

**SPECIES: Schinus terebinthifolius**

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**INTRODUCTORY**

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Shirley Denton, Atlas of Florida Vascular Plants

**AUTHORSHIP AND CITATION:**

Meyer, Rachelle. 2005. Schinus terebinthifolius. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: <http://www.fs.fed.us/database/feis/> [2007, September 24].

**FEIS ABBREVIATION:**

SCHTER

**SYNONYMS:**

None

**NRCS PLANT CODE [108]:**

SCTE

**COMMON NAMES:**

Brazilian pepper  
 Brazilian peppertree  
 Christmas berry  
 Florida holly  
 aroeira

**TAXONOMY:**

The scientific name for Brazilian pepper is *Schinus terebinthifolius* Raddi (Anacardiaceae) [[8,54,55,108](#)].

The following varieties are recognized:

*Schinus terebinthifolius* var. *raddianus* Engl. [[8,54,55](#)]

*Schinus terebinthifolius* var. *rhoifolius* Engl. [[8,54](#)]

**LIFE FORM:**

Shrub-tree

**FEDERAL LEGAL STATUS:**

None


**OTHER STATUS:**

In Florida, Brazilian pepper is a serious pest and its sale is prohibited [[44,45,107](#)]. Brazilian pepper is included in the [California Invasive Plant Council's](#) [[15](#)] list of "species of greatest ecological concern."

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## DISTRIBUTION AND OCCURRENCE

**SPECIES:** *Schinus terebinthifolius*

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	<p>Vic Ramey, U of FL, IFAS-Center for Aquatic and Invasive Plants</p>

**GENERAL DISTRIBUTION:**

A native to Brazil, Argentina, and Paraguay [[17,39,49](#)], Brazilian pepper has established in many areas outside its native range, including Australia, South Africa, Mediterranean Europe, southern Asia, and the United States [[9,39](#)]. Although Brazilian pepper was introduced to the U.S. as an ornamental from the mid- to late 1800s [[5,39,70,80,116](#)], it did not establish outside of cultivation in Florida until the 1950s [[3](#)]. Brazilian pepper occurs throughout southern and central Florida, including islands off its coast [[60,80](#)]. According to unpublished surveys, over 700,000 acres (300,000 ha) in Florida are inhabited by Brazilian pepper [[43](#)], including occurrences in 91% of preserves in southern Florida [[12](#)]. In Texas, sporadic occurrences have been reported since the 1950s in Cameron and Hidalgo Counties. More recently, establishment of Brazilian pepper has also been reported in Aransas County,

Texas [64]. In Hawaii, Brazilian pepper was spreading and considered a range pest by the late 1940s. In 1991, communication with weed managers led to an estimate of 120,000 acres (50,000 ha) of moderate to dense stands of Brazilian pepper on the 6 largest Hawaiian islands [119]. In the early 1990s, Brazilian pepper began establishing outside cultivation in southern California [2,29,33,91] and it may occur outside cultivation in central California [33,91]. Brazilian pepper also occurs in Puerto Rico [39,107].

The distribution of the different varieties of Brazilian pepper in the United States is uncertain. As of 1982, Brazilian pepper in southern Florida had not been identified to variety level [39]. However, *S. terebinthifolius* var. *raddianus* is reported throughout Brazilian pepper's United States distribution [55] and an occurrence of *S. t.* var. *rhoifolis* was reported in Texas [64]. Barkley's [8] 1944 investigation of the *Schinus* genus reported cultivation of *S. t.* var. *raddianus* in Florida, and cultivation of *S. terebinthifolius* in California and Florida. Given the lack of distinction between varieties in the literature and the uncertainty of their relative importance across Brazilian pepper's range, variety will not be addressed further in this review.

[Plants database](#) [108] provides a distributional map of Brazilian pepper.

The following biogeographic classification lists are presented to demonstrate where Brazilian pepper is likely invasive. Since detailed distribution information is limited, the lists are based on reported distribution, associated species, and biological tolerance factors. Therefore, they are speculative and not exhaustive. There is a strong possibility that Brazilian pepper occurs in other communities within its range.

#### ECOSYSTEMS [47]:

FRES12 Longleaf-slash pine  
 FRES16 Oak-gum-cypress  
 FRES32 Texas savanna  
 FRES34 Chaparral-mountain shrub  
 FRES39 Prairie  
 FRES41 Wet grasslands

#### STATES/PROVINCES: [\(key to state/province abbreviations\)](#)

##### UNITED STATES

CA	FL	HI	TX	PR
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#### BLM PHYSIOGRAPHIC REGIONS [11]:

3 Southern Pacific Border  
 14 Great Plains

#### KUCHLER [61] PLANT ASSOCIATIONS:

K033 Chaparral  
 K035 Coastal sagebrush  
 K061 Mesquite-acacia savanna  
 K062 Mesquite-live oak savanna  
 K077 Bluestem-sacahuista prairie  
 K078 Southern cordgrass prairie  
 K079 Palmetto prairie  
 K080 Marl everglades  
 K090 Live oak-sea oats  
 K091 Cypress savanna  
 K092 Everglades  
 K105 Mangrove  
 K112 Southern mixed forest  
 K113 Southern floodplain forest  
 K115 Sand pine scrub

## K116 Subtropical pine forest

## SAF COVER TYPES [40]:

- 68 Mesquite
- 74 Cabbage palmetto
- 89 Live oak
- 100 Pondcypress
- 101 Baldcypress
- 104 Sweetbay-swamp tupelo-redbay
- 105 Tropical hardwoods
- 106 Mangrove
- 111 South Florida slash pine

## SRM (RANGELAND)COVER TYPES [98]:

- 205 Coastal sage shrub
- 206 Chamise chaparral
- 207 Scrub oak mixed chaparral
- 217 Wetlands
- 711 Bluestem-sacahuista prairie
- 719 Mesquite-liveoak-seacoast bluestem
- 728 Mesquite-granjeno-acacia
- 806 Gulf Coast salt marsh
- 807 Gulf Coast fresh marsh
- 808 Sand pine scrub
- 811 South Florida flatwoods
- 813 Cutthroat seeps
- 814 Cabbage palm flatwoods
- 816 Cabbage palm hammocks
- 817 Oak hammocks
- 818 Florida salt marsh
- 819 Freshwater marsh and ponds
- 820 Everglades flatwoods
- 822 Slough

## HABITAT TYPES AND PLANT COMMUNITIES:

Although Brazilian pepper can establish in intact communities, it is most often found in areas with some level of disturbance [39,46,58,119]. In these areas Brazilian pepper can form dense thickets that include few other species [37,39,58]. For instance, densities between 200 and 2,500 Brazilian pepper trees per hectare were recorded on abandoned farmland in southern Florida [39]. Species that have been reported on sites in southern Florida where Brazilian pepper reaches high coverage (>75%) include Guianese colicwood (*Myrsine floridana*), groundsel-tree (*Baccharis halimifolia*), and Virginia creeper (*Parthenocissus quinquefolia*) [58]. Species such as wax myrtle (*Morella cerifera*), silverling (*Baccharis glomeruliflora*), and grapes (*Vitis* spp.) often co-occur with Brazilian pepper on disturbed sites [3,37,39,58,77]. Herbaceous species that may inhabit Brazilian pepper stands in Florida are blue mistflower (*Conoclinium coelestinum*), Florida Keys thoroughwort (*Koanophyllon villosum*), and ferns such as leatherferns (*Acrostichum* spp.) and Kunth's maiden fern (*Thelypteris kunthii*) [3,58,77,104]. Brazilian pepper also frequently occurs with redbay (*Persea borbonia*), dahoon (*Ilex cassine*), cabbage palmetto (*Sabal palmetto*), and Florida poison tree (*Metopium toxiferum*) [3,37,39,58,104,115,117]. On disturbed sites in Florida and Hawaii, Brazilian pepper is often associated with other nonnative species such as guava (*Psidium guajava*), Australian-pine (*Casuarina equisetifolia*), and melaleuca (*Melaleuca quinquenervia*) [3,39,46,58,60,77].

Brazilian pepper is well documented in south Florida slash pine (*Pinus elliottii* var. *densa*) forests. In a pineland community in the Everglades, Brazilian pepper, wax myrtle, groundsel-tree, Florida poison tree, and Florida clover ash (*Tetrazygia bicolor*) formed a subcanopy under an open overstory of south Florida slash pine [37]. In a pineland dominated by Brazilian pepper (93 trees > 2 m tall/ 300 m<sup>2</sup>), 28 south Florida slash pine taller than 6 feet (2 m)

occurred in a 300 m<sup>2</sup> area and the understory was comprised mainly of Guianese colicwood, Brazilian pepper, wild guava (*Guettarda scabra*), pineland fern (*Anemia adiantifolia*), and pineland milkberry (*Chiococca parvifolia*) [69]. In 1969, Brazilian pepper seedlings were present in a National Key Deer Refuge pineland that had not burned since 1951 [4]. South Florida slash pine dominated the 12- to 55-foot (4-17 m) size class, while Florida silver palm (*Coccothrinax argentata*), Florida Keys blackbead (*Pithecellobium keyense*), mangroveberry (*Psidium longipes* var. *longipes*), and Key thatch palm (*Thrinax morrisii*) were the most abundant species in the smaller size classes [4]. Densities of 2 rare pine rockland species, pineland milkpea (*Galactia pinetorum*) ( $p=0.008$ ) and wedge sandmat (*Chamaesyce deltoidea* ssp. *adhaerens*) ( $p=0.048$ ), are negatively correlated with Brazilian pepper densities in pine rockland dominated by south Florida slash pine [85].

Brazilian pepper occurs in several other Florida forest types. Several species including Brazilian pepper, gumbo limbo (*Bursera simaruba*), tietongue (*Coccoloba diversifolia*), false mastic (*Sideroxylon foetidissimum*), lancewood (*Nectandra coriacea*), live oak (*Quercus virginiana*), Florida swampprivet (*Forestiera segregata* var. *segregata*), and cabbage palmetto occur in dredged hammocks in south Florida [3,23]. Brazilian pepper saplings were reported at a density of 40 per hectare in the understory of a laurel oak (*Quercus laurifolia*)/cabbage palmetto association dominated by laurel oak, island marlberry (*Ardisia escallonoides*), Seminole balsamo (*Psychotria nervosa*), cabbage palmetto, and the nonnative Java plum (*Syzygium cumini*) [96]. Common species on 2 cypress forests sites described by McJunkin [75] included baldcypress (*Taxodium distichum*), melaleuca, Peruvian primrose-willow (*Ludwigia peruviana*), Guianese colicwood, and Brazilian pepper. On one site, cabbage palmetto, wax myrtle, Australian pine, and icaco coco plum (*Chrysobalanus icaco*) were also present. On the other site, Brazilian pepper only occurred as an epiphyte above high water on baldcypress knees and buttresses. Additional associates on that site included pond apple (*Annona glabra*), coastal plain willow (*Salix caroliniana*), and wild banyantree (*Ficus citrifolia*), and the understory was comprised of Jamaica swamp sawgrass (*Cladium mariscus* ssp. *jamaicense*), toothed midsorus fern (*Blechnum serrulatum*), and inland leatherfern (*Acrostichum daneaefolium*) [75]. Brazilian pepper grew on root mounds of wind thrown baldcypress trees on a site that also included icaco coco plum, toothed midsorus fern, and leatherfern [3]. Long [68] described pond and river margin communities of southern Florida in which Brazilian pepper, buttonbush (*Cephalanthus occidentalis*), Carolina ash (*Fraxinus caroliniana*), water hickory (*Carya aquatica*), sugarberry (*Celtis laevigata*), redbay, and Virginia chain-fern (*Woodwardia virginica*) were common species. In wax myrtle- and Brazilian pepper-dominated forests on tree islands in the Everglades, the dominant species of the less frequently flooded forest were Brazilian pepper (cover 55%, frequency 96%), wax myrtle (cover 6%, frequency 48%), and lizard's tail (*Saururus cernuus*) (cover 2%, frequency 70%). The more frequently flooded forest contained less Brazilian pepper (cover 5%, frequency 63%) and included clustered bushmint (*Hyptis alata*) and Jamaica saw grass (*Cladium mariscus* ssp. *jamaicense*), in addition to those species that occurred on the less frequently flooded site [74]. Brazilian pepper can also invade mangrove swamps dominated by black mangrove (*Avicennia germinans*), red mangrove (*Rhizophora mangle*), or white mangrove (*Laguncularia racemosa*) [3,48]. Saltgrass (*Distichlis spicata*), cordgrass (*Spartina* spp.), melaleuca, and button mangrove (*Conocarpus erectus*) may also be present in these communities [3].

Seasonally wet grasslands and marshes in Florida can be inhabited by Brazilian pepper. Hairawn muhly (*Muhlenbergia capillaris*) dominated a site with scattered sawgrass, occasional cabbage palmetto, and small patches of saw-palmetto (*Serenoa repens*). Brazilian pepper, Florida poison-tree, dahoon, and silverling occurred infrequently on the site as seedlings ( $\leq 3$  feet; 1 m). Species such as Brazilian pepper, button mangrove, buttonbush, and melaleuca may form "shrub islands" among graminoids like cordgrass, saltgrass, and stout rush (*Juncus nodatus*) [3]. Shrubs such as Brazilian pepper, groundsel-tree, and wax myrtle occur in Jamaica saw grass-dominated marshes of Sanibel Island [111]. At a site in the transition zone between hammock and marsh, Brazilian pepper was dominant and occurred with common elderberry (*Sambucus nigra* ssp. *canadensis*), Florida strangler fig (*Ficus aurea*), silverling, and Peruvian primrose-willow [3].

In Hawaii, Brazilian pepper occurs in disturbed sites with other nonnative species including guava, melaleuca, strawberry guava (*Psidium cattleianum*), guineagrass (*Urochloa maxima*), and octopus tree (*Schefflera actinophylla*) [115,117,119]. In a melaleuca stand on Oahu, Brazilian pepper occurred in the understory with native Hawaiian species, such as pukiaawe (*Styphelia tameiameia*), 'ohi'a lehua (*Metrosideros polymorpha*), and Oahu false ohelo (*Wikstroemia oahuensis*) [115]. Wright and others [117] reported Brazilian pepper in a shrubland with natives such as white leadtree (*Leucaena leucocephala*) and uhaloa (*Waltheria indica*). Brazilian pepper invasion

"negatively affects" several populations of endangered native Hawaiian plant species including Hawaii lady's nightcap (*Bonamia menziesii*) and erect island spleenwort (*Diellia erecta*) [109].

Little is known about Brazilian pepper distribution in Texas and California. On a southeastern Texas site, Brazilian pepper occurred with honey mesquite (*Prosopis glandulosa*), agarito (*Mahonia trifoliolata*), Brazilian bluewood (*Condalia hookeri*), lime pricklyash (*Zanthoxylum fagara*), cactus apple (*Opuntia engelmannii*), Texas swampprivet (*Forestiera angustifolia*), and wax mallow (*Malvaviscus arboreus*) [64]. In southern California, Brazilian pepper was documented in 52% of canyon fragments studied, where vegetation was classified into 3 major types. One type was dominated by California sagebrush (*Artemisia californica*), black sage (*Salvia mellifera*), and eastern Mojave buckwheat (*Eriogonum fasciculatum*), and another by Nuttall's scrub oak (*Quercus dumosa*), laurel sumac (*Malosma laurina*), and lemonade sumac (*Rhus integrifolia*). Chamise (*Adenostoma fasciculatum*) stands characterized the last type. The extent to which Brazilian pepper occurred in each of these types was not reported [2].

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## BOTANICAL AND ECOLOGICAL CHARACTERISTICS

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- [SUCCESSIONAL STATUS](#)
- [SEASONAL DEVELOPMENT](#)



Dan Busemeyer, Illinois Natural History Survey

### GENERAL BOTANICAL CHARACTERISTICS:

This description provides characteristics that may be relevant to fire ecology, and is not meant for identification. Keys for identification are available (e.g. [8,49,64]).

Brazilian pepper is a nonnative, root-sprouting, evergreen shrub or tree that is capable of rapid growth [39,49,62,80]. Rockwood and Geary [93] reported a mean height of 15 feet (4.6 m) after 20 months in southern Florida. Brazilian pepper grows 10 to 43 feet (3-13 m) tall [39,49,52,64]. It typically has a multiple-stemmed trunk with most stems being less than 4 inches (<10 cm) dbh [39], although trees with trunks of up to 3 feet (1 m) dbh have been reported [80]. Brazilian pepper has dense spreading to erect branches that, due to a lack of self-pruning, can form thickets to ground level [39,52,62,80]. Young twigs are covered in smooth bark that becomes furrowed and somewhat scaly with age [62,64].

Brazilian pepper has alternate compound leaves with generally 7 (3-15) glabrous leaflets ranging from 1 to 4 inches (2-10 cm) long and 0.4 to 1.4 inches (1-3.5 cm) wide [49,52,64]. The oblong to elliptical leaflets are nearly or completely sessile [49,52,64,80].

Brazilian pepper's tiny flowers occur in axillary panicles up to 5 inches (15 cm) long on the distal portion of

branches [39,49,62,64,80]. The flowers have 5 petals between 1.5 and 2.0 mm long and 5 sepals about 0.5 mm long [49,62,64,80]. The globose fruits are drupes between 3.5 and 6.0 mm wide and contain a single seed [49,64,80].

Mycorrhizae have been shown to significantly ( $p < 0.05$ ) increase the size of Brazilian pepper in a greenhouse experiment [17], and mycorrhizae were present in Brazilian pepper samples collected from 2 southern Florida sites [77]. Aziz and others [6] observed 16% to 25% arbuscular mycorrhizae colonization of Brazilian pepper roots collected from southern Florida field sites.

Laboratory studies using Brazilian pepper plant extracts suggest the potential for allelopathy in Brazilian pepper [50,79,83], although field tests are not available. Lettuce (*Lactuca sativa*) [83], riggut brome (*Bromus rigidus*) [50], and romerillo (*Bidens alba*) [79] germination were reduced when treated with Brazilian pepper fruit or leaf extracts.

RAUNKIAER [92] LIFE FORM:

[Phanerophyte](#)

REGENERATION PROCESSES:

Brazilian pepper reproduces by seed and by root sprouting. It also sprouts from the stem, root crown, and roots following damage [114].

**Breeding system:** Brazilian pepper is mainly [dioecious](#) [39,62]. Of 395 flowering Brazilian pepper trees surveyed in Everglades National Park, 49.6% of trees were males and 50.4% were females. Fruiting trees that later produced male flowers were also observed. Whether the fruit originated from female or [perfect](#) flowers is unknown. However, Brazilian pepper with perfect flowers [39,64] and trees with flowers of each sex [39] have been observed.

**Pollination:** Insects pollinate Brazilian pepper flowers. Ewel and others [39] found that an average of 34.7% of exposed flowers produced fruit while less than 3% of enclosed flowers did. The major pollinator was a syrphid fly but species of dipterans, hymenopterans, lepidopterans, a hemipteran, and a coleopteran were also netted at Brazilian pepper trees. The syrphid fly, 2 wasps, and honeybees were observed on both male and female trees. Due to Brazilian pepper's sticky anthers and pollen, wind dispersal occurs rarely even across short distances [39].

### Seed production:

Brazilian pepper can produce large amounts of seed. Brazilian pepper can reproduce 3 years after germination. Ewel and others [39] determined the number of fruits on 2 inflorescences (1 from the outer canopy and 1 from the inner canopy) of 20 separate trees in Everglades National Park. Five trees were sampled early in the fruiting season, 5 late in the season, and 10 in the peak of the season. The total seed count for the 40 inflorescences was 10,415. Individual trees produced between 0 and 1,211 fruits on the 2 inflorescences. Each fruit contains 1 seed [39].

Brazilian pepper parasitized by the vine devil's gut (*Cassytha filiformis*) in southern Florida had significantly ( $p \leq 0.001$ ) fewer fruits than individuals nearby that were not parasitized. Parasitized Brazilian pepper had an average of 321.9 fruits in a 2.7 ft<sup>2</sup> (0.25 m<sup>2</sup>) area on the canopy, while the same area on nonparasitized trees averaged 1,119.8 fruits [14].

### Seed dispersal:

Brazilian pepper seed is dispersed by birds and small mammals and to a lesser extent by water and gravity [39]. Avian dispersal agents of Brazilian pepper seed include mockingbirds, cedar waxwings, and catbirds [39,80]. In southern Florida, when robins are abundant during the winter fruiting period, they may disperse more Brazilian pepper seeds than all other dispersers combined [39]. Less is known regarding mammal dispersal of Brazilian pepper seed. Raccoons are known to disperse Brazilian pepper seeds [39], and opossums, deer, and cattle may also disperse the seed [39,62].

Humans are the main disperser of Brazilian pepper. This occurs on many scales, including introduction into totally new areas as an ornamental, creation of disturbed areas facilitating spread [9,59,70], and improper disposal of garden waste leading to spread into neighboring areas [9].

Proximity to a seed source is likely an important factor influencing the spread of Brazilian pepper. In Queensland, Australia, percent and number of weed species were much greater in areas near residences than those further away, and observations suggested that dumping of garden waste was a major source of weeds, including Brazilian pepper [9]. Observational evidence suggests that the seed bank and/or proximity to a seed source was probably more important than several other site factors, such as differences in substrate or hydrology, in determining which species would dominate successional vegetation sites within the Hole-in-the-Donut area of Everglades National Park [58]. In addition, seed traps in Brazilian pepper-dominated forests captured more Brazilian pepper seeds than those in other habitats [39]. Brazilian pepper's phenology may influence its successful dispersal by frugivores, since there are fewer species fruiting when Brazilian pepper fruits than during other times of the year. Mammal dispersal may provide an advantage to Brazilian pepper seed due to the high nutrient content of their scat [39].

### Seed banking:

Brazilian pepper seeds are relatively short-lived. In a greenhouse investigation, no Brazilian pepper seeds sprouted from soil or litter samples taken from under female Brazilian pepper in southeastern Queensland collected just before fruiting began. In a field experiment, viability of seeds decreased fairly rapidly, with little germination of seeds with their exocarp removed occurring 21 weeks after sowing. Seeds that were left in the fruit remained viable for slightly longer, with 15% of seeds in buried fruits and 2.9% of seeds in surface sown fruits viable after 26 weeks [88]. In seed introduction experiments in Florida, less than 0.05% of Brazilian pepper seeds placed in field plots were viable after 5 months and by 6 months no Brazilian pepper seeds germinated [39].

### Germination:

The timing of Brazilian pepper germination in laboratory and field environments has been investigated. In laboratory studies most germination takes place within 30 days [39,82,83,88], and no germination after about 55 days occurred in a greenhouse experiment [39]. Seeds buried in commercial potting mix and grown outdoors in southeast Queensland began emerging 8 weeks after sowing [88]. Field studies in southern Florida indicate that germination of Brazilian pepper seeds begins to decline 30 days after planting on most sites [88].

Several factors, including scarification or exocarp removal, depth of burial, and exposure to heat, may affect Brazilian pepper seed germination.

The exocarp of Brazilian pepper seed inhibits germination. Several researchers found increased germination rates following exocarp removal [73,82,88]. In one study, less than 5% emergence resulted from whole fruits, while extracted seeds sown on the soil surface had a mean total emergence of 39.2% and those buried to 0.3 inch (1 cm) depth had 17.7% emergence [88]. In addition, Brazilian pepper seeds scarified with a metal sieve under running water had significantly ( $p < 0.05$ ) increased germination rates over unscarified seeds [82]. Acid scarification may also increase Brazilian pepper germination, although laboratory results do not report consistent increases (e.g. [39,83]). Seed source [39] and planting conditions [83] may affect germination rates of acid-scarified seeds.

Digestion of Brazilian pepper seed may increase germination compared to manually extracted seeds. Brazilian pepper seeds from Reunion Island in the Indian Ocean, digested by Red-whiskered bulbuls had significantly ( $p < 0.001$ ) higher germination (97%) in laboratory conditions than manually extracted seeds (68%) [73]. However, germination rate ( $p = 0.43$ ) and total germination percentage ( $p = 0.85$ ) of seeds collected from southeastern Queensland, digested by silvereyes and germinated in the laboratory, did not differ significantly from manually extracted seeds [88].

Little information is available regarding the effects of heat on Brazilian pepper seed. In a laboratory study, Brazilian pepper seeds heated to 158 °F (70 °C) for 1 hour did not germinate [83]. It is unclear how heat from fire may affect Brazilian pepper germination and viability.

Germination of Brazilian pepper seed is influenced by many site conditions including soil type, soil salinity, moisture conditions, disturbance, and associated species.

Soil type can influence Brazilian pepper seed germination. For instance, Brazilian pepper germination was significantly ( $p = 0.0002$ ) higher on marl soil (36%) than on peat (13%), both collected from Everglades National



Park [82]. However, percent germination of acid-treated Brazilian pepper seeds sown in greenhouse soil mix (10%) and sown in soil collected from bare ground in a southern Californian chaparral community (7%) was similar [83].

Germination and viability of Brazilian pepper seeds decline with increasing salinity in both field and laboratory experiments. Scarified fruits sown on filter paper exhibited decreasing germination with increasing salinity ( $p=0.0001$ ). Germination of Brazilian pepper seeds in 0% saline solution was 80%. Germination rate declined linearly with increasing salinity, with Brazilian pepper seeds in the 20% saline solution exhibiting 12% germination. Brazilian pepper seeds sown in marl and peat soils from Everglades National Park did not germinate when watered with 5%, 10%, or 15% saline solution in the laboratory. Similarly, germination in the field occurred only in ecotone vegetation where salinities were between 2% and 5% [82].

Mesic conditions are likely to result in increased Brazilian pepper seed germination. A laboratory experiment found a significantly ( $p=0.0002$ ) higher germination rate (37%) with a mesic watering regime, where the soil was always moist but never saturated, compared to dry and saturated conditions. In dry conditions, where soil was moist at time of watering but dry within 24 hours, germination rate was 20%. When the water level was maintained at the top of the soil surface (saturated conditions) germination rate was 16% [82]. Similarly, in another laboratory experiment, low humidity may have led to decreased germination rates (<10%) of both control and treatment groups compared to germination rates observed "under environmentally controlled conditions" (21%) [35]. In the field, a heavy, dry-season, rainfall event increased germination in drier areas but decreased germination in wetter, low-lying areas [39].

Site conditions such as disturbance and associated species may also influence Brazilian pepper germination in the field. In an ecotone association in southern Florida, Brazilian pepper germination was 50% in disturbed plots and 13% in undisturbed plots after 4 months [82]. In Everglades National Park, Brazilian pepper germinated in all the habitat types investigated, though there was substantial variation within and between sites. Percent germination in the field varied between <1% and >30% [39], with early successional sites having generally higher germination rates. In mature communities, Brazilian pepper germination and subsequent survival was highest in pineland and lowest in hammock vegetation. While Brazilian pepper seed germination was reduced by about 10% when exposed to Brazilian pepper exocarp extracts in the laboratory [83], allelopathic affects were not evident in the field as germination rates of over 100 Brazilian pepper seedlings emerging/m<sup>2</sup> per 15 days were recorded in associations dominated by Brazilian pepper [39]. Allelopathic potential for wax myrtle on Brazilian pepper germination was not evident in the laboratory; however, the low overall germination, likely due to low humidity, could have interfered with the ability to detect significant differences between treatments [35]. Field studies are needed to assess allelopathic potential of associated species on Brazilian pepper.

### **Seedling establishment/growth:**

Brazilian pepper seedling establishment and survival are influenced by moisture availability, salinity, light levels, and associated vegetation.

Brazilian pepper seedlings grow on sites with varying water availability, from areas that are rarely inundated to those that are flooded for several weeks [39]. Brazilian pepper seedlings (~ 1 year old) in treatments that were flooded to under 1 inch (1-2 cm) above soil level for 56 days exhibited 100% survival. After 20 days a 36% reduction in stomatal conductance and a 29% reduction in net photosynthesis were observed in flooded seedlings compared to control seedlings. In addition, flooded seedlings had significantly ( $p<0.01$ ) smaller root biomass [78]. Nilsen and Muller [84] demonstrate that Brazilian pepper seedlings are more drought tolerant than Peruvian pepper (*Schinus molle*) seedlings, a related species that established in California before Brazilian pepper. It took 6 to 7 days for 2 month-old Brazilian pepper seedlings to reach permanent wilting (when turgor was not recovered after exposure to 100% humidity). At permanent wilting, soil moisture content was 39.4% and seedlings had 11.1% moisture [84]. In the field either lack of water or flooding can be responsible for Brazilian pepper seedling mortality. In Florida, seedlings are susceptible to mortality during the dry period, which ends in June, and during summer flooding. On very wet sites survival of outplanted seedlings was between 30% and 50%. Some of the seedlings that died were completely submerged during this period. Rapid changes in water levels can also result in seedling mortality [39].

Brazilian pepper seedlings require no to low salinity for survival in the field. Seedlings 3 to 4 inches (8-10 cm) tall

were planted on 3 sites each containing 3 vegetation types: mangrove, herbaceous, and the ecotone between the two. Mortality of seedlings on sites with salinities of more than 5% was 100%. The greatest survival over 9 months, 89%, occurred on a disturbed ecotone plot with salinity between 2% and 5% [82]. However, in a greenhouse experiment Brazilian pepper seedlings exposed to salinities up to 15% survived. In addition, growth, resource allocation, and gas exchange parameters were not significantly ( $p \leq 0.05$ ) affected by slowly increasing salinity to 8% or 15% and then maintaining these levels for 1 month [38].

Brazilian pepper seedlings survive and grow in a wide range of light levels, but grow faster in full sunlight. Two-week-old Brazilian pepper seedlings assigned to 4 light treatments, ranging from 300 to 60  $\mu\text{E}/\text{m}^2/\text{sec}$ , had positive growth during a 12-week experiment. However, the total dry weight of seedlings in the 300  $\mu\text{E}/\text{m}^2/\text{sec}$  group was over 3.0 grams after 6 weeks, while it was less than 1.0 gram for seedlings in the 60  $\mu\text{E}/\text{m}^2/\text{sec}$  treatment [84]. In another greenhouse experiment, several Brazilian pepper seedling characteristics, including relative growth rate, carbon dioxide assimilation, and light saturated photosynthetic rates were all significantly ( $p \leq 0.05$ ) higher in 100% full sunlight than in 5% full sunlight. Relative growth of Brazilian pepper seedlings in full sunlight and partial shade (31% full sunlight) was typically about twice that of native Hawaiian species in the same treatment group. Despite decreased values of many parameters, Brazilian pepper survived and grew in 5% full sunlight [89]. Survival rates of naturally occurring Brazilian pepper seedlings were relatively high across several habitats of varying density in southern Florida. Brazilian pepper seedling survival over 22 months in dense habitats was over 25%, while in open habitats survival was nearly 100%. In the field Brazilian pepper seedlings are capable of increased growth when light levels increase. After 2 years, creation of canopy gaps in Everglades National Park resulted in Brazilian pepper seedlings that were over twice the height of control seedlings [39].

Investigations of Brazilian pepper invasibility by Ewel and others [39] suggest that young successional vegetation (vegetation less than 8 years old on sites that were previously farmed) provides optimum habitat for Brazilian pepper survival and growth. The highest survival rates (<5%) over approximately 9 months for seedlings arising from experimentally introduced seeds occurred in young successional vegetation. Survival of these seedlings in undisturbed and generally older successional communities were much lower. For example, no seedlings survived approximately 9 months in hammock vegetation and survival was less than 1% in other undisturbed communities and some older Brazilian pepper stands. Seedlings that were transplanted when 4 to 12 inches (10-30 cm) tall had higher survival rates across habitat types. On 8 of 10 sites of varying ages and vegetation community, these Brazilian pepper seedlings had survival of  $\geq 50\%$ . However, survival rates were still generally higher in young successional vegetation than mature communities. For instance, the 2 sites with survival below 50% were an older Brazilian pepper stand (>8 years; ~38%) and a pineland (20%) [39].

Brazilian pepper seedlings can grow quickly. Brazilian pepper seedlings grown in a greenhouse and adequately watered had relative growth rates of 1.12 g/g/wk between 1 and 2 months since germination [84]. Brazilian pepper seedlings that were 4 to 12 inches (10-30 cm) in height when transplanted into Everglades National Park reached reproductive maturity and a height of about 7 feet (> 2m) in approximately 2 years [39]. In another southern Florida site, seedlings planted on previously farmed land when 10 to 12 inches (25-30 cm) tall reached a mean height of 15 feet (4.6 m) after 20 months [93]. In a relatively open pineland habitat, which is a typically infertile type, 87% of Brazilian pepper seedlings had positive growth rates, and the average growth of all seedlings was 0.41 cm/month. The highest growth rate observed was 2 cm/month [69].

### **Asexual regeneration:**

Brazilian pepper forms root suckers which can form whole new plants. Damage to the plant apparently does not need to occur to trigger root sprouting [114]. Brazilian pepper can also sprout from above ground stems and root crown following damage [100,114]. Growth of sprouts can be rapid. For example, 2 years after cutting Brazilian pepper in Everglades National Park to less than 1 inch (1-2 cm), aboveground biomass was 4 times more than before cutting [100].

Season of cutting influences sprouting and the subsequent growth rate of Brazilian pepper. On 2 sites in Florida, cutting between June and October resulted in the majority of Brazilian pepper mortality. The following table shows percent mortality of Brazilian pepper cut to less than an inch (1-2 cm) above ground in each month of 1987 (typically  $n=12$ ; \* $n=11$ ).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Everglades National Park	0	0	8	0	0	25	8	25	33	17	0	0
Big Cypress National Preserve	0	0	0	0	0	18*	17	9*	0	33	0	8

Mean percent biomass recovery of cut Brazilian pepper in Big Cypress National Park was lowest, about 25% of the maximum recovery, for trees cut in June. Maximum recovery was less than 100% of original biomass over 2 years and occurred in Brazilian pepper cut in February. For Brazilian pepper in Everglades National Park, maximum recovery (>400% original biomass) also occurred for individuals cut in February but minimum recovery (<5% maximum recovery) occurred for those cut in August. Cutting a second time after 2 years did not result in substantially higher mortality, except for trees in Big Cypress National Preserve cut in June, which had 60% cumulative mortality [100].

#### SITE CHARACTERISTICS:

Disturbed sites are particularly susceptible to Brazilian pepper invasion [39,42,58]. In southern Florida, Brazilian pepper is common along roads, canals, and power lines [39]. It can form dense thickets on abandoned farmland [39,58]. Altered soil characteristics are thought to contribute to Brazilian pepper's success on these sites [27].

Brazilian pepper can occur on a wide range of sites but performs best in low-elevation, mesic areas [39,82]. In California, Brazilian pepper occurs in low-elevation canyons and washes [2,52]. In Hawaii, Brazilian pepper stands typically occur on comparatively dry, disturbed sites, at low elevation [22,119]. Although sensitive to freezing, Brazilian pepper sprouts after frost damage. Recovery 3 months after frost in Florida, lead Duever and others [34] to conclude that several nonnatives, including Brazilian pepper, were more cold tolerant than native species such as strangler fig and pond apple.

**Water:** Brazilian pepper occurs on a variety of sites, from seasonally flooded to mesic areas [39,62,89,105,118]. In Hawaii, it is most abundant on comparatively dry sites that receive between 40 and 70 inches (100-175 cm) of rain each year [119]. In southern Florida, the driest community Brazilian pepper occurred in was a hammock with a water table that was typically deeper than 16 inches (40 cm) below the soil surface. Large seasonal fluctuations in the water table occur on some southern Florida sites where Brazilian pepper occurs. For instance, on a site dominated by wax myrtle with clusters of Brazilian pepper, the water table in the dry season was 5.5 feet (1.7 m) below the soil surface, but rose to within 5 inches (12 cm) of the surface after a very heavy rain. In the wet season, some study sites were 80% flooded for up to 2 months [39]. Kruer and others [59] report that Brazilian pepper can survive flooding for up to 6 weeks. In an investigation of seasonal water use by Brazilian pepper, Ewe and Sternberg [36] found evidence that it is more tolerant of wet season soil saturation than Florida native species such as wax myrtle, groundsel-tree, Guianese colicwood, and white indigoberry (*Randia aculeata*). Brazilian pepper typically does not occur in areas flooded for long periods, including areas where historical water levels have been restored [18,27]. In southern Florida, very small declines in elevation can result in increased hydroperiods that may have detrimental effects on Brazilian pepper [27]. For example, a tree island with no Brazilian pepper was over 3 feet (1 meter) lower in elevation than a tree island dominated by Brazilian pepper, although several other factors were likely contributing to Brazilian pepper's occurrence [74]. Brazilian pepper has been observed occurring as an epiphyte on cypress trees above the high water level [75].

Water use efficiency of Brazilian pepper at different sites and times of year has been the topic of several studies (e.g.[37,105]). Results imply that Brazilian pepper has higher water use efficiency than native species studied in Hawaii and Florida. However, findings between studies vary. For example, in Hawaii, Brazilian pepper had higher water use efficiency in the dry season [105], while in Florida, higher water use efficiency was observed in the wet season [37].

Effects of water level on seedlings are discussed in [Seedling establishment/ growth](#).

**Soil:** Brazilian pepper occurs in a wide range of soil types. Langeland [62] reports Brazilian pepper occurring on poor to good fertility soils. In southern Florida the soil of a hammock community where Brazilian pepper occurred was comprised of a layer of organic matter approximately 8 inches (20 cm) thick over oolitic limestone. Brazilian

pepper occurred in a pineland community where the sparse soil consisted of limestone and organic debris [39]. Soils on sites with Brazilian pepper were extremely variable in Hawaii, including sites with thick fertile soils and those with lava flows less than 100 years old [119]. Peat soils may provide a less suitable substrate for Brazilian pepper establishment. See the [Germination](#) section for more detail.

Farming results in changes to soil properties that favor Brazilian pepper. In addition to changes in elevation that can influence the hydroperiod, farming increases soil nutrients and aeration. Total concentrations of copper, zinc, and phosphorus are higher on previously farmed sites of Hole-in-the-Donut in Everglades National Park. The correlation between Brazilian pepper leaf phosphorus and plant available phosphorus in the soil implies that increased levels of phosphorus facilitated Brazilian pepper colonization of the area [67]. Addition of superphosphate resulted in significantly ( $p < 0.05$ ) larger Brazilian pepper in a greenhouse experiment [17]. Characteristics such as soil volume, macro-pore space, and percentage of rock fragments also increased after farming in southern Florida. These changes can increase aeration and drainage [67,77]. The results of a soil removal experiment demonstrate that changes to soil due to farming can facilitate Brazilian pepper colonization [27].

For information on the effects of soil characteristics, such as type and salinity, on [germination](#), [seedling establishment](#), and [growth](#) see those sections.

**Elevation:** Brazilian pepper occurs primarily at low elevations. It occurs from sea level to over 2,300 feet (700 m) [39]. In California it is typically found below 700 feet (200 m) [52]. Brazilian pepper is most abundant below 2,300 feet (700 m) in Hawaii, but scattered plants can be found up to 3,000 feet (1,000 m) [89,117,119].

#### SUCCESSIONAL STATUS:

Brazilian pepper is primarily an early successional species. It can colonize areas within a few years of disturbance [3,30]. Older successional communities and mature native communities are generally less susceptible to Brazilian pepper colonization than young successional sites. Of mature communities, pinelands are at higher risk of Brazilian pepper establishment than wet prairies, while hammocks had the smallest risk of colonization among the mature communities investigated [39]. However, unlike many pioneer species, Brazilian pepper recruitment continues under a closed canopy, resulting in a self-maintaining stand [39,58]. In a disturbed area in southern Florida, Doren and Whiteaker [30] observed Brazilian pepper stands of varying ages and found that colonization progresses from low density, to high density of small stems (<10 cm basal diameter), to moderate density of larger-stemmed (>10 cm basal diameter) Brazilian pepper.

The effect of light on Brazilian pepper seedlings is discussed in the [Seedling establishment/ growth](#) section.

#### SEASONAL DEVELOPMENT:

In Florida, Brazilian pepper flowering is synchronous. The majority occurs in fall with a peak in October. Approximately 10% of Brazilian pepper flower again in April or May. Fruits typically ripen between December and March. Germination occurs between November and April, with the majority occurring in January and February [39,106].

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## FIRE ECOLOGY

**SPECIES:** *Schinus terebinthifolius*

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- [FIRE ECOLOGY OR ADAPTATIONS](#)
- [POSTFIRE REGENERATION STRATEGY](#)

#### FIRE ECOLOGY OR ADAPTATIONS:

Brazilian pepper can produce rapidly growing sprouts from aboveground stems, root crown and/or roots following fire [39,69]. See [Discussion and Qualification of Plant Response](#) in the Fire Effects section for more information.

Brazilian pepper may establish from sprouts or seed on recently burned sites [31,32,69,113]. For example, small

Brazilian pepper plants have been reported on pineland sites burned approximately every 5 years, although the origin of these plants was not discussed [69]. In addition, Brazilian pepper is well known for its ability to establish in disturbed areas (see [Site Characteristics](#)). Given the lack of Brazilian pepper germination in a laboratory experiment in which seeds were heated to 158 °F (70 °C) for an hour [83] and Brazilian pepper's short-lived [seed bank](#), the source of recruitment is more likely from sprouts, seeds from on-site trees that survived the fire, and seeds from trees in neighboring areas rather than from seeds in the soil seed bank. The time required for Brazilian pepper to establish on these sites is not known. More research is needed on the degree to which Brazilian pepper's establishment on these sites depends on fire severity, site characteristics, and the presence of Brazilian pepper in and around the site.

### Fire regime:

Information on fire regimes in which Brazilian pepper evolved is lacking. In North America, there are a wide range of fire regime characteristics in habitats where Brazilian pepper occurs. The majority of naturally occurring fires in Florida is ignited by lightning during the wet season from May to September [106]. In many areas where Brazilian pepper occurs, presettlement fire regimes have been dramatically altered due to fire exclusion and massive disturbances resulting from human settlement. It is unclear how presettlement fire regimes in invaded communities would affect Brazilian pepper establishment, persistence, and spread.

The ability of Brazilian pepper to colonize frequently burned areas seems to depend, to some extent, on site characteristics. Brazilian pepper continued to spread on several abandoned farmland sites in southern Florida despite multiple fires over a 5-year period [31]. However, there is evidence that Brazilian pepper establishment is limited in southern Florida pinelands subject to regular burning. Brazilian pepper has established in pineland sites outside of Everglades National Park that are not regularly burned, while on pinelands inside the park that are regularly burned, Brazilian pepper is relatively uncommon. Loope and Dunevitz [69] suggest the lack of Brazilian pepper on pinelands of Everglades National Park is due to a combination of regular burning and poor growing conditions slowing Brazilian pepper growth such that plants rarely reach a fire resistant size between burns.

In general, in ecosystems where Brazilian pepper replaces plants similar to itself (in terms of fuel characteristics), invasion may alter fire intensity or slightly modify an existing fire regime. However, if Brazilian pepper is qualitatively unique to the invaded ecosystem, it has the potential to completely alter the fire regime (sensu [13,25]). Brazilian pepper stands may inhibit the spread of fire under some conditions. Observers described decreased severity as an "extremely hot" prescribed fire in a pineland reached the ecotone with a Brazilian pepper stand [69]. Brazilian pepper stands burned patchily after use of delayed aerial incendiary devices. In addition, there was little fire spread into a Brazilian pepper stand under dry conditions even with the addition of gasoline [56]. It is likely that the decrease in herbaceous cover [30] and typically moist conditions (see [Site Characteristics](#)) associated with stands dominated by Brazilian pepper are at least partly responsible for the fire retardant characteristic of these stands [30,113].

The following table provides fire return intervals for plant communities and ecosystems where Brazilian pepper is likely to occur. For further information, see the FEIS review of the dominant species listed below. This list may not be inclusive for all plant communities in which Brazilian pepper occurs. If you are interested in plant communities or ecosystems that are not listed below, see the complete [FEIS Fire Regime Table](#).

Community or Ecosystem	Dominant Species	Fire Return Interval Range (years)
California chaparral	<i>Adenostoma</i> and/or <i>Arctostaphylos</i> spp.	<35 to <100
bluestem-Sacahuista prairie	<i>Andropogon littoralis</i> - <i>Spartina spartinae</i>	<10
coastal sagebrush	<i>Artemisia californica</i>	<35 to <100 [90]
mangrove	<i>Avicennia nitida</i> - <i>Rhizophora mangle</i>	35-200
Everglades	<i>Mariscus jamaicensis</i>	<10 [81]
sand pine	<i>Pinus elliottii</i> var. <i>elliottii</i>	25-45 [112]

South Florida slash pine	<i>Pinus elliottii</i> var. <i>densa</i>	1-15 [ <a href="#">81</a> , <a href="#">101</a> , <a href="#">112</a> ]
longleaf-slash pine	<i>Pinus palustris</i> - <i>P. elliottii</i>	1-4 [ <a href="#">81</a> , <a href="#">112</a> ]
mesquite	<i>Prosopis glandulosa</i>	<35 to <100 [ <a href="#">76</a> , <a href="#">90</a> ]
Texas savanna	<i>Prosopis glandulosa</i> var. <i>glandulosa</i>	<10 [ <a href="#">90</a> ]
oak-gum-cypress	<i>Quercus</i> - <i>Nyssa</i> -spp.- <i>Taxodium distichum</i>	35 to >200 [ <a href="#">81</a> ]
live oak	<i>Quercus virginiana</i>	10 to <100 [ <a href="#">112</a> ]
cabbage palmetto-slash pine	<i>Sabal palmetto</i> - <i>Pinus elliottii</i>	<10 [ <a href="#">81</a> , <a href="#">112</a> ]
southern cordgrass prairie	<i>Spartina alterniflora</i>	1-3 [ <a href="#">90</a> ]
baldcypress	<i>Taxodium distichum</i> var. <i>distichum</i>	100 to >300
pondcypress	<i>Taxodium distichum</i> var. <i>nutans</i>	<35 [ <a href="#">81</a> ]

\*fire return interval varies widely; trends in variation are noted in the species review

#### POSTFIRE REGENERATION STRATEGY [[103](#)]:

Tree with adventitious bud/root crown/soboliferous species root sucker

Tall shrub, adventitious bud/root crown

Small shrub, adventitious bud/root crown

Initial off-site colonizer (off-site, initial community)

Secondary colonizer (on-site or off-site seed sources)

## FIRE EFFECTS

**SPECIES:** [Schinus terebinthifolius](#)

- [IMMEDIATE FIRE EFFECT ON PLANT](#)
- [DISCUSSION AND QUALIFICATION OF FIRE EFFECT](#)
- [PLANT RESPONSE TO FIRE](#)
- [DISCUSSION AND QUALIFICATION OF PLANT RESPONSE](#)
- [FIRE MANAGEMENT CONSIDERATIONS](#)

#### IMMEDIATE FIRE EFFECT ON PLANT:

Typically, Brazilian pepper survives or is top-killed by fire [[31](#),[69](#)].

#### DISCUSSION AND QUALIFICATION OF FIRE EFFECT:

Plant size is an important factor influencing Brazilian pepper's ability to survive fire. Larger Brazilian pepper are more likely than smaller individuals to survive and sprout following fire [[31](#),[69](#)]. Fire-induced mortality of Brazilian pepper less than 20 inches (50 cm) tall is nearly 100% [[39](#),[69](#)]. However, 20% of Brazilian pepper seedlings less than 2 feet ( $\leq 60$  cm) transplanted to a pineland site survived and sprouted after a fall prescribed burn. The smallest surviving Brazilian pepper was 12 inches (30 cm) tall. In a separate fall prescribed burn, the shortest naturally occurring Brazilian pepper to sprout was 2 feet (58 cm) tall before the fire. While 30% of Brazilian pepper under 3 feet (<1 m) tall survived and sprouted after this prescribed burn, the lowest percentage of sprouting in larger size classes was 85%. The following table shows greater survival, as well as basal and top sprouting, in larger size classes after another fall prescribed burn in a pineland-Brazilian pepper ecotone in southern Florida; the numbers in parentheses are percentages [[69](#)].

Size class	n	Number with no green leaves	Number with some branches not fire killed	Number only top sprouting	Number only basal sprouting	Number both top and basal sprouting
< 2 m	7	2 (28.6)	1 (14.3)	0	4 (57.1)	1 (14.3)

2.5 m	35	0	7 (20.0)	1 (2.9)	22 (62.9)	8 (22.9)
5 m	13	2 (15.4)	3 (23.1)	1 (7.7)	5 (38.5)	5 (38.5)
Total	55	4 (7.3)	11 (20)	2 (3.6)	31 (56.4)	14 (25.5)

#### PLANT RESPONSE TO FIRE:

Brazilian pepper may continue to grow and establish even after repeated fires [32].

#### DISCUSSION AND QUALIFICATION OF PLANT RESPONSE:

Sprouts of fire-damaged Brazilian pepper can grow rapidly. Some sprouts grew to over 3 feet (1 m) tall within 6 months of a fall prescribed burn [69]. Average shoot growth was over 5 inches (14 cm) per month. Occurrence of sprouting increased in larger size classes after a different fall prescribed burn in a pine-Brazilian pepper ecotone near a southern Florida campground. Most large (> 3 feet (>1 m)) Brazilian pepper sprouted after prescribed burns, with percentages of sprouting individuals varying between about 85% and 100% [69].

In disturbed areas it is unlikely that fire has substantial negative effects on Brazilian pepper. In a previously farmed area within Everglades National Park, Brazilian pepper stem densities increased [32] and recruitment into many size classes continued [31] despite successful burning between 2 and 4 times in a 5-year period. Brazilian pepper density declined on 1 site, but this was most likely due to a long hydroperiod. Brazilian pepper density increased linearly on sites that were burned 4 times during the 5-year period, and exponentially on sites burned less frequently and/or less completely. Higher fuel production is suggested as the reason for some sites burning more frequently and/or completely [32]. It is possible that the site characteristics that allowed for increased fuel production and competition for resources with the plants producing these higher fuel loads contributed to the slower Brazilian pepper colonization rates on sites with more frequent and/or complete burns.

In native communities fire may impact Brazilian pepper more severely. In some areas Brazilian pepper establishment may be largely preventable when regularly burned. For instance, in Everglades National Park, pineland sites burned about every 5 years have few Brazilian pepper plants [69]. In addition, Brazilian pepper seed rain in a pineland site was reduced from 2.6 seeds trapped/m<sup>2</sup>/30 days to 0 seeds trapped/m<sup>2</sup>/30 days after a fall prescribed fire [39]. However, Wade and others [113] report Brazilian pepper on recently burned sites in southern Florida, and small Brazilian pepper plants have been reported on pineland sites burned approximately every 5 years [69]. Fire may also prevent dominance of shrubs in marshy areas. Although details regarding effects on Brazilian pepper were lacking, burning in marshes of Sanibel Island was reported to decrease woody species [111]. Koepf [56] also mentions use of fire to reduce Brazilian pepper occurrence in marshes and pinelands as "partially successful." Given the descriptive and circumstantial nature of this data, more research on fire's ability to prevent Brazilian pepper establishment in specific habitats is necessary.

Time of burning also influences the response of Brazilian pepper to fire. Snyder [100] demonstrated a seasonal trend in sprouting response for Brazilian pepper top-killed by cutting to less than an inch (< 2.5 cm) above ground. Most mortality occurred in Brazilian pepper cut between June and October (see [Asexual regeneration](#) for more details). This corresponds fairly well with the natural fire regime in Florida, in which the majority of fires are ignited by lightning during the wet season from May to September [106]. These fires also occur when fewer seeds are available (see [Seasonal Development](#)) to colonize recently burned areas. However, the wet conditions prevalent at this time of year may reduce the effect that fire has on Brazilian pepper. Direct investigation of the effect of seasonal burning on Brazilian pepper is needed to clarify the importance of contributing factors, such as physiological activity, prevailing site conditions, and abundance of Brazilian pepper seed.

#### FIRE MANAGEMENT CONSIDERATIONS:

**Postfire colonization potential:** Brazilian pepper can establish on at least some recently burned sites [69,113]. This is most pronounced in areas where Brazilian pepper invasion is well underway [31,32]. Research is needed to determine the factors influencing this ability. See the [Fire adaptations](#) and [Discussion and qualifications of plant response](#) sections for more detail.

**Fire as a control method:** The low flammability of Brazilian pepper stands [56,69], its postfire sprouting response [69], and its ability to establish on some recently burned sites [31,32,69,113] seriously limit the use of fire as a tool

for managing Brazilian pepper in southern Florida. For undisturbed sites with naturally short fire intervals and without abundant Brazilian pepper, repeated burning may prevent Brazilian pepper establishment and spread [56,69]. However this burning regime may conflict with other management objectives in these habitats. For example, in Everglades National Park pinelands, pine regeneration may require less frequent but more severe fires than the 5-year prescribed burn interval used to maintain Brazilian pepper at low levels [69]. Much more information is needed regarding the potential for prescribed fire as a tool for managing Brazilian pepper, especially in communities outside of Florida.

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## MANAGEMENT CONSIDERATIONS

**SPECIES:** *Schinus terebinthifolius*

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- [IMPORTANCE TO LIVESTOCK AND WILDLIFE](#)
- [OTHER USES](#)
- [IMPACTS AND CONTROL](#)

### IMPORTANCE TO LIVESTOCK AND WILDLIFE:

Birds and raccoons eat Brazilian pepper fruits [39] and insects eat Brazilian pepper leaves, seeds, and nectar [53,116,119]. Otherwise it is not widely eaten and may be toxic to some animals [80].

### Palatability/nutritional value:

Brazilian pepper fruits and leaves may be toxic to humans, young cows, and horses [80]. Some birds are known to eat the seeds regularly [39,73] and some have been reported to become intoxicated from consumption of Brazilian pepper fruits [80,116]. Domestic goats appear to eat Brazilian pepper without consequence [80] as do a variety of insects [53,116,119].

**Cover Value:** Brazilian pepper stands are used by many types of animals. Curnutt [24] reported 6 bird species nesting in Brazilian pepper in Everglades National Park. Red-winged blackbird, common yellowthroat, and eastern towhee densities were higher in a Brazilian pepper stand than densities previously reported for pineland or forest-edge habitats [24]. Conditions at given sites have been shown to have a larger impact on reptile and amphibian species occurrence than the vegetation association. On dry Brazilian pepper sites amphibians and reptiles trapped per check day was low (0.2) and similar to dry sites in hammocks, while on wet Brazilian pepper sites animals trapped per check day was high (2.3) compared to most wet sites in other habitats. Species common to disturbed habitats include the southern toad and the eastern narrow-mouthed toad [26]. Cotton mice and cotton rats were common rodents in a roadside area dominated by Brazilian pepper [86]. Florida panthers have even been observed in Brazilian pepper stands [71].

Despite use by a wide range of animals, the habitat Brazilian pepper stands provide is less suitable than native communities for many taxa. For example, in a short-term investigation of breeding birds in a Brazilian pepper stand, Curnutt [24] found lower total densities and lower diversity than found in studies of other habitats. Difference in methodology between studies may explain at least some of this discrepancy. Stout and others [104] summarize work by Auffenberg and Iverson that shows a positive correlation between gopher tortoise density and basal cover of grass. It is likely that dense stands of Brazilian pepper, with their low herbaceous cover [30], are poor habitat for gopher tortoises. Despite the relative unimportance of vegetation association, some species of reptile and amphibian including the Florida chorus frog and the ground skink were rarely or never captured in previously farmed areas in the Everglades, which are commonly dominated by Brazilian pepper. Nonnatives such as the brown anole lizard and the Cuban tree frog were most common in these habitats [26]. In addition, native insects have been shown to occur in smaller numbers in Brazilian pepper stands. Although a Brazilian pepper stand investigated by Clouse [19] had high diversity of ant species in leaf litter, 55% were nonnative and only 16 individuals of native ants were collected. Gould and Hammer [51] assert that butterflies native to pineland and hammock communities are threatened by the spread of Brazilian pepper due to replacement of host plants. Brazilian pepper is also likely to replace species used as food by white-tailed deer, which are important in the diet of Florida panthers [72].



#### OTHER USES:

Brazilian pepper has a variety of uses. In the U.S. it was originally introduced as an ornamental plant and is still sold for this purpose in some areas [5,39,70,80,116]. Brazilian pepper leaves and berries are used in decorations including Christmas wreaths. A resin of Brazilian pepper is reportedly used to preserve fishing lines and nets [80]. In addition, alkaloids from Brazilian pepper leaves have shown promise as a natural mosquito larvicide [1]

Brazilian pepper is a honey plant in Florida and Hawaii [7,119]. Although the honey is not considered table grade, it is used by bakers and its peppery flavor is appreciated in some areas [7,80]. In addition, the nectar and pollen of Brazilian pepper are considered an important fall food source for honeybees by Hawaiian apiarists [119].

In many areas extracts of Brazilian pepper are used as medicine. Morton [80] lists many possible medicinal uses of Brazilian pepper including use as an antiseptic, relief of respiratory problems, and treatment of arthritis and muscular and tendon complaints. Several investigations have shown Brazilian pepper to have antibacterial [20,99] and antifungal properties [94,95]. In addition, Velazquez and others [110] demonstrated antioxidant properties of Brazilian pepper methanol extracts. However, de Carvalho and others [28] found that extract from the bark of Brazilian pepper stems had positive mutagenic responses and they do not recommend its use for topical wounds.

#### Wood Products:

Although Brazilian pepper is not useful as a pulp wood, it is used in toothpicks, posts, railway sleepers, and construction [80].

#### IMPACTS AND CONTROL:

**Impacts:** Given the already limited distribution of rock pinelands in Florida [85] invasion by Brazilian pepper is a major concern, as is Brazilian pepper's negative impact on endangered Hawaiian species [109]. The degree to which Brazilian pepper can establish in these and other communities ([Distribution and Occurrence](#)) and its ability to replace native vegetation on disturbed sites ([Successional Status](#)), as well as the degree to which it affects animal species ([Cover Value](#)) and alters fuel characteristics ([Fire Regime](#)), have been addressed in previous sections of this review. A brief summary Brazilian pepper's possible allelopathic effects is included in the [General Botanical Characteristics](#) section.

**Control:** Reviews on the various methods of Brazilian pepper control are available [43,91]. Removal should be performed carefully, since direct contact with the sap causes serious rashes and people who are sensitive may have respiratory reaction to chemicals emitted by Brazilian pepper blooms [80]. It is important that results of control efforts are monitored [43] and soil disturbances and thinning of the canopy are minimized, especially during January and February when Brazilian pepper typically germinates [39,56,106].

Education and public participation have been important to several Brazilian pepper control initiatives. Zarillo [120] describes the creation of "pepper busting days," and Clark [18] acknowledges the importance of collaboration between public and private groups to form an effective Brazilian pepper control program on Sanibel Island.

Kruer and others [59] describe mapping Brazilian pepper using field surveys, and Lass and Prather [63] used a hyperspectral sensor to detect Brazilian pepper stands.

#### Prevention:

The most effective method for managing invasive species is to prevent their establishment and spread. Some methods of prevention include limiting seed dispersal, containing local infestations, minimizing soil disturbances, detecting and eradicating weed introductions early, and establishing and encouraging desirable competitive plants [97]. To decrease the seed source, commercial sale of Brazilian pepper was banned in Florida in 1990 [43].

Fire may also prevent Brazilian pepper establishment in some communities. See the [Discussion and Qualification of Plant Response](#) in the Fire Effects section for more detail.

#### Integrated management:

Combining methods for Brazilian pepper control is common practice. For instance, use of herbicide after cutting is a frequently used Brazilian pepper control technique [23,43,62]. Herbicide application after fire has also been suggested, but not tested [114]. More extensive integrated management including biological control is in the planning stages [43].

#### Physical/mechanical:

Manual removal of Brazilian pepper seedlings is recommended in natural areas, since use of heavy machinery creates an environment favorable to Brazilian pepper establishment. Heavy equipment is used in already disturbed areas, such as ditch banks [43]. Whether removed manually or with machinery, much of the roots must be removed or the plant will sprout [56,91]. Use of herbicide to reduce sprouting is common [43,62] and was successfully used, at least in the short-term, by Cunningham [23].

In some areas soil removal may be appropriate. In a previously farmed area within Everglades National Park, complete soil removal resulted in minimal re-establishment of Brazilian pepper. Removal of the disturbed substrate and slightly longer hydroperiod allowed for wetland plants to establish [27]. This method will only be useful in a narrow range of circumstances. It is likely that other techniques for restoring historic water regimes of southern Florida would be effective, given the intolerance of Brazilian pepper to flooding of over a few months (See [Site Characteristics: Water](#)).

Fire: See the [Fire Management Considerations](#) section of this summary.

#### Biological:

There is a proliferation of work investigating insect biological control agents for Brazilian pepper control. They have been studied in Hawaii since the 1950s [57] and in Florida since the late 1980s [10]. Releases in Hawaii do not appear to have resulted in substantial effects on Brazilian pepper [57,119]. Currently no biocontrol agents have been released in Florida. Hight and others [53] and Yoshioka and Markin [119] provide reviews of Brazilian pepper biological control. Cuda and others [21] summarize the results of recent tests on possible biological control agents.

Plants and fungi can also have detrimental impacts on Brazilian pepper. For instance, in a laboratory experiment Brazilian pepper given nutrient solution drained through pots containing wax myrtle had significantly ( $p < 0.01$ ) lower leaf production and stem weights than Brazilian pepper in the control, which were given nutrient solution drained through pots containing kidney beans (*Phaseolus vulgaris*). The experiment also provided circumstantial evidence that the Brazilian pepper in the wax myrtle treatment were more susceptible to disease [35]. In Florida field sites, Brazilian pepper parasitized by the vine devil's gut had significantly ( $p \leq 0.001$ ) lower leaf area and fruit production than Brazilian pepper nearby that were not parasitized [14]. Brazilian pepper is also host to several fungi, such as root rot, and Verticillium wilt [102].

#### Chemical:

Several investigations of herbicide effectiveness for Brazilian pepper control have been undertaken. Some of the most extensive investigations include a study of various herbicides and application times and methods in Queensland [87] and experiments addressing the most cost effective way to control Brazilian pepper stands with minimal impacts on neighboring mangroves in southern Florida [66]. The effect of season of application was demonstrated by a reduction in the effectiveness of basal bark applications between March and May, presumably due to inefficient translocation of the herbicide due to dry conditions [32]. The effectiveness and efficiency of matricide using chemical control was initially investigated by Ewel and others [39], and Doren and Whiteaker [30] concluded this method would not control Brazilian pepper. Reviews which provide information on chemical control are available (e.g. [43,91]).

#### Cultural:

Successful control of Brazilian pepper and other nonnative species was reported after control efforts were followed by planting of native hardwood swamp species in Boyd Hill Nature Trail, a park in St. Petersburg, Florida [16].

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