Solanum viarum

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AUTHORSHIP AND CITATION:
Waggy, Melissa A. 2009. Solanum viarum. 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/ [2010, January 21].

FEIS ABBREVIATION:
SOLVIA

NRCS PLANT CODE [96]:
SOV12

COMMON NAMES:
tropical soda apple
sodom apple
tropical soda-apple

TAXONOMY:
The scientific name of tropical soda apple is *Solanum viarum* Dunal (Solanaceae) [49,107].

SYNONYMS:
Solanum khasianum Cl. var. *chatterjeeanum* Sen Gupta [5]

LIFE FORM:

Forb-shrub

FEDERAL LEGAL STATUS:
Noxious weed [94]

OTHER STATUS:
Information on state-level noxious weed status of plants in the United States is available at Plants Database.

DISTRIBUTION AND OCCURRENCE

SPECIES: Solanum viarum

Many of the citations used throughout this section and the following sections resulted from collaborative research efforts at the University of Florida. Publications generated from the primary researchers at the University of Florida include original research [1,2,28,36,37,57,60,61,63,64,66,68,69,70,76,78,106,108] as well as reviews [26,27,65,71], conference proceedings [53,67], and extension literature [35,58,84,85]. Other reviews referenced within this text include the following publications, which summarize original research being conducted at the University of Florida but were not authored by any of the primary researchers: [23,24,25,34,52,74,102,103].

GENERAL DISTRIBUTION:
Tropical soda apple is native to Brazil, Paraguay, Uruguay, and Argentina [70,75]. It has been introduced in the southeastern United States, Africa, India, Nepal [70,75], and parts of tropical Asia [5]. It is considered a common weed in Honduras, Mexico, and West Indies [70]; however, it is unclear whether it is native or nonnative in these countries. It is expected to spread to other subtropical areas outside its current range [75].

In the United States, tropical soda apple is most common in Florida and has been reported in Texas, Arkansas, Louisiana, Mississippi, Alabama, Georgia, South Carolina, North Carolina, Texas, Tennessee, Pennsylvania [59,71,90,96], and Puerto Rico [13,71]. By 2002, researchers reported that tropical soda apple may have been eradicated from Louisiana, Tennessee, and Pennsylvania [25], so its occurrence in these states is uncertain. By 2007, many of the small infestations of tropical soda apple had been eliminated in Mississippi [11], so its spread may be on the decline in that state. Tropical soda apple was first collected in the United States in southern Florida between 1987 and 1988 and spread to other southeastern and mid-Atlantic states soon after [70,108]. Herbaria records show that it had spread to at least one county (Jasper County) in Texas by 2004 [90]. Tropical soda apple has the potential to invade the remaining southern states and some central states including Colorado, Kansas, and Illinois [78]. It may be able to overwinter as a perennial at or below 33° N latitude and may persist as an annual in cooler areas [11]. Plants Database provides a distributional map of tropical soda apple in the United States.

Tropical soda apple's introduction likely occurred through the unintentional movement of plants or seeds from South America, although its exact means of introduction is unclear [71]. The spread of tropical soda apple within Florida and to other southeastern states has been facilitated by movement of cattle, pasture grasses, and composted manure from infested areas [71,108].

HABITAT TYPES AND PLANT COMMUNITIES:
In Florida, tropical soda apple most often occurs in cultivated pastures, primarily pastures planted with bahia grass (*Paspalum notatum*) [26,66,68]. Tropical soda apple also invades sites associated with other anthropogenic disturbance (see Site Characteristics) and native plant communities.

Tropical soda apple occurs on wildlands and in native plant communities [26,52,68]; however, little information was available on specific plant associations as of 2009.

Florida: In Florida, tropical soda apple has been observed in native plant communities such as hammocks [63], hammock edges [74], cabbage palmetto (*Sabal palmetto*) hammocks, cypress (*Taxodium distichum*) heads or domes [26,68,74], depression marshes, riparian areas, and pinelands (*Pinus* spp.). Herbaria collections indicate that tropical soda apple occasionally occurs in strand swamps, scrub, and mesic flatwoods [106]. Of these Florida communities, tropical soda apple is most commonly noted in hammocks and cypress heads.

Hammocks: Hammock is a general term for a forest clump or a narrow band of vegetation often dominated by evergreen tree species, often oaks (*Quercus* spp.) ([40], review by [81]). Tropical soda apple occurred in the understory margins of saw-palmetto (*Serenoa repens*) [72], a species commonly found on the perimeter of hammocks [40]. Hammocks can be hydric, mesic, or xeric and are most frequently defined by their topographic location (e.g., high, middle, or low slope) rather than their moisture content. Hammocks vary in their plant species composition and distribution ([40], review by [81]) and most commonly contain temperate species, but they contain tropical species in the very southern parts of Florida (review by [81]). Canopies may be open or closed [40]. Hammocks are typically embedded within larger plant communities such as prairies, marshes [40], or pastures [1].

Cypress heads: Cypress heads are shallow, forested, usually circular depressions. Because small trees grow in the shallow water at the outer edge and large trees grow in the deeper water in the interior [40], cypress heads generally present a symmetrical, domed profile [62]. Important tree species include pondcypress (*T. distichum* var. *imbricarium*), swamp tupelo (*Nyssa sylvatica* var. *biflora*), slash pine (*Pinus elliottii*), red maple (*Acer rubrum*), and wax-myrtle (*Myrica cerifera*). There is a diverse understory of shrubs and forbs including laurelleaf greenbrier (*Smilax laurifolia*), fetterbush (*Lyonia lucida*), poison-ivy (*Toxicodendron radicans*), grape (*Vitis* spp.), gallberry (*Ilex glabra*), Virginia chain-fern (*Woodwardia virginica*), and cinnamon fern (*Osmunda cinnamomea*) [40,62].

Mesic flatwoods: Tropical soda apple occasionally occurs in mesic flatwoods, which are of interest from a fire perspective. Mesic flatwoods have relatively open overstories dominated by longleaf pine (*P. palustris*), typical slash pine (*P. elliottii* var. *elliottii*), south Florida slash pine (*P. elliottii* var. *densa*), and pond pine (*P. serotina*) [40,81]. Several variations of mesic flatwood are recognized and typically differ from one another in ground cover composition [40].

For a complete description of these and other Florida plant communities, see [40].

Other states: In other southeastern states, tropical soda apple is most invasive in pastures but also occurs in croplands and native plant communities. It invades oak hammocks and cypress heads in Mississippi, Alabama, and Georgia [13] and wooded areas in Mississippi (reviews by [11,16]). In Texas, it occurs in native grasslands and forested areas (review by [43]). As of this writing (2009), nothing had been published about tropical soda apple's plant associations in states farther north.

Because tropical soda apple is a relatively new invader to North America, it may occur in or spread to plant communities not mentioned above.

BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: Solanum viarum

GENERAL BOTANICAL CHARACTERISTICS:

- **Botanical description**
- **Raunkiaer life form**

Botanical description: This description covers characteristics that may be relevant to fire ecology and is not meant for identification. Wunderlin and Hansen [107] provide a key for identification.

Aboveground: In North America, tropical soda apple has been described as a broadleaf herb [23,69,102], subshrub [59], or shrub [59,108]. In India, it is considered a "woody" herb [80]. It is generally a perennial where it occurs in warm climates [11,23,70] and may remain green over the winter [23,59]. In places that experience frost, tropical soda apple may be an annual [11]. It typically grows from 3 to 6 feet (1-2 m) tall, and the leaves and stems are lined with thorn-like prickles up to 1 inch (2.5 cm) long [70]. Leaves are 2 to 8 inches (6-20 cm) long × 2 to 6 inches (6-15 cm) wide [70]. Its inflorescence is a 1- to 3- flowered cyme [108]. Fruits are globular berries. They are typically about 0.8 to 1 inch (2-3 cm) in diameter at maturity [70], but viable seed may develop in ripe fruits as small as 0.4 inch (1 cm) in diameter [11] (see Germination). As fruits ripen, they transition from green to yellow [85]. The seeds are lens-shaped [102] and about 2 mm long [108].

Belowground: The root system of tropical soda apple can be extensive. In Florida, feeder roots, which are 0.25 to 1.0 inch (0.63-2.54 cm) in diameter, are located a few inches below the soil surface and are about 3 to 6 feet (1-2 m) long [85]. Roots examined on a site in Mississippi were up to 1 foot (30 cm) deep with lateral branched roots up to about 3 feet (1 m) long and 0.6 to 1 inch (1.5-2.5 cm) in diameter [12].

Population structure: Tropical soda apple is an aggressive invader. It rapidly populates new sites and may eventually form monocultures [85] that occur in patches of 10 acres (4 ha) or more [97]. Prior to control efforts, tropical soda apple commonly occurred in monocultures of 50 acres (20 ha) or more in Florida [70,85]. Dense monocultures occur primarily in cultivated pastures and may be less frequent on rangelands and wildlands [34].

Raunkiaer [82] life form:
Chamaephyte
Geophyte
Therophyte (possibly, especially in northern climates)

SEASONAL DEVELOPMENT:
Available information to date (2009) indicates that tropical soda apple's phenology may vary within its North American range. One review indicated that in Florida, tropical soda apple seedlings emerge, or new sprouts develop from perennial roots, primarily during the October to May dry season [85]. Another review indicated that in Florida, most tropical soda apple seedlings emerge by March [2]. In southern Florida, tropical soda apple seedlings emerged year-round, but the majority emerged from August to March (Mislevy and others 1997 cited in [61]). In warm

climates where tropical soda apple is considered a perennial, tropical soda apple stays green year-round or persists from its root crown [23,59]. Information pertaining to its seasonal development as an annual in North America was lacking.

In Florida, tropical soda apple flowers and produces fruit throughout the year [2,70], but both events may be more concentrated during certain times. Periods of high flower and fruit production may vary with location. In Florida, most flowering and fruiting occurs from September to May, with fewer fruits produced in summer [65,70]. Another report from Florida found most flowering and fruit production occurred from February to August [2]. In Mississippi, tropical soda apple's flowering and fruiting period begins in June and continues until the first fall frost, with peak production occurring in August (Bryson and Byrd unpublished data cited by [11]). In its native and nonnative ranges outside North America, tropical soda apple has been reported to flower primarily from September to April [75]. In parts of India where it is hot, tropical soda apple can be an annual that produces flowers 3 months after germination and mature berries in another 2 months [80].

REGENERATION PROCESSES:

Although seed is the primary mechanism for tropical soda apple spread [71], it also sprouts from the roots [11,69] and possibly from the root crown.

- **Pollination and breeding system**
- **Seed production**
- **Seed dispersal**
- **Seed banking**
- **Germination**
- **Seedling establishment and plant growth**
- **Vegetative regeneration**

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Pollination and breeding system: Flowers of tropical soda apple are perfect [109]. Information pertaining to pollination and breeding in tropical soda apple was lacking as of 2009. Orchid bees have been observed collecting pollen from tropical soda apple [79] and may serve as pollinators.

Seed production: Tropical soda apple is generally considered a prolific seed producer [27,59,70,75,85,102]; however, seed production may vary between populations. In Florida, 1 plant may produce, on average, 125 fruits containing 413 seeds. One mature tropical soda apple plant has the potential to produce >50,000 seeds annually [70]. Cook [24] indicated fruit production may be greater in Mississippi than in Florida. Eight to 10 tropical soda apple plants in Mississippi have the potential to produce 1 million seeds annually [24]. Seed production may be less in other parts of the world. In hot climates in India, tropical soda apple completes its life cycle in 5 months [80], which may contribute to its reduced seed production in parts of its range. Studies in India found that 1 tropical soda apple plant produced 30 fruits [80]. A review on tropical soda apple populations outside North America indicates that a single tropical soda apple fruit may contain 190 to 385 seeds [75]. Fruit production may be greater in plants on phosphate-rich soils than in plants on unenriched soils (see Seedling emergence and plant growth).

Seed dispersal: Tropical soda apple seed dispersal throughout Florida and into other parts of the southeastern United States has been largely facilitated by cattle and operations associated with the transport of livestock and feed

[26,59,65,85]. Cattle eat tropical soda apple fruit and disseminate the seed via feces [10,23,63,70]. In Florida, cow manure contained 35,000 to 75,000 seeds/ton of dry manure [63]. Tropical soda apple seed is spread long distances as a contaminant in hay, grass seed, and sod, and by moving water [12,68]. Tropical soda apple seed was probably dispersed from Florida to other states by interstate transport of livestock, primarily cattle [36].

Wildlife, primarily feral pigs, northern raccoons, and white-tailed deer, also eat tropical soda apple fruit and spread the seed through their feces [23,26,59,63,85]. While it has been suggested that birds eat tropical soda apple fruit [102], one review indicated that birds had not been observed feeding on the fruits and that birds may not serve as a vector for tropical soda apple's spread [23].

Tropical soda apple seed may be dispersed by equipment or human and other animal movement. The seeds contain a sticky substance that adheres to the undersides of mowers, tires, front grills, blades, and shoes. Contaminated mowers, vehicles, and other equipment can transfer seed to uninfested pastures [64]. The seed may also adhere to animal fur, providing another means for tropical soda apple seed dispersal.

As of this writing (2009), it was uncertain what happens to tropical soda apple seeds that are not dispersed by animals or equipment. They are likely gravity dispersed and fall near the parent plant.

Seed banking: Available evidence suggests that tropical soda apple forms a soil seed bank in its North American range, but seed bank longevity is unclear. There may be little opportunity for seed bank formation in areas like southern Florida, where tropical soda apple seedlings emerge year-round.

In cypress heads, tropical soda apple may reestablish from a soil seed bank after mature plants are eradicated by flooding [65]. Herbicides that prevent seedling establishment from the soil seed bank are preferred for tropical soda apple control (see Chemical control) [36]. Dormancy may allow tropical soda apple to form at least a short-term soil seed bank. In Mississippi, 10% to 18% of tropical soda apple seed buried in a field and exposed to cold winter temperatures germinated and emerged when moved to the greenhouse the following spring [11], suggesting that tropical soda apple can form a seed bank until at least the following growing season. Tropical soda apple seed may deteriorate rapidly in soil [11,63], but viability may be extended if seed is protected from deterioration. Tropical soda apple seed placed in dry, dark storage in the laboratory for up to 12 months remained viable [63,78]. One review suggested that tropical soda apple seed may survive for 2 or more years if soil is relatively dry [26]. Seed overwintering on the soil surface may be protected from deterioration if the fruit remains intact [11].

Because tropical soda apple is commonly dispersed by wildlife, sites where wildlife congregate—such as oak hammocks, roadsides, ditch banks, and other fallow areas— may contain a disproportionate amount of tropical soda apple seed in the soil seed bank [1].

Germination: In the laboratory, seed viability and germination rates were high for tropical soda apple seed sown under variable conditions. Germination in tropical soda apple is epigeal [69]. While some seed may undergo a short period of dormancy, dormancy may not be required for germination. Fruit size may be a better determinant of seed maturity than fruit ripeness. Germination may be enhanced by scarification and may be sensitive to changes in temperature, light, pH, moisture availability, and fruit ripeness.

Fruit diameter may be a better predictor of seed maturity than fruit ripeness in tropical soda apple. Under laboratory conditions, tropical soda apple seedlings did not emerge from seed removed from ripe fruit <0.4 inch (1 cm) in diameter or from unripe fruit <0.6 inch (1.5 cm) in diameter. Seedling emergence increased proportionally with increased fruit diameter (r^2=0.9), with maximum emergence (90%) occurring from ripe fruits that were =1 inch (2.8 cm) in diameter. Although seed from unripe fruit may be sufficiently mature to germinate, germination may be greater with seed of ripe fruit (yellow) than from unripe fruit (green) [11].

In Florida, viability of tropical soda apple seed is likely high [2,63]. Laboratory testing found that viability of tropical soda apple seed was 89% [2] to 98% [63]. Viability of tropical soda apple seed collected from cow manure ranged from 80% to 90% [63], suggesting that seed viability may be minimally affected by digestion.

Most fresh seed is apparently viable, but some tropical soda apple seed may be dormant [2,63,88]. In the laboratory, tropical soda apple seed germinated in 6 to 7 days (Mullahey unpublished data cited in [69]). In the laboratory, 20% of tropical soda apple seed collected in Florida was dormant [2]. Other researchers in Florida reported that 4% to 16% of tropical soda apple seed was dormant. However, no seed remained viable after 90 days [63]. An unpublished study (Wahaj and others cited in [22]) suggested that solasodine, a poisonous substance found in *Solanum* spp. (see Palatability and/or nutritional value), may inhibit tropical soda apple germination.

Germination rates of 69% [2] to 82.5 % [10,70] have been reported for tropical soda apple in the laboratory, and scarification of seed coat may improve germination [2,10]. In the laboratory, germination of seed removed from fruit was 82.5%. Germination increased to 90% when seed passed through the digestive tract of cattle within 24 hours, indicating that scarification or partial digestion of the seed coat may increase germination rates. Seed taking longer than 6 days to pass through the digestive tract may no longer germinate [10]. Although scarified tropical soda apple seed germinated more quickly than unscarfied seed, percent germination was reduced, presumably from injury to the embryo [2].

In the greenhouse, tropical soda apple seeds germinated in constant temperatures ranging from 50 [2] to 95 °F (10-35 °C) [2,33]. Germination increased with increased temperatures up to 86 °F (30 °C), and declined thereafter. Germination did not occur at temperatures =104 °F (40 °C) or =41 °F (5 °C) [2]. Germination may be stimulated [88] or percent germination increased (Vincente 1972 cited in [70]) with alternating temperatures. In India, tropical soda apple seed did not germinate at constant temperatures of 68 °F (20 °C) or 86 °F (30 °C), but 10% germinated when temperatures were alternated between these 2 temperatures. Germination rates increased up to 82% when seed was subject to dormancy-breaking acid treatments and exposed to the same alternating temperatures [88].

In Florida, optimal germination temperature for tropical soda apple occurs from October until March [2]. Based on results obtained in the laboratory, researchers concluded that air temperature ranges in much of the southeastern United States may be sufficient to allow tropical soda apple seed to germinate year-round [2]. Ferrel [36] indicated that tropical soda apple seeds germinate anytime soil temperatures are 41 to 104 °F (5-40 °C). This means that for states like Florida, with average monthly soil temperatures ranging from 64 to 100 °F (18-38 °C), tropical soda apple can germinate year-round [36].

Based on its associated habitats (see Habitat Types and Plant Communities and Site Characteristics), tropical soda apple seed may germinate in full light or in shade. In Florida, seedlings occurred along the margins of saw palmetto canopies [72], suggesting seeds may germinate in partial shade. Under laboratory conditions, tropical soda apple seeds germinate in the dark [2,63]. Light may stimulate germination in tropical soda apple (Vincente 1972 cited in [70]).

Other factors that may influence germination in tropical soda apple seed include pH and moisture availability. Moderately alkaline soils may promote germination. Although tropical soda apple seed germinated in buffer solutions when the pH ranged from 3 to 13, germination was highest (71%) when the pH was 8. Germination declined sharply when pH was greater than 8 [2]. Tropical soda apple seed germinates across a wide range of moisture conditions and may germinate under moderate water stress, but the percent of seed germinating may decline [2]. Germination may be low for tropical soda apple seeds on the soil surface (see Seedling emergence and plant growth).

Seedling emergence and plant growth: Available information suggests that seedlings begin to emerge shortly after seed is dispersed (see Seasonal Development), and plants can produce fruit in as little as 2.5 months. Seedling emergence may be greater for buried seed than for seed on the soil surface. Precipitation and geographic location may influence length of tropical soda apple's growing season.

In the greenhouse, tropical soda apple seed sown at various depths, ranging from the soil surface to about 3 inches (8 cm), began to emerge 6 to 7 days after planting. Fifty percent of seedlings emerged within approximately 15 days of planting [69]. Seedlings emerged from all depths, but most (63%) emerged from seed buried about 1 inch (3.6 cm) deep. Fewest (7%) emerged from seed on the soil surface [69]. In another laboratory study, seedling emergence was greatest for seed planted about 2 inches (6 cm) below the soil surface (63%) and did not occur for seed sown more than about 5 inches (12 cm) deep. As in the previous study, seedling emergence from seed left on the soil surface was low (6.9%) [2]. Seedlings emerging from unburied seed may grow more slowly and have lower vigor compared to

seedlings emerging from buried seed. The authors attributed reduced emergence of seed on the soil surface to dry conditions [69].

After seedlings emerge, growth and fruiting occur rapidly [55,69,80,95], especially when nutrients are sufficient [91]. In the greenhouse, tropical soda apple seed planted about 0.4 inch (1 cm) deep germinated, grew to a height of about 8 inches (20 cm), and had an average of 20 leaves within 60 days after planting. During the next 60 days, tropical soda apple plants underwent a "rapid" increase in height. Wild tropical soda apples may grow more slowly than greenhouse plants. Seedlings in a Florida pasture took 60 to 80 days to get about 8 inches (20 cm) tall and only had 4 to 8 leaves/plant. Flowering time for pasture plants was 120 days compared to 75 to 83 days for greenhouse plants [69]. Trenholm and others [91] reported substantial growth in tropical soda apple plants in pastures and hammocks during the first 125 days of growth. Some plants developed fruit at 75 to 100 days of age; most other plants developed fruit by 125 days. [91]. In India, cultivated tropical soda apple plants mature within 5 months of germination [80] and have up to 4 to 6 leaves within 45 days of emergence [55]. In the greenhouse, increases in phosphorus increased tropical soda apple plant height and fruit production [17].

Plants in pastures may be more productive than plants in wildlands (hammocks). In southwestern Florida, growth and nutrient accumulation were compared between tropical soda apple plants in a pasture and a hammock. Although plants in both habitats grew well, plants in the pasture produced at least twice as much dry matter as plants in the hammock. Hammock plants had more dry matter production apportioned to their stem tissue than pasture plants, and they expanded their root system faster than pasture plants, presumably to enhance nutrient uptake. Nutrient concentrations in tropical soda apple plants were similar, regardless of habitat. Nutrient concentrations varied between plant parts (e.g., stem, root) and plants of different age classes [91].

Tropical soda apple height and diameter may increase with increased precipitation, but fruit production may be unaffected [11]. Tropical soda apple populations may increase "rapidly" when several years of normal rainfall follow a drought [26].

Growth of tropical soda apple may slow or stop during winter. In the laboratory, overall growth of tropical soda apple increased with increases in night temperature. A regression model was developed to predict growth potential of tropical soda apple throughout the United States. In most southern states, tropical soda apple may grow during much of the year; however, it was predicted that 30% or more of its maximum growth occurs from April through October. If tropical soda apple spreads farther north and west, it may grow at rates similar to those predicted for southeastern climates; however, its growth would likely be restricted to warm months [78].

Vegetative regeneration: New shoots sprout from tropical soda apple's extensive roots [11,102], root buds [85], and probably from its root crown. Regeneration from root segments can also occur [24,33,69] and may be influenced by segment size. In the greenhouse, 6-inch (15 cm) root segments produced significantly (P<0.02) more shoots than 2-inch (7.5 cm) root segments [69]. Regeneration from rootstocks of the previous year may be limited to areas with mild winters or may occur after unseasonably warm winters in cooler climates [11].

Mature tropical soda apple plants that are cut or mowed may regrow from adventitious buds that develop on the callused tissue of the remaining stem apex. In a controlled experiment, tropical soda apple plants of various ages (1-55 days old) regrew from adventitious buds after cutting. The average percentage of 1-day-old plants that regrew after mowing was 75%. Bud formation was greater in 20-day-old plants than for plants cut 1 or 10 days after emergence, and a higher proportion of regrowth occurred on plants that were 25 days old than in plants that were cut sooner [18].

SITE CHARACTERISTICS:
Tropical soda apple occurs primarily on sites associated with human alteration and soil disturbance [23,65,70,85,107]. It is common in pastures, fence rows, ditch banks, citrus groves, and sugar cane fields [103,108]. Tropical soda apple occurs on sites where activities such as field disking, cattle feeding, ditch bank cleaning, or the rooting of feral pigs has disturbed the soil [65]. Reviews indicate that tropical soda apple is most common in cultivated pastures [85], but it also occurs in wildlands [23]. In Florida, wooded areas comprise an estimated 10% of the total land with tropical soda apple [67].

In its native range, tropical soda apple occurs in tropical climates and is found at low elevations, mostly below 300 feet (100 m) [75]. In North America, it is "well suited" for warm temperatures [91]; however, it has spread to northern areas such as Pennsylvania, where January temperatures can fall to 28 °F (18 °C) or lower [105]. Field tests indicated that tropical soda apple can survive as a perennial at winter temperatures =50 °F (10 °C) at 33 °N latitude and may survive colder temperatures as an annual [11]. Germination of tropical soda apple seed may be influenced by soil temperature as well as air temperature.

In southern Florida, tropical soda apple may occur on seasonally wet soils [85]; however, it does not tolerate inundation for more than 3 weeks [70]. Cypress heads support tropical soda apple until their centers become completely flooded; then tropical soda apple dies back to the outer, drier regions. As the water in the cypress head recedes during the dry season, new tropical soda apple plants establish from the soil seed bank and begin to occupy the inner regions of the cypress head [65]. Tropical soda apple's ability to germinate under moderate water stress [2] suggests it could establish in dry habitats or during periods of moderate drought. Its ability to tolerate a range of environmental conditions (e.g., temperature, moisture) may allow tropical soda apple to persist during years that are unfavorable for reproduction [71].

Information pertaining to tropical soda apple's preferred substrate is limited. In Florida, tropical soda apple occurs in somewhat poorly drained [108], sandy soils [12,36,61]. In an experimental field in Florida, it occurred in soils that were 96% to 99% sand and contained a small percentage of silt and clay [36]. On 5 sites in Mississippi, tropical soda apple grew in sandy loam soils [12]. In bahia grass pastures, where tropical soda apple can be abundant, soil pH is maintained from 5 to 7 [2]. Alkaline conditions may favor germination. Tropical soda apple may flourish in soils rich in phosphorus [3,17].

SUCCESSIONAL STATUS:
At the time of this writing (2009), tropical soda apple was a relatively recent invader to North America—present in Florida for just over 20 years and less than that in other states. Consequently, there was little opportunity to observe its successional role. Tropical soda apple is most commonly associated with anthropogenic disturbance and cattle pastures, but its ability to establish on naturally disturbed sites (e.g., after hurricanes and landslides) has not been documented to date (2009). Nee [75] describes tropical soda apple as a "common weed of second growth and edges of forests" in its range outside of North America.

In North America, tropical soda apple grows in open and shaded sites, as evidenced by its occurrence in both pasture and wooded plant communities (see Habitat Types and Plant Communities), and seedlings may establish in shade (see Germination). One review suggested that tropical soda apple preferred open to semishaded sites [85], suggesting it may be intolerant of deep shade. In Mississippi, some tropical soda apples were observed in shade, but most were in full sunlight [12].

Tropical soda apple occurs in oak hammocks, cypress heads, and other plant communities in Florida and the southeastern United States (see Habitat types and plant communities); however, nothing has been documented about its successional status in these communities as of 2009. General information pertaining to successional patterns in Florida's plant communities is available in these publications: [40,81].

FIRE EFFECTS AND MANAGEMENT

SPECIES: Solanum viarum

FIRE EFFECTS:

Immediate fire effect on plant: As of this writing (2009), no published information was available on the immediate effect of fire on tropical soda apple. Because it can sprout from the roots, tropical soda apple is likely only top-killed by fire. Its root crown may be damaged or killed, depending on fire severity, but plants will likely survive because tropical soda apple's root system is located deep enough in the soil to be protected from fire (see Botanical description). Chapman and Crow [20] commented that plants with perennating buds protected well below the soil surface are typically least affected by fire. Generally, the deeper roots are located in the soil, the greater their chance for survival [38]. Roots are less likely to be damaged by low-severity fires than by severe fires that consume all surface organic matter and heat mineral soil above lethal temperatures (review by [15]). Additional information is needed pertaining to tropical soda apple's root system and its ability to survive fire.

Postfire regeneration strategy [86]:
Small shrub, adventitious buds and/or a sprouting root crown
Caudex or an herbaceous root crown, growing points in soil
Geophyte, growing points deep in soil
Initial off-site colonizer (off site, initial community)
Secondary colonizer (on- or off-site seed sources)

Fire adaptations and plant response to fire: As of this writing (2009), no published information was available on fire adaptations of tropical soda apple or its ability to establish after fire. Tropical soda apple's ability to regenerate vegetatively, produce abundant seed, and establish on disturbed sites suggests that fire may favor its spread. Postfire establishment may occur by vegetative regeneration or by seed. There is potential for postfire sprouting to occur from roots, root buds, and possibly the root crown. Tropical soda apple is known to sprout from adventitious buds on the stem apex after being cut and may do so after fire if fire severity is low and the stem apex is not killed.

Postfire seedlings may establish from residual or off-site seed sources. Tropical soda apple may establish from off-site seed source dispersed by wildlife, cattle, humans, or contaminated equipment. In some species, fire induces postfire germination through heat scarification of seed in the soil seed bank (reviews by [32,47]). Germination of tropical soda apple seed increased when scarified by digestion (see Seed banking and Germination), and heat scarification of residual seed may promote a similar response.

FUELS AND FIRE REGIMES:
Fuels: As of this writing (2009), no published information was available on tropical soda apple's fuel characteristics. Large patches of tropical soda apple may contribute to fuel loads, especially in areas where it dies back in the winter.

Fire regimes: Information pertaining to tropical soda apple on wildlands is limited, making it difficult to infer what

relationship, if any, tropical soda apple has with fire. It is possible, however, to discuss fire regimes as they pertain to broad classifications of plant communities in which tropical soda apple occurs.

Plant communities associated with tropical soda apple, such as oak hammocks and cypress heads, are typically described as islands or clumps of vegetation embedded within larger, characteristically open plant communities (e.g., wet grasslands, prairies) ([40], review by [87]). Fire may play a greater role in maintaining surrounding communities than the embedded communities. For example, wet grasslands in southeastern United States tend to be flammable and are adapted to frequent fire (review by [87]). Presettlement fire regimes for these communities have been classified as stand-replacement types with 1- to 10-year return intervals (reviews by [73,100]). Conversely, oak hammocks within wet grasslands may rarely burn and generally develop in the absence of fire. Low-intensity fires (review by [81]) characterized by short flame lengths (<2 feet) may occur in hammocks (review by [73]). Fire may be less frequent in hammocks than in surrounding plant communities, because vegetation in hammocks is generally considered less flammable than surrounding vegetation (review by [81]). Hammock litter generally holds more moisture than litter of surrounding communities, making hammocks more resistant to fire (reviews by [73,81]). Furthermore, embedded vegetation types may be somewhat protected from the frequent fires that normally spread through the surrounding vegetation because they often occur near wetlands, ponds, or lakes where they are rarely exposed to direct head fire (review by [73]). Fires may be more frequent on the upper slopes rather than low to midslopes of hammocks and may play an important role in the formation and maintenance of xeric hammocks (review by [81]). During times of drought, or where hammocks have expanded out to surrounding vegetation, hammocks may experience high-intensity fires (reviews by [73,81]). Little is known about fire's relationship to cypress heads (reviews by [73,87], but understory fire may play a role in their formation [101].

Tropical soda apple also occurs [106] in fire-maintained communities such as mesic flatwoods ([40,50], review by [81]). Mesic flatwoods experience surface fires that generally burn much of the groundlayer vegetation. On average, surface fires occur every 2 years and stand-replacing fires every 65 years. Fire severity is moderate overall, generally resulting in top-kill of the lower and middle layers; however, fire periodically kills patches of young regeneration and occasionally, individual older trees. Nearly all plants inhabiting these communities are adapted to fire [40]. It is unknown whether tropical soda apple survives or establishes after fire in mesic flatwoods or if it establishes on these sites in the absence of fire.

Although tropical soda apple has not been studied for its potential to alter fire regimes in wildlands, it may alter fuel characteristics and impact fire regimes, especially where it dominates the plant community. Impacts of invasive species on fire regimes have been discussed by several authors (e.g., [9,30]). A review by D'Antonio [29] suggests that species that alter the disturbance regime of a site are qualitatively different from the rest of the species in a community. Where invaders are similar in life form to natives, they tend to alter primarily fuel biomass per unit area of ground, which may influence fire intensity or slightly modify the existing fire regime. Where invaders differ in life form from natives, they have the potential to substantially alter fire frequency and the ecological community [8,9,30]. Before a determination can be made on tropical soda apple's ability to alter fire regimes on wildlands, more information is needed on tropical soda apple's fuel characteristics and the species composition typical of plant associations where it is invasive.

See the Fire Regime Table for further information on fire regimes of vegetation communities associated with tropical soda apple. If you are interested in fire regimes of plant communities not listed there, see the Expanded Fire Regime Table.

Most of those descriptions are for large plant community classifications that contain the embedded community types that may contain tropical soda apple; fire regimes for embedded communities are likely different. However, information on the fire regimes of these large plant community types may provide some information about the fire ecology of embedded plant communities. Tropical soda apple was probably not present when reference fire regimes were functioning but has established since habitat alteration and fire exclusion began.

FIRE MANAGEMENT CONSIDERATIONS:
As of this writing (2009), there were no published recommendations for fire management of tropical soda apple. Fire may temporarily reduce tropical soda apple populations if individual plants are top-killed, but intact root systems

and/or root crowns may provide a means for regeneration. Additionally, tropical soda apple's ability to invade open, disturbed sites from off-site seed sources (see Site Characteristics and Seed dispersal) suggests that fire might create favorable conditions for tropical soda apple establishment. Based on tropical soda apple's ability to reproduce rapidly and invade disturbed sites, prescribed fire alone is not likely to control tropical soda apple. More information is needed on tropical soda apple's response to fire before considering prescribed fire for its control.

In general, preventing invasive plants from establishing in weed-free burned areas is the most effective and least costly management method. There are a number of general guidelines, which may help to prevent tropical soda apple's postfire establishment and spread on burned sites where it previously occurred or on sites that are near tropical soda apple infestations. This can be accomplished through early detection and eradication of new infestations, careful monitoring and follow-up, and limiting dispersal of its seed on burned sites. General recommendations for preventing postfire establishment and spread of invasive plants include:

- Incorporate cost of weed prevention and management into fire rehabilitation plans
- Acquire restoration funding
- Include weed prevention education in fire training
- Minimize soil disturbance and vegetation removal during fire suppression and rehabilitation activities
- Minimize the use of retardants containing nitrogen and phosphorus
- Avoid areas dominated by high priority invasive plants when locating firelines, monitoring camps, staging areas, and helibases
- Clean equipment and vehicles prior to entering burned areas
- Regulate or prevent human and livestock entry into burned areas until desirable site vegetation has recovered sufficiently to resist invasion by undesirable vegetation
- Monitor burned areas and areas of significant disturbance or traffic from management activity
- Detect weeds early and eradicate before vegetative spread and/or seed dispersal
- Eradicate small patches and contain or control large infestations within or adjacent to the burned area
- Reestablish vegetation on bare ground as soon as possible
- Avoid use of fertilizers in postfire rehabilitation and restoration
- Use only certified weed-free seed mixes when revegetation is necessary

For more detailed information on these topics see the following publications: [4,8,44,95].

MANAGEMENT CONSIDERATIONS

SPECIES: Solanum viarum

MPORTANCE TO WILDLIFE AND LIVESTOCK:
Cattle, and various wildlife, including feral pigs, northern raccoon, and white-tailed deer, eat tropical soda apple fruit [23,26,56,59,63,63,70,85]. Numerous reviews indicate birds eat tropical soda apple fruit [27,34,59,85]; however, one review reported that direct observation of birds eating tropical soda apple fruit had not been reported [23]. Female orchid bees have been observed collecting pollen from tropical soda apple flowers [79].

Palatability and/or nutritional value: Like many plants in the Solanaceae family, tropical soda apple contains solasodine, a substance poisonous to humans and other animals [41]. Solasodine is concentrated in tropical soda apple's fruit, especially in the mucilaginous layer surrounding the seed [65,80]. The level of solasodine increases as tropical soda apple berries mature and declines as berries become overripe [80]. Although tropical soda apple fruit may be bitter-tasting to humans [23], the taste apparently does not preclude livestock and wildlife from eating tropical soda apple fruit [68].

Livestock do not eat tropical soda apple foliage [70]. Wunderlin speculated [108] that the spines and glandular hairs on the foliage prevent cattle from eating the foliage.

Cover value: In Brazil, *Mechanitis lysimnia*, a butterfly, lays its eggs on the leaves of tropical soda apple and other *Solanum* spp. [99].

OTHER USES:
Steroids produced by tropical soda apple have been used to treat cancer, Addison's disease, rheumatic arthritis, chronic asthma, leukemia, obesity, palsy, and skin diseases [80]. Tropical soda apple has been cultivated in India and Mexico for its pharmaceutical properties [68,80,83]. As of 1996, propagation of tropical soda apple was thought to have substantially declined or ceased altogether in these 2 countries [68], presumably because other plants from the Solanaceae family had higher levels of solasodine [27].

IMPACTS AND CONTROL:
Impacts: In Florida, tropical soda apple is an invasive, nonnative plant that is a major agricultural pest and a serious threat to wildlands (Mullahey 1997 personal communication cited in [52]). Since its introduction to Florida in the 1980s, it spread rapidly throughout the state, infesting an estimated 1.2 million acres (500,000 ha) by 1995. Its estimated annual rate of spread between 1990 and 1995 was 117% in Florida and 35% in other southeastern states. Its rapid spread in the Southeast has been attributed to its tremendous reproductive potential and highly effective seed dispersal (see Regeneration Processes) [27]. It is not considered invasive in its native range, presumably because it has native biological controls [28,57].

Due to its rapid spread, tropical soda apple is on the Federal Noxious Weed List [94]. In Florida, tropical soda apple was listed in 1994 on the state's noxious weed list as a Category I invasive, making it unlawful to introduce, have in one's possession, move, or release it in the state [26,67]. Category I invasive species in general are "nonnative species that have invaded natural areas and are displacing native plants or are disrupting natural community structure and function" [39]. Tropical soda apple's greatest impact in Florida has been to bahia grass pastures, where it displaces the shade-intolerant nonnative grass [27,34,66,103] and can eventually form monocultures [27]. When it establishes in wooded areas, it prevents cattle from seeking shelter from the sun [27,103], presumably because its spines restrict livestock movement [66]. As of 2009, tropical soda apple was estimated to infest nearly 1 million acres (400,000 ha) of pasture in Florida [85].

It is unclear what impacts tropical soda apple has in states outside Florida, but research in Mississippi indicates it has the potential to become a threat [11]. Georgia declared tropical soda apple a "Public Nuisance" for its impacts to the agricultural and horticultural industries [42]. The Tennessee Exotic Pest Plant Council has given tropical soda apple a ranking of 1. Plants in this category pose a severe threat in Tennessee because of their invasive tendencies and their ability to spread easily into native plant communities and displace native vegetation [89].

Tropical soda apple's ecological impacts have not been well documented [45], and little has been reported on its impacts to wildlands. It is assumed that tropical soda apple displaces native plants and interferes with natural ecosystem processes [23,26,66]. However, it has been suggested that on uncultivated rangelands and wildlands, tropical soda apple may not form dense monocultures (Mullahey personal communication cited in [34]). Eight years after its introduction to North America, tropical soda apple was reported in 20 natural areas from as far north as Alachua County, Florida (Florida EPPC 1996 cited in [52]). In Florida, it is estimated that wooded areas comprise 10% of the total land infested by tropical soda apple [67]. The spines on tropical soda apple can degrade wildlife habitat by creating physical barriers for animal movement, especially in large infestations [26]. Tropical soda apple is reported in numerous native plant communities in North America and, based on its ability to adapt to a wide range of environmental conditions, it has the potential to establish in many other communities throughout its current and predicted range [2] (see General Distribution).

Because tropical soda apple may invade phosphate-mine reclamation sites, it may interfere with restoration efforts [3]. Tropical soda apple's increased fecundity with increased phosphorus levels (see Seedling emergence and plant growth) has led researchers to conclude that soils high in phosphorus may be predisposed to invasion by tropical soda apple [17].

Economic impacts: Tropical soda apple is a serious economic threat to the beef cattle industry. If left uncontrolled, it can infest a pasture in 1 to 2 years [67], reducing pasture productivity and lowering stocking rates [70]. Surveys taken in 1993 indicated that Florida's beef cattle producers attributed $11 million dollars in production losses to tropical soda apple. Losses were associated with lower carrying capacity of pastures and heat stress on cattle that could not access shade [67]. Based on field tests in Florida, 20 tropical soda apple plants/acre of pasture could result in an estimated revenue loss of $49/acre due to a decrease in bahia grass yield [66]. Restrictions on the interstate movement of livestock, seed, hay, soil, and manure may have additional economic impacts to the beef cattle industry [34].

Because it interferes with crop production, tropical soda apple is a threat to the vegetable crop industry [26,27]. It also acts as an alternative host for the potato fungus *Alternaria solani* [34] and 6 viruses [56] that cause economic damage to vegetable crops of the Solanaceae family [56]. Tropical soda apple may be a host to *bidens mottle virus*, which causes damage to crops outside of the Solanaceae family [6]. Additionally, numerous crop pests utilize tropical soda apple as an alternative host [34]. Although no estimates of monetary losses to this industry were found, one review predicted that tropical soda apple "will" have major economic impacts to agriculture [23].

Control: As of this writing (2009), research is ongoing. The University of Florida's West Florida Research and Education Center and the Center for Aquatic and Invasive Plants provide information on tropical soda apple control.

Tropical soda apple is difficult to control due to its extensive root system, which can generate new shoots, its prolific seed production (see Regeneration Processes), and its tendency to form large patches. The sharp prickles act as barriers, limiting access to infested sites [23]. Complete eradication may be unlikely [69]. Efforts to control tropical soda apple may be most effective if the entire plant, including its immature and mature fruit and its root system, is removed [12,24]. Effective weed control strategies need to account for a soil seed bank lasting approximately 3 to 12 months (see Seed banking) [63]. To prevent reintroduction of seed from neighboring uncontrolled populations of tropical soda apple, repeat control measures and follow-up monitoring may be required [23,85].

Invasive plant control is most effective when it employs a long-term, ecosystem-wide strategy rather than a tactical approach focused on battling individual invaders [54]. In all cases where invasive species are targeted for control, the potential for other invasive species to fill their void must be considered regardless of what control method is employed [9]. Efforts to control tropical soda apple would be enhanced if more were known about ecosystem responses to tropical soda apple invasion in wildlands.

Fire: For information on the use of prescribed fire to control this species, see Fire Management Considerations.

Prevention: Regulations and collaborative efforts have been initiated to prevent the spread of tropical soda apple to areas outside its current (2009) North American range. Since it is on the Federal Noxious Weed List, the interstate movement of tropical soda apple plants or products containing tropical soda apple is prohibited [93]. Additionally, Vermont, Massachusetts, Kansas, Minnesota, Arizona, California, and Oregon have placed restrictions on tropical soda apple transportation and/or have listed it as a potential noxious weed or pest plant in their state [13]. In 1994, numerous southern and mid-Atlantic states formed the Tropical Soda Apple Task Force to develop effective strategies to control and limit the dissemination of tropical soda apple. As of 2009, a set of best management practices was being developed to help control tropical soda apple and slow its spread [48,71]. The tropical soda apple Research and Extension Group was organized in 1993 at the University of Florida to facilitate communication among the various researchers and extension programs involved with tropical soda apple control [67].

Florida cattlemen and sod farmers have been targeted for cooperative participation in programs and/or regulation related to cattle transport activities in an effort to slow the spread of tropical soda apple [71]. The Tropical Soda Apple Task Force collaborates with industry representatives to find cooperative approaches to slow the spread of tropical soda apple. As of 2009, no official regulatory policies had been issued in Florida restricting cattle movement as it pertains to tropical soda apple spread; however, other states may have regulations concerning the acceptance of cattle from Florida [48]. At the time of this writing (2009), Florida Department of Agriculture and Consumer Services was charging a fee to certify sod as tropical soda apple-free [71].

Various other methods have been suggested to prevent the spread of tropical soda apple by seed. Control methods that reduce tropical soda apple fruit production [63] or seed dispersal, such as mowing, may help prevent the spread of tropical soda apple (see Physical or mechanical control). Cleaning off all equipment and vehicles that have been used on sites infested with tropical soda apple may help to reduce the spread of tropical soda apple seed [64]. Researchers studying tropical soda apple seed viability in the digestive tracts of cattle concluded that cattle grazing on tropical soda apple-infested lands be held in small feedlots that are tropical soda apple-free prior to transporting them to noninfested pastures. Cattle removed from tropical soda apple-infested sites for at least 1 week prior shipping are less likely to spread tropical soda apple seed through their feces [10]. A laboratory study indicated that there was potential to prevent the spread of viable tropical soda apple seed by feeding cattle herbicide-treated feed [53]. The authors, however, did not indicate how this treatment could influence the health of cattle or consumers of beef.

Cultural control: Following greenhouse and field tests, Akanda and others [1] suggested that maintaining a thick cover of grass may help reduce emergence of tropical soda apple seedlings in pastures.

Physical or mechanical control: For small patches, tropical soda apple seedlings and mature plants can be pulled or dug out, but care must be taken to remove the entire root to prevent regrowth [102]. Mechanical procedures such as mowing or plowing may be inappropriate in wildlands.

For established populations and large patches of tropical soda apple in pastures, maintaining plants in a fruit-free condition may limit seed dispersal [63,69]. Moderate tropical soda apple control (83%) has been achieved by mowing plants 3 consecutive times at 60-day intervals, preferably before they set fruit. Improved control was achieved (93-100%) when mowing was done in combination with an herbicide application (see Integrated management) [65]. Since tropical soda apple plants typically regrow and produce fruit in approximately 70 to 80 days after being cut [65], mowing every 50 to 60 days is recommended to prevent seed dispersal [65,67,69]. Because laboratory tests showed that tropical soda apple seed from fruits <0.4 inch (1.0 cm) in diameter did not germinate, Bryson and Byrd [11] suggested that mowing or handpicking tropical soda apple when fruits are <0.4 inch in diameter may help reduce seed dispersal and subsequent seedling establishment.

A greenhouse study suggests that control strategies that keep tropical soda apple seed at the soil surface (e.g., mowing) or at depths >4 inches (10 cm) (e.g., plowing) could substantially reduce tropical soda apple seedling establishment [69] (see Germination).

Since new shoots can regenerate from root fragments, tilling is not recommended for mechanical control of tropical soda apple [69].

Biological control: Biological control of invasive species has a long history that indicates many factors must be considered before using biological controls [98,104]. Tu and others [92] provide background information and considerations for biological control of invasive species in general in their Weed Control Methods Handbook. Additionally, the University of Florida's West Florida Research and Education Center and the Center for Aquatic and Invasive Plants provide information on biological control of tropical soda apple.

Efforts to identify an effective biological control for tropical soda apple were initiated in the early 1990s. Researchers, mostly affiliated with the University of Florida, have been studying a variety of insects, fungi, bacteria, and viruses for their potential to control tropical soda apple. As of this writing (2009), researchers had released a South American beetle for biological control for tropical soda apple, and other South American insects were being evaluated [58].

Gratiana boliviana was approved for field release in 2003. Since then, more than 220,000 of the leaf beetles have been released throughout Florida and parts of Alabama, Georgia, and South Carolina [48,58,97]. Populations of the beetle have established on several of these sites [58]. In 2007, *G. boliviana* was released in Jasper County, Texas, to control tropical soda apple [48,97]. Since its release in 2003, *G. boliviana* has spread as far north as Rhea County, Tennessee, at 35.6 ° N latitude [31]. After evaluating *G. boliviana*'s generational turnaround and tolerance to cold, Diaz [31] concluded that the northern extent of this beetle's range in the United States would be near 32 to 33 ° N latitude.

Initial evaluations of *G. boliviana's* release reported extensive (20-100%) defoliation on tropical soda apple by the

beetle [58]. One review reported that this beetle chews holes in the upper leaves of tropical soda apple, substantially reducing the weed's survival [25]. A later review indicated that *G. boliviana* has not typically controlled individual plants unless the beetles were present in "very high" numbers. The beetle may, however, reduce the number of fruits and/or reduce a plant's overall fitness. The review also suggested that *G. boliviana* is better suited for control of small infestations of tropical soda apple than large or remote infestations [85]. No nontarget effects had been reported within 3 years of the beetle's release [58].

Tobaviruses are being evaluated for their potential to control tropical soda apple [77]. In the greenhouse, tropical soda apple plants inoculated with *Tobacco mild green virus* died within 14 days of inoculation. Researchers concluded that *Tobacco mild green virus* was lethal to tropical soda apple and should be further evaluated for possible use in integrated management of tropical soda apple [21]. Overholt and others [77] investigated the influence of *Tropical soda apple mosaic tobamovirus* on the beetle *G. boliviana*, and also tested transmission of the virus by the beetle. Under laboratory conditions, there was no evidence of viral transmission by *G. boliviana*; however, the virus reduced the effectiveness of *G. boliviana* as a biological control agent on tropical soda apple, which may limit its use for integrated management.

Chemical control: Research on chemical control of tropical soda apple was ongoing as of 2009. See West Florida Research and Education Center and the Center for Aquatic and Invasive Plants databases for information on chemical control of tropical soda apple.

Herbicide treatments have and continue to be developed to control tropical soda apple and are being used in the field to reduce tropical soda apple populations and slow its spread. In the greenhouse, tropical soda apple was controlled 90 days following herbicide treatments [33]. Field tests in Florida indicated that herbicide applied in April could reduce tropical soda apple cover from 11% to 98% in 50 to 335 days, depending on the type of herbicide applied [36]. Seed production may be stopped if herbicide is applied prior to tropical soda apple flowering [1]. Combining herbicides with a growth regulator that prevents flowering, such as maleic hydrazide, may extend the number of days that herbicide controls tropical soda apple [33]. While control may be achieved with one application of herbicide, repeat herbicide applications may be necessary for herbicides that lack preemergence control [36,84,85]. Herbicides must be translocated to the roots of tropical soda apple to kill root buds; otherwise, root sprouting occurs. Results from a greenhouse study suggest that translocation of herbicide to the roots of tropical soda apple is optimized in September and October in southern Florida [69].

Many chemicals have been studied to control tropical soda apple, especially for large infestations in pastures. Reports from the University of Florida Extension service indicate that "excellent" chemical control may be achieved if herbicide is applied correctly. As of this writing (2009), aminopyralid and triclopyr were recommended for control of tropical soda apple [35,84,85]. Herbicide treatments developed for tropical soda apple control have been designed for specific circumstances, and each has strengths and weaknesses. Therefore, it is important to understand the benefits of these herbicides to achieve maximum effectiveness [35]. A few publications contain specific information on the use of these and other herbicides to control tropical soda apple: [84,85]. Trenholm [91] provides a detailed analysis of nutrient accumulation in tropical soda apple that may help to identify optimal herbicide application timing.

Herbicide treatments developed for pasture use may not necessarily be appropriate for oak hammock areas [1] or other wildlands. Because imazapyr usually stays within the top 20 inches (50 cm) of soil and may not affect mature oak trees, one study recommended its use to control tropical soda apple in oak hammocks. Lowering herbicide rates from those recommended for pasture use may help to reduce risk to immature oak trees [1].

Herbicides are effective in gaining initial control of a new invasion or a severe infestation, but they are rarely a complete or long-term solution to weed management [14]. See the Weed Control Methods Handbook [92] for considerations on the use of herbicides in wildlands and detailed information on specific chemicals.

Integrated management: As of this writing (2009), mowing in combination with herbicide treatment was being recommended as one method to control tropical soda apple [61,85]; however, mowing-herbicide treatment may be difficult and/or inappropriate in wildlands, and is likely limited to pastures.

Herbicide treatment following frost may control tropical soda apple. In Florida, over 95% of tropical soda apple plants were controlled within 120 days following various herbicide treatments that were applied to regrowth 60 days following a heavy frost. Effectiveness of this integrated approach may be influenced by herbicide concentration and timing of application [60].

Ferrell and others [37] investigated the potential to use *Tobacco mild green mosaic tobamovirus* in conjunction with herbicide for tropical soda apple control. The tobavirus was mixed with various synthetic herbicides and rubbed on the leaf surface of tropical soda apple plants. On the average, mixtures containing the tobavirus reduce tropical soda apple by 81% compared to the control rate from herbicide alone [37].

APPENDIX: FIRE REGIME TABLE

SPECIES: Solanum viarum

The following table provides fire regime information that may be relevant to tropical soda apple's habitats. Follow the links in the table to documents that provide more detailed information on these fire regimes. If you are interested in fire regimes of plant communities not listed here, see the Expanded Fire Regime Table.

Fire regime information on vegetation communities in which tropical soda apple may occur. This information is taken from the LANDFIRE Rapid Assessment Vegetation Models [51], which were developed by local experts using available literature, local data, and/or expert opinion. This table summarizes fire regime characteristics for each plant community listed. The PDF file linked from each plant community name describes the model and synthesizes the knowledge available on vegetation composition, structure, and dynamics in that community. Cells are blank where information is not available in the Rapid Assessment Vegetation Model.

Southeast

Southeast

- Southeast Grassland
- Southeast Forested

Vegetation Community (Potential Natural Vegetation Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Southeast Grassland					
Floodplain marsh	Replacement	100%	4	3	30
Everglades (marl prairie)	Replacement	45%	16	10	20
	Mixed	55%	13	10	
Palmetto prairie	Replacement	87%	2	1	4
	Mixed	4%	40		
	Surface or low	9%	20		

Pond cypress savanna	Replacement	17%	120		
	Mixed	27%	75		
	Surface or low	57%	35		
Southeast Forested					
Mesic-dry flatwoods	Replacement	3%	65	5	150
	Surface or low	97%	2	1	8

*Fire Severities—
Replacement: Any fire that causes greater than 75% top removal of a vegetation-fuel type, resulting in general replacement of existing vegetation; may or may not cause a lethal effect on the plants.
Mixed: Any fire burning more than 5% of an area that does not qualify as a replacement, surface, or low-severity fire; includes mosaic and other fires that are intermediate in effects.
Surface or low: Any fire that causes less than 25% upper layer replacement and/or removal in a vegetation-fuel class but burns 5% or more of the area [46,50].

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