieties and hybrids) from 43 families showed that the psyllid was only able to colonize Brazilian peppertree (Diaz et al. 2014b). On average, 77% of Florida Brazilian peppertrees are susceptible to attack by Calophya latiforceps Burckhardt.

Brazilian peppertree is a perennial woody plant native to Brazil, Argentina, and Paraguay that has become one of the most invasive upland weeds in Florida (Cuda et al. 2006). Originally introduced to Florida in the 1840s as an ornamental (Mack 1991), it escaped cultivation in the 1950s (Morton 1978, Austin and Smith 1998), and invaded disturbed sites, natural communities, and environmentally sensitive areas such as the Everglades National Park (Ewel et al.1982). In central and south Florida, Brazilian peppertree occupies more than 2,833 km2 (Cuda et al. 2006, Manrique et al. 2013), and outcompetes native species by exhibiting fast growth, prolific seed production, and vigorous resprouting.

Brazilian peppertree tolerates a wide range of growing conditions including high salinity, moisture, and shade (Ewel 1979; Ewe and Sternberg 2005, 2007). In FY 2015 – 2016, the South Florida Water Management District spent over $2.6 million controlling Brazilian peppertree on district lands (Rodgers et al. 2017). Because of its severe environmental impacts, Brazilian peppertree is listed as a prohibited plant in Florida (UF/IFAS Assessment).

Economic Importance

Calophya latiforceps Burckhardt is highly host specific, and is capable of decreasing photosynthesis, inhibiting growth and inducing leaf abscission (Prade et al. 2016). Nymphal feeding habits are detrimental to the plant whereas the damage by the adults is insignificant. Injury to the plant results from the injection of toxic saliva, which causes toxemia in the host. Psyllid damage may be localized and/or systemic and may manifest as necrosis, leaf rolling and changes in leaf color, withering, and gall formation (Hodkinson 1974). *Calophya latiforceps* Burckhardt was recommended for release in Florida for biological control of Brazilian peppertree in April 2016. If the insect establishes in Florida post-release, it will contribute to the sustainable management of Brazilian peppertree, while posing minimal risk to non-target species.

Common name: Brazilian peppertree thrips (suggested common name) Scientific name: Pseudophilothrips ichini (Hood) (Insecta: Thysanoptera: Phlaeothripidae)

Introduction

The Brazilian peppertree thrips, *Pseudophilothrips ichini* (Hood) (Thysanoptera: Phlaeothripidae), is an insect native to Brazil **(Figure 1)**. This species has been studied for over 20 years as a potential biological control agent of Brazilian peppertree, Schinus terebinthifolia Raddi (Sapindales: Anacardiaceae), in Florida (Cuda et al. 2008, Manrique at al. 2014, Wheeler et al. 2016a, b). Host specificity experiments demonstrated that *Pseudophilothrips ichini* has a limited host range (Cuda et al. 2008, Cuda et al. 2009, Wheeler et al. 2017) and can cause a severe reduction of Brazilian peppertree biomass (Manrique at al. 2014).

Figure 1. *Pseudophilothrips ichini* Hood adults on *Schinus terebinthifolia Raddi.* Photograph by Carey R. Minteer, University of Florida, Fort Pierce, FL.

Distribution

Pseudophilothrips ichini currently is concentrated in eastern Brazil, overlapping some of the areas of distribution of Brazilian peppertree, as documented by Wheeler et al. (2016b, 2017) **(Figure 2)**. *Pseudophilothrips ichini* was recommended to be released in Florida in 2016 by the Technical Advisory Group (TAG). Insects were first released in Florida in July 2019 in Saint Lucie, Collier, and Broward counties.

Figure 2. Distribution of Brazilian peppertree thrips, *Pseudophilothrips ichini* Hood and its primary host plant *Schinus terebinthifolia* Raddi in Brazil. Map produced by Lyndall C. Brezina, adapted from Wheeler et al. (2016b), University of Florida, Gainesville, FL.

Using data from cold tolerance experiments, Manrique et al. (2014) predicted that *Pseudophilothrips ichini* can potentially establish in the southeastern USA, Arizona, California, and Texas, overlapping some of the areas where Brazilian peppertree is present. **(Figure 3)**.

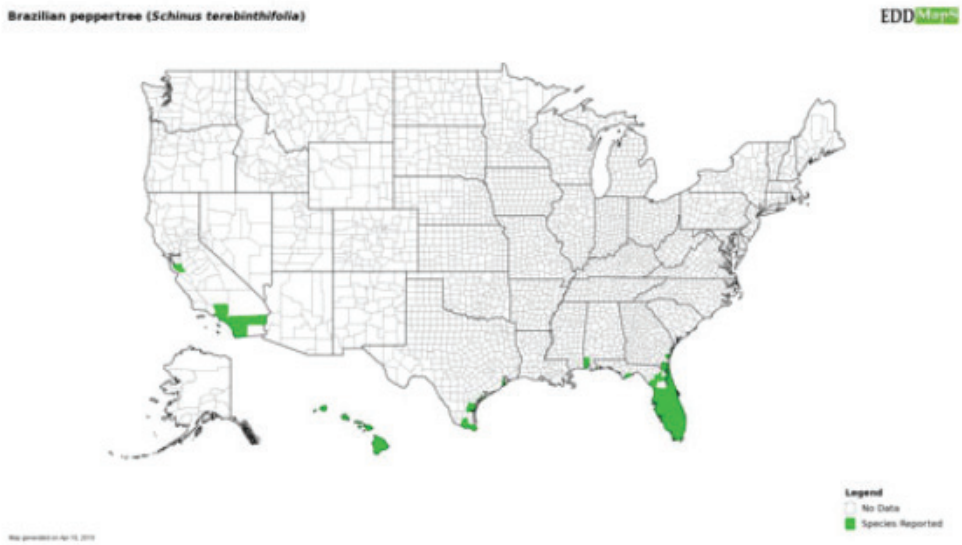

Figure 3. *Schinus terebinthifolia* Raddi distribution in North America. Map from the Center for Invasive Species and Ecosystem Health, EDDMaps, University of Georgia, GA.

Description

Eggs: Pseudophilothrips ichini adults lay eggs on leaflet blades and pedicels of new growth tissues of Brazilian peppertree. Eggs are 0.02 inches (0.4 mm) in length, ovoid and golden in color (Figure 4) (Cuda et al. 2008).

Figure 4. Egg of the Brazilian peppertree thrips, *Pseudophilothrips ichini* Hood. Photograph by Nick Silverson, USDA-ARS.

Larvae: *Pseudophilothrips ichini* has two larval instars. The first larval instar is yellow or light orange in color and is 0.03 inches (0.7 mm) in length **(Figure 5, A)**. The second larval instar is similar in color to the first larval instar but is 0.04 inches (1.0 mm) in length **(Figure 5, B)**. Besides body size, the second larval instar can be differentiated from the first by the presence of two horizontal lines on the last few segments of the body (Cuda et al. 2008, Wheeler et al. 2016b).

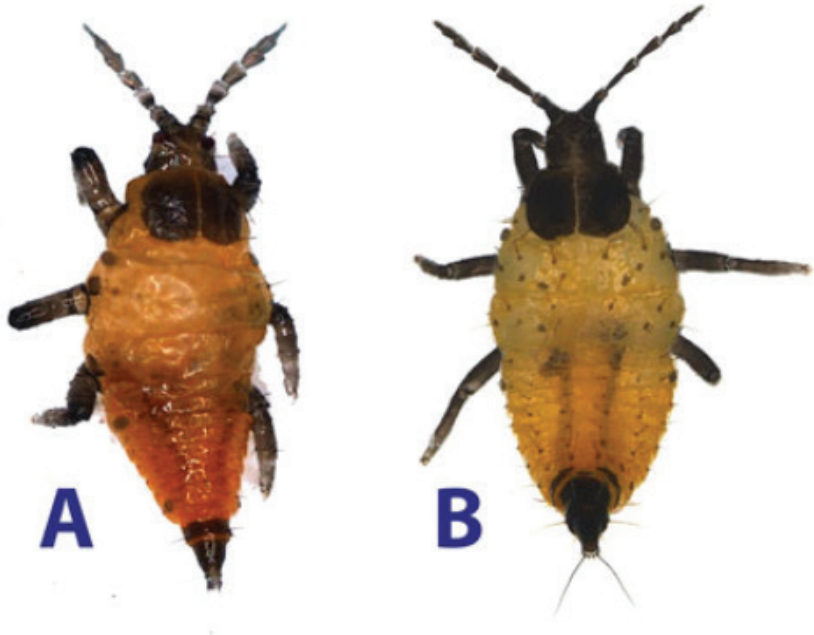

Figure 5. Larvae of Brazilian peppertree thrips, *Pseudophilothrips ichini* Hood. A: first larval stage and, B: second larval stage. Photograph by Nick Silverson, USDA-ARS.

Pupae: There are three pupal instars. The first stage called the pre-pupal instar is 0.6 inches (1.6 mm) in length, has short antennae and lacks wing buds **(Figure 6, A)**. The next stage called the first pupal instar is 0.07 inches (1.9 mm) in length and has small wing buds **(Figure 6, B)**. The final instar referred to as the second pupal stage is 0.8 inches (2.1 mm) in length, has longer antennae, and wing buds **(Figure 6, C)** (Wheeler et al. 2016b).

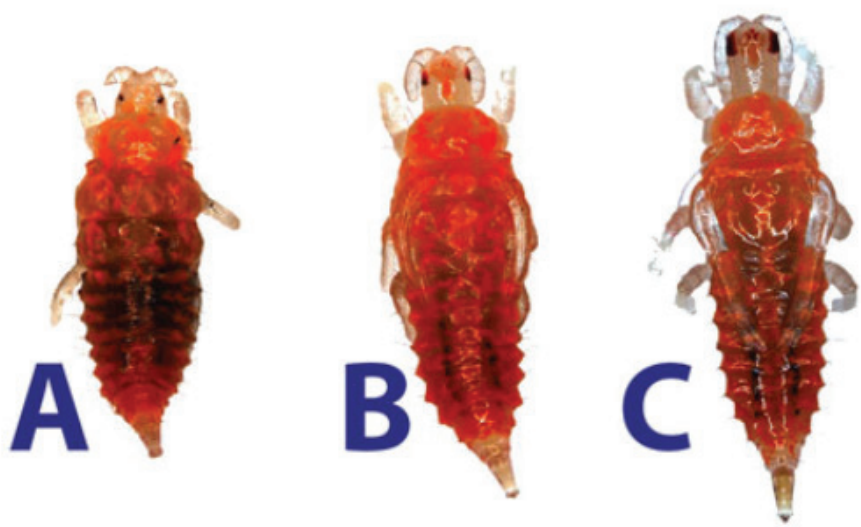

Figure 6. Pupal instars of Brazilian peppertree thrips, *Pseudophilothrips ichini* Hood. A: pre-pupal stage, B: first pupal stage, and C: second pupal stage. Photograph by Nick Silverson, USDA-ARS.

Adults: Adults are winged, small (0.08 to 0.12 inches) (2 to 3 mm), black, and sexually dimorphic **(Figure 7)**. Sexually dimorphic in this particular species means the adult males are relatively smaller than females (Cuda et al. 2009)

Life Cycle

Reproduction can be sexual or by arrhenotoky, which is the production of females from fertilized eggs and males from unfertilized eggs (Bowen and Stern 1966, Cuda et al. 1999, Cuda et al. 2008, Wheeler et al. 2016b). Developmental time from egg to adult ranges from 18 to 34 days and is temperature dependent. Adults and larvae feed on ruptures made on the cells with their rasping sucking mouthparts of Brazilian peppertree; pupation occurs in the soil and all pupal stages do not feed. Adults lay eggs on new growth and after 5 to 8 days, the larvae hatch. Larval stage lasts for 8 to 12 days, and pupal stage for 5 to 14 days (Manrique et al. 2014).

Hosts

Schinus terebinthifolia, the primary host of *Pseudophilothrips ichini*, is a perennial shrub native to Argentina, Brazil, Paraguay, and Uruguay (Barkley 1944) **(Figure 8)**. Introduced into Florida in the mid-1800s, Brazilian peppertree is considered one of the most aggressive invasive weed species in Florida (Morton 1978, Schmitz et al. 1997, Cuda et al. 1999, Cuda et al. 2006, Manrique et al. 2013). Native range observations and host-range tests show that *Pseudophilothrips ichini* is highly specific to Brazilian peppertree (Cuda et al. 1999, Cuda et al. 2009, Wheeler et al. 2016b).

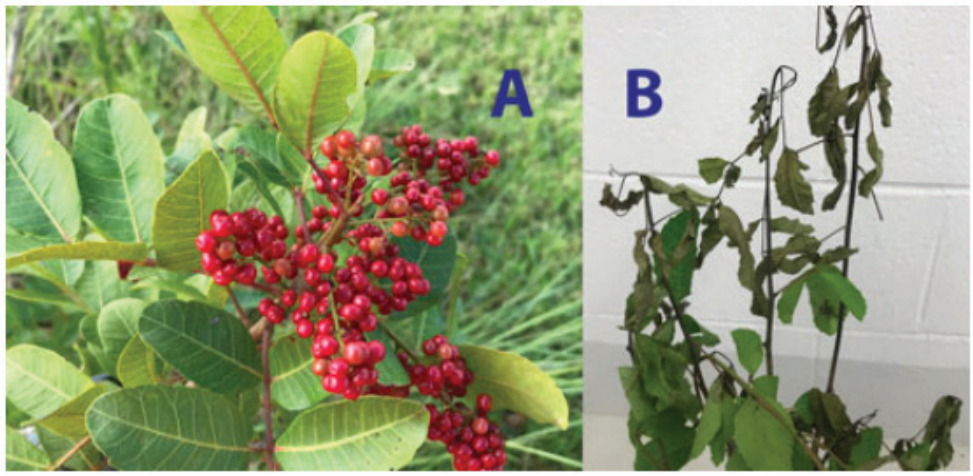

Figure 8. *Schinus terebinthifolia* Raddi plants. A: Plant with fruits, B: Plant damaged by *Pseudophilothrips ichini* Hood. Photographs by Patricia Prade, University of Florida, Fort Pierce, FL.

Wheeler et al. (2017) found that during no-choice host specificity experiments, *Pseudophilothrips ichini* was able to complete development and produce offspring on Brazilian peppertree (target species) and 10 other species (non-target species). Reproduction and survival on non-target species were reduced compared to reproduction and survival on Brazilian peppertree. The average number of adults produced on Brazilian peppertree was 124. However, 20.3 adults on average were produced from Peruvian peppertree, *Schinus molle L.* (Sapindales: Anacardiaceae), a non-native invasive ornamental in California, and on average 1.8 adults were produced on each of the other nine species tested. When given a choice between Brazilian peppertree and non-target species, *Pseudophilothrips ichini* was able to produce adult offspring on only four non-target species (*Schinus molle* L., *Pistacia vera* L., *Rhus glabra* L., and *Rhus sandwicensis* A. Gray). However, the number of adult offspring produced on Brazilian peppertree was on average 71, much higher than on non-target species that had an average of 0.9 adult offspring produced (Wheeler et al. 2017).

Economic Importance

Feeding by *Pseudophilothrips ichini* reduces Brazilian peppertree growth, reduces plant height, reduces the number of green stems produced, and causes flower abortion. More importantly, plants attacked by *Pseudophilothrips ichini* are slow to recover and less vigorous, with a reduction in the number of leaves and green stems, plant height, growth rate and limited fruit production when compared with non-attacked plants (Cuda et al. 1999, Manrique et al. 2014).

Brazilian peppertree management costs are high. In Fiscal Year 2015-2016, the South Florida Water Management District spent $2.6 million to control Brazilian peppertree (Cuda et al. 2017, Rodgers et al. 2017). *Pseudophilothrips ichini* was recommended for release by the United States Department of Agriculture - Technical Advisory Group in 2016 (Cuda et al. 2016). When the biological control program for Brazilian peppertree is implemented, *Pseudophilothrips ichini* is expected to reduce the impact of Brazilian peppertree on the environment, and potentially reduce the need for other control techniques.

UF IFAS Extension UNIVERSITY of FLORIDA

UF/IFAS PEER REVIEWED SS-AGR-17

Brazilian Peppertree Control[1]

K. T. Gioeli, S. F. Enloe, C. R. Minteer, and K. A. Langeland[2]

Common Name: Brazilian peppertree
Scientific Name: *Schinus terebinthifolia*
Family Name: Anacardiaceae (cashew or sumac family)

The invasion of many non-native species is harming Florida's natural ecosystems. Invasive plants are a major component of this phenomenon. Brazilian peppertree is one of the worst offenders (Cuda et al. 2006). This plant is encroaching upon nearly all terrestrial ecosystems in central and south Florida. Brazilian peppertree is the most widely distributed and abundant invasive species in the Florida Everglades, occupying 30,379 ha (Rodgers, Pernas, and Hill 2014). Brazilian peppertree is native to Brazil, Argentina, and Paraguay (Langeland et al 2008). It is thought to have been introduced to Florida in the 1840s as an ornamental plant (Figure 1) (Barkley 1944).

Figure 1. Brazilian peppertree with berries.
Credits: C. Minteer, UF/IFAS

Habitat

Brazilian peppertree is sensitive to cold temperatures, so it is more abundant in south Florida and protected areas of central and north Florida. Brazilian peppertree colonizes native tree hammocks, pine flatlands, and mangrove forest communities. It has also colonized the margins of countless roads, rights of way, levees, and canals throughout south and central Florida.

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2. K. T. Gioeli, county program Extension agent IV, UF/IFAS Extension St. Lucie County; S. F. Enloe, associate professor, Agronomy Department, UF/IFAS Center for Aquatic and Invasive Plants; C. R. Minteer, assistant professor, Department of Entomology and Nematology, UF/IFAS Indian River Research and Education Center; and K. A. Langeland, professor emeritus, Agronomy Department, UF/IFAS Center for Aquatic and Invasive Plants; UF/IFAS Extension, Gainesville, FL 32611.

Identification

The cotyledons (embryonic leaves) are simple; both the apex and the base have an obtuse outline. The margin is generally curved inward on one side. The first true leaves are simple with a toothed margin (Figure 2). The later leaves are compound.

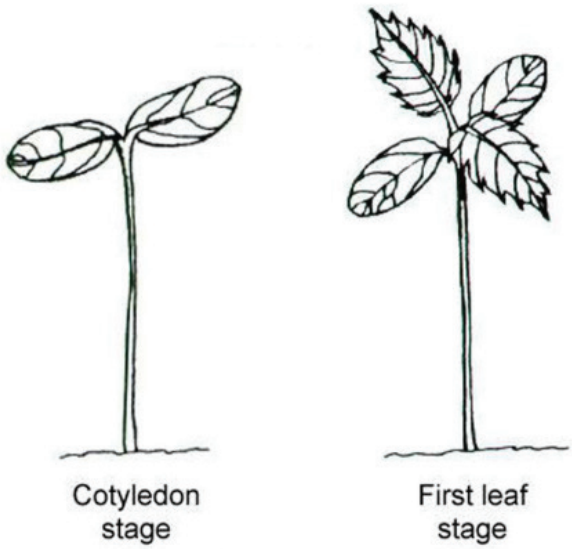

Figure 2. Brazilian peppertree seedlings.
Credits: UF/IFAS Center for Aquatic and Invasive Plants

Mature Plant

Brazilian peppertree is a shrub or small tree that grows to 10 m (33 ft) tall with a short trunk which is usually hidden in a dense head of contorted, intertwining branches. The leaves have a reddish and sometimes winged midrib (Figure 3), and three to 13 sessile, oblong or elliptic, finely toothed leaflets, 2.5 to 5 cm (1 to 2 in) long. Leaves smell of turpentine when crushed. The plants have separate male or female flowers. Each sex occurs on separate plants (Figure 5). The male and female flowers are white (Figure 4) and consist of five parts with male flowers having 10 stamens in two rows of five (Figure 5). Petals are 1.5 mm (0.6 in) long. The male flowers also have a lobed disc within the stamens. The fruits are found on female plants in clusters. These fruits are glossy, green, and juicy at first. They become bright red on ripening and grow to 6 mm (2.4 in) wide. The mature fruit is a small, bright red, spherical drupe (Langeland et al. 2008). Seeds measure 0.3 mm in diameter and are dark brown in color (UF/IFAS Center for Aquatic and Invasive Plants 2018).

Figure 3. Brazilian peppertree winged midrib.
Credits: C. Minteer, UF/IFAS

Figure 4. White flowers of the Brazilian peppertree.
Credits: C. Minteer, UF/IFAS

Figure 5. Brazilian peppertree fruiting and flowering.
Credits: UF/IFAS Center for Aquatic and Invasive Plants

Biology

Flowering occurs predominantly from September through November in Florida. Fruits are usually mature by December. Birds and mammals are the primary means of seed dispersal. The removal of the pulp around the seed by the digestive tract of birds increases the seed's germination rate (Dlamini, Zachariades, and Downs 2018). Brazilian peppertree's high seed viability combined with animal dispersal may help explain widespread colonization.

Chemical Control

Using Herbicides

Herbicides that aid in the control of Brazilian peppertrees are available (Table 1). Only herbicides recommended for Brazilian peppertree control should be used. It is illegal to use an herbicide in a manner inconsistent with the label's instructions; therefore, read the label carefully and follow the instructions. For more information on the individual plant treatments listed below, see EDIS document SSAGR-260, Herbicide Application Techniques for Woody Plant Control (http://edis.ifas.ufl.edu/ag245).

Cut Stump Application

Cutting down Brazilian peppertrees and treating the tops of the stumps with herbicide comprise one method of control. A saw should be used to cut the trunk as close to the ground as possible. Within five minutes, an herbicide containing the active ingredient glyphosate or triclopyr should be applied carefully to the thin layer of living tissue, called the cambium, which is just inside the bark of the stump. The best time to cut Brazilian peppertrees is when they are not fruiting. Seeds in the fruits can produce new Brazilian peppertrees. If fruiting Brazilian peppertrees are cut, care should be taken not to spread the fruits to locations where they might become established.

Caution: Brazilian peppertree produces a sap that may result in contact dermatitis in some people. When cutting trees, avoid the sap if possible. Individuals who are highly sensitive to the sap may also be affected simply by touching the leaves. Use proper protective gear when cutting the tree and applying the herbicides.

Basal Bark Herbicide Application

Brazilian peppertrees can be controlled using basal bark herbicide application. In this method, an application of an herbicide product containing the active ingredient triclopyr ester is applied to the lower part of the trunk in a 12- to 18-in band around the circumference of the tree. Further research is needed to confirm positive control results. It may take several weeks before the herbicide's effects become apparent. Defoliation, a lack of new shoots, and the presence of termites are indicators that the treatment has been successful. Basal bark treatments are most effective in the fall when Brazilian peppertrees are flowering due to the high level of translocation occurring within the trees. Fruiting occurs during winter, and Brazilian peppertrees that have been treated using a basal bark application may retain their fruit. The herbicide will move downward to the roots with the sap flow. In this situation, the area will need to be checked for seedlings on a regular basis.

Foliar Herbicide Application

Foliar herbicide application can be used on Brazilian peppertree seedlings and saplings. An herbicide containing triclopyr or glyphosate is applied directly to the foliage. Spray to wet, but not to the point of runoff. Good coverage is essential. Although both herbicides translocate throughout the plant, coverage on only one side of a tree with glyphosate or triclopyr will not completely kill it. Keep in mind that foliar applications require considerably more herbicide to control Brazilian peppertree. Take precautions to prevent herbicide drift injury to nearby plants.

Biological Control

For biological control agents to be approved for release in Florida, scientists must show that those agents are specific to Brazilian peppertree. Scientists have identified four insect species that may prove to be effective biological control agents: one thrips and three species of leaf-galling insects in the family Calophyidae. Both the thrips and the leaf gallers feed on new shoots. The Technical Advisory Group for Biological Control of Weeds recommended the thrips (Pseudophilothrips ichini) and one of the galling species (Calophya latiforceps) for release in 2016. Scientists from UF/IFAS expect authorization to release these insects in the future. As of June 2018, release permits for both of these species were in the process of being approved. Both of these species are host-specific to Brazilian peppertree and have been shown to damage the plant in laboratory studies (Prade et al. 2016; Manrique et al. 2014).