

# Triadica sebifera

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## INTRODUCTORY

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### FEIS ABBREVIATION:

TRISEB

### NRCS PLANT CODE [[207](#)]:

TRSE6

### COMMON NAMES:

Chinese tallow  
tallowtree  
popcorn tree  
Florida aspen  
chicken tree

**TAXONOMY:**

The scientific name of Chinese tallow is *Triadica sebifera* (L.) Small (Euphorbiaceae) [[53](#),[56](#),[94](#)].

**SYNONYMS:**

*Sapium sebiferum* (L.) Roxb. [[63](#),[145](#),[214](#)]

**LIFE FORM:**

Tree

**DISTRIBUTION AND OCCURRENCE**

**SPECIES:** *Triadica sebifera*

- [GENERAL DISTRIBUTION](#)
- [HABITAT TYPES AND PLANT COMMUNITIES](#)



Photo by Cheryl McCormick, The University of Georgia, IPM Images

**GENERAL DISTRIBUTION:**

Chinese tallow is a native of China and Japan [[52](#),[112](#),[113](#),[125](#),[210](#),[214](#)]. It is nonnative and has been introduced to many areas including southeastern United States, Puerto Rico [[205](#)], Costa Rica [[50](#)], Taiwan, India, Martinique, Sudan, and southern France [[13](#),[112](#),[174](#)]. Chinese tallow was initially introduced to South Carolina in the 1700s. It was more widely introduced starting in the early 1900s due to use as an ornamental and attempts to establish it as a commercial crop [[89](#),[170](#),[197](#)]. In the United States it occurs from North Carolina south to Florida and west through Louisiana and Arkansas to Texas [[13](#),[94](#),[127](#),[128](#),[207](#)]. A single naturalized Chinese tallow was identified at a private residence in Kentucky [[30](#)]. Chinese tallow populations are suspected to occur in Tennessee [[126](#)], but this had not been confirmed [[203](#)] as of this writing (2010). Chinese tallow recently established in Sacramento County and the San Francisco Bay Area of California from ornamental plantings [[15](#),[23](#),[124](#)]. [Plants Database](#) provides a distributional map of Chinese tallow.

**HABITAT TYPES AND PLANT COMMUNITIES:**

Chinese tallow invades several plant communities including Gulf coastal prairies and many types of forests in the southeastern United States. It commonly occurs on disturbed sites such as spoilbanks [[9](#),[10](#),[137](#)], roadsides [[2](#),[118](#),[215](#)], agricultural lands [[146](#)], urban areas [[115](#)], and storm-damaged forests [[36](#),[96](#),[117](#)]. Chinese tallow is also known to occur in riparian areas of central California [[15](#),[124](#)].

Chinese tallow woodland may establish in several habitats. Cameron and Spencer [[27](#)] report scattered sugarberry (*Celtis laevigata*) and black willow (*Salix nigra*) within a Chinese tallow woodland in the coastal prairie region about 35 miles (56 km) southeast of Houston, Texas. Outside of nearby Alvin, Texas, the most common species in Chinese tallow woodland sites of the coastal prairie were sugarberry, yaupon (*Ilex vomitoria*), stiff dogwood (*Cornus foemina*), and American elm (*Ulmus americana*) [[19](#)]. However, their density and cover were much lower (maximum 93

stems/ha, combined covers <2% for all stands) than that of Chinese tallow (up to 4,432 stems/ha, several stands with cover >80%) [18,19]. In forested habitat of South Carolina's Bull Island, Chinese tallow, cabbage palmetto (*Sabal palmetto*), loblolly pine (*Pinus taeda*), redbay (*Persea borbonia*), and in some areas southern bayberry (*Morella cerifera*) were codominants. Chinese tallow dominated-stands had a dense shrub layer (9,689 stems/ha), of which 79% (7,656 stems/ha) were Chinese tallow stems. American beautyberry (*Callicarpa americana*) (625 stems/ha) and dwarf palmetto (*S. minor*) (469 stems/ha) were the next most common shrubs [81]. Jubinsky [92] reported high densities of Chinese tallow in wetlands and along the shore of Lake Jackson in Florida. Despite it only being present at the site for approximately 20 years, Chinese tallow had the highest density (0.452/m<sup>2</sup>), the highest relative frequency (0.636), and the second highest mean DBH-based cover (6.69 cm<sup>2</sup>/m<sup>2</sup>) of woody species. The only species with more cover was sweetgum (*Liquidambar styraciflua*), and neither sweetgum nor any other woody species present, which included American black elderberry (*Sambucus nigra* subsp. *canadensis*), oaks (*Quercus* spp.), black willow, and stiff dogwood, had densities greater than 0.055/m<sup>2</sup> [92]. The extent to which Chinese tallow invades other wet [92,132] and riparian [138] forests is discussed below.

Chinese tallow invades grassland communities [199] and is especially successful in coastal prairies [19,67]. In these areas bluestems (*Andropogon* spp. and *Schizachyrium* spp.), blazing stars (*Liatris* spp.), coneflowers (*Echinacea* spp.), and prairie coneflowers (*Ratibida* spp.) occur with cordgrasses (*Spartina* spp.), morning glories (*Ipomoea* spp.), pine lilies (*Alophia drummondii* spp.), and sundews (*Drosera* spp.) [67]. As Chinese tallow invades, graminoid cover declines [19]. Kincaid and Cameron [97] reported Chinese tallow in 2 categories of coastal prairie. In one type it occurred with goldenrods (*Solidago* spp.). The second type included little bluestem (*Schizachyrium scoparium*), groundsel-tree (*Baccharis halimifolia*), southern dewberry (*Rubus trivialis*), blue mistflower (*Conoclinium coelestinum*), gulf cordgrass (*Spartina spartinae*), and bushy bluestem (*Andropogon glomeratus*), in addition to goldenrods [97]. Density of Chinese tallow trees larger than 1.6 feet (0.5 m) tall in a grass-sedge (*Carex* spp.) meadow typical of southern bogs was 13 stems/ha [200]. Trees were sparse and included longleaf pine (*P. palustris*), loblolly pine, black tupelo (*Nyssa sylvatica*), sweetgum, and sweetbay (*Magnolia virginiana*). The dominant grass was little bluestem. Sundews, tenangle pipewort (*Eriocaulon decangulare*), clubmosses (*Lycopodium* spp.), coastal plain yelloweyed grass (*Xyris ambigua*), and sedges such as beaksedge (*Rhynchospora* spp.) and hairy umbrella-sedge (*Fuirena squarrosa*) were common [200]. Examples of dominant species of coastal interdunal swales in Florida that are invaded by Chinese tallow include southern umbrella-sedge (*F. scirpoidea*), Atlantic St Johnswort (*Hypericum reductum*), Carolina redroot (*Lachnanthes caroliana*), spadeleaf (*Centella asiatica*), Elliott's yelloweyed grass (*Xyris elliotii*), and broomsedge bluestem (*A. virginicus*) [57].

Chinese tallow invades several woodland types in southeastern United States, including bottomland hardwood [146,212], floodplain [73,77,153], riparian [138], pine [146,163] and mixed [77,81,146,151,163] woodlands. Typical associated species include baldcypress (*Taxodium distichum*) [37,47,77,136,146], water tupelo (*N. aquatica*) [37,47,77,146], red maple (*Acer rubrum*) [47,77,146,212], sugarberry, black willow [132,136,212], hawthorns (*Crataegus* spp.) [132,136,163], sweetgum [73,77,138,151,163], and loblolly pine [77,81,146,151,163]. In a Louisiana bottomland forest [212] and in forests on Cheniers of southwestern Louisiana [132], Chinese tallow occurred with several species including live oak (*Quercus virginiana*), sugarberry, black willow, and common persimmon (*Diospyros virginiana*). In the floodplain of the Neches River in Texas, Chinese tallow, water tupelo, river birch (*Betula nigra*), water oak (*Q. nigra*), and redbay were establishing in a longleaf pine/bluestem stand where fire had been excluded in Village Creek State Park [153], and Chinese tallow occurred with sweetgum, deciduous holly (*Ilex decidua*), swamp chestnut oak (*Q. michauxii*), water oak (*Q. nigra*), and American hornbeam (*Carpinus caroliniana*) in the Big Thicket National Preserve [73,77]. In oak-elm (*Ulmus* spp.) riparian forests at the Armand Bayou Nature Center in Texas, Chinese tallow, sweetgum, yaupon, and American beautyberry were more likely to occur in western plots than eastern plots [138]. Chinese tallow trees from 0.4 to 4.0 inches (1-10 cm) in diameter occurred with baldcypress, black willow, sugarberry, sycamore (*Platanus occidentalis*), green ash (*Fraxinus pennsylvanica*), common persimmon, planertree (*Planera aquatica*), water hickory (*Carya aquatica*), and/or hawthorns in 3 communities along the Trinity River in Texas [136]. In the Big Branch March National Wildlife Refuge, Chinese tallow occurred with Jesuit's bark (*Iva frutescens*), saltwater false willow (*B. angustifolia*), southern bayberry, dwarf palmetto, and groundsel-tree in areas of the slash pine/saltmeadow cordgrass-black rush-switchgrass (*Pinus elliotii* var. *elliotii*/*Spartina patens*-*Juncus roemerianus*-*Panicum virgatum*) association with infrequent fire [163]. In mixed woodlands, Chinese tallow commonly occurs with loblolly pine [77,151,163], sweetgum [77,151,163], and oaks such as live oak, laurel oak (*Q. laurifolia*) [151], water oak, white oak (*Q. alba*) [77], southern red oak (*Q. falcata*), and/or bottomland post oak (*Q.*

*similis*) [163]. Renne and others [151] observed few Chinese tallow trees in a longleaf pine-turkey oak (*Q. laevis*) forest of Georgetown County, South Carolina. Although rare, Chinese tallow was present in an oak-hickory-pine forest of Big Thicket National Preserve in Texas [77].

Chinese tallow occurred in southern bayberry floating marsh thickets in coastal Louisiana. Common species in the understory included bryophytes, eastern marsh fern (*Thelypteris palustris*), and maidencane (*Panicum hemitomon*) [10,137]. Chinese tallow occurrence was significantly ( $P < 0.0001$ ) positively associated with southern bayberry in a floating marsh community dominated by bulltongue arrowhead (*Sagittaria lancifolia*) and maidencane with areas of dense southern bayberry [11].

In California, Chinese tallow is known to occur in riparian areas [24] including those adjacent to the American [15,124], Sacramento, and San Joaquin rivers [15]. Chinese tallow has established at North Davis Pond, a constructed wetland that drains into the Sacramento-San Joaquin River Delta and is dominated by narrowleaf willow (*Salix exigua*), Goodding's willow (*S. gooddingii*), boxelder (*Acer negundo*), and Fremont cottonwood (*Populus fremontii*) [15]. Chinese tallow occurs in a wildland preserve adjacent to housing along the American River; the vegetation is dominated by valley oak (*Q. lobata*), Fremont cottonwood, Oregon ash (*Fraxinus latifolia*), and California boxelder (*A. negundo* var. *californicum*). Along with native poison-oak (*Toxicodendron diversiloba*), nonnative species including giant reed (*Arundo donax*), poison hemlock (*Conium maculatum*), Himalayan blackberry (*Rubus discolor*), and bigleaf periwinkle (*Vinca major*) form the understory [124].

## BOTANICAL AND ECOLOGICAL CHARACTERISTICS

SPECIES: *Triadica sebifera*

- [GENERAL BOTANICAL CHARACTERISTICS](#)
- [SEASONAL DEVELOPMENT](#)
- [REGENERATION PROCESSES](#)
- [SITE CHARACTERISTICS](#)
- [SUCCESSIONAL STATUS](#)



Photo by Chuck Barger, The University of Georgia, IPM images

### GENERAL BOTANICAL CHARACTERISTICS:

- [Botanical description](#)
- [Raunkiaer life form](#)

**Botanical description:** This description provides characteristics that may be relevant to fire ecology and is not meant for identification. Keys for identification are available (e.g., [63,145,214]).

Chinese tallow is a quick-growing, deciduous tree capable of root and basal sprouting [52,63,67,112,126,170]. It typically grows from 24 to 35 feet (7-11 m) tall [125,210], but individuals up to 65 feet (20 m) tall and over 3 feet (1

m) in diameter have been reported [69]. Chinese tallow leaves are alternate, simple, and typically oval to round [112,113], but they may also be rhombic [112]. They range from 1.4 to 3.3 inches (3.5-8.5 cm) long and from 1.4 to 3.5 inches (3.5-9.0 cm) wide [112,145]. The length of petioles ranges from 0.6 to 3.5 inches (1.5-9.0 cm) [112]. Sharma and others [174] found a maximum leaf area of 2.7 inches<sup>2</sup> (SD 0.2) (17.36 cm<sup>2</sup> (SD 1.23)) and mature leaf moisture content of 66.3% (SD 1.3) before leaf fall. Trunks may be gnarled [112] with fissured bark [126] that thickens as the tree grows [67]. Tiny, imperfect flowers occur in terminal spikes 2.4 to 7.9 inches (6-20 cm) long, with fascicles of up to 5 pistillate flowers near the base and fascicles of up to 15 staminate flowers along the spike [52,62,63,112,126,145]. Fruits are capsules about 9.5 to 19 mm in diameter [112,126]. They contain 3 wax-coated seeds about 6 to 10 mm long and 4.3 to 6.1 mm wide [112,126].

Little information regarding belowground features of Chinese tallow is available. However, Nijjer and others [134] observed greater colonization of Chinese tallow roots with arbuscular mycorrhizae than native tree species such as black tupelo and water oak.

The lifespan of Chinese tallow stems seems to be less than 100 years, although roots may live longer [89]. Scheld and others [169] report that Chinese tallow is short-lived, surviving 40 to 50 years. Grace and others [69] state that Chinese tallow over 50 years old become "somewhat senescent".

**Allelopathy:** [Allelopathic](#) effects of Chinese tallow appear limited. Chinese tallow extracts have not been shown to have an allelopathic effect on little bluestem [95,164], black willow [39], baldcypress [39,42], or sweetgum [86,164]. Effects of exposure to Chinese tallow extracts on sweetgum, little bluestem, King ranch bluestem (*Bothriochloa ischaemum* var. *ischaemum*), and perennial ryegrass (*Lolium perenne*) did not differ from effect of exposure to extracts from sweetgum, silver maple (*Acer saccharinum*), and sycamore [86]. Little bluestem exposed to Chinese tallow extracts exhibited significantly ( $P<0.05$ ) larger mass [95]. Baldcypress exposed to Chinese tallow extracts exhibited increased germination rates and/or growth, although variation was observed across seasons and source of extracts (leaves, litter, and soil). Chinese tallow also had consistently higher germination and growth rates in Chinese tallow-exposed treatments, which suggests that at least in some communities, increased performance of tallow itself may be more important in the species' success than limiting the success of other species [42]. There is some evidence that Chinese tallow extracts have a negative effect on loblolly pine germination and seedling growth [71].

### **Raunkiaer [148] life form:**

[Phanerophyte](#)

### SEASONAL DEVELOPMENT:

Chinese tallow flowers from April until June and produces fruit from August to January in the southeastern United States [126,145]. Chinese tallow seeds planted in the field in northern Florida started germinating at the end of February, and germination peaked in mid-March [21,167] and mid-April. Chinese tallow seeds of varying ages exhibited the greatest germination rates when planted in greenhouses in January or February [25] (see [table](#) for more details). May was the latest seeds were observed germinating in northern Florida [21].

### REGENERATION PROCESSES:

- [Pollination and breeding system](#)
  - [Seed production](#)
  - [Seed dispersal](#)
  - [Seed banking](#)
  - [Germination](#)
    - [Environmental factors](#)
    - [Seed characteristics](#)
  - [Seedling establishment](#)
  - [Plant growth](#)
-

## Vegetative regeneration

Chinese tallow regenerates by seed and by sprouting from the roots, particularly after incurring damage.

**Pollination and breeding system:** Imperfect flowers of both sexes occur in the same inflorescence [52,62,63,112,126,145]. There are 2 inflorescence types, called "grape-like" and "eagle claw", which differ in morphology and development [20,112].

Mechanisms of Chinese tallow pollination are uncertain. A fact sheet asserts that Chinese tallow is wind pollinated [54]. However, Chinese tallow is a honey tree used by beekeepers [126] and was the dominant pollen in 1 of 7 samples examined in Louisiana [110]. The extent to which bees, other insects, and/or wind pollinate Chinese tallow has not been investigated.

**Seed production:** Chinese tallow likely begins producing seed when 3 to 8 years old [51,171,208]. Scheld and others [168] noted that about 50% of Chinese tallow populations developed flowers in their third growing season. Some Chinese tallow seeds planted in a greenhouse reached maturity in a year (Grace 1977 personal communication in [208]). Near the border of Pakistan and India, 16% of a population of Chinese tallow in waterlogged conditions flowered in their 3rd year, while those on agricultural land flowered in their 4th year [191].

Chinese tallow can produce large amounts of seed. Tree age, inflorescences type, and habitat influence seed production. Average yields of Chinese tallow in Taiwan were approximately 1 pound (0.5 kg) for 5-year-old trees, 7.4 pounds (3.4 kg) for 10-year-old trees, and a maximum of approximately 26.4 pounds (12.0 kg) for 20-year-old trees. Mean seed weight over all sites for seeds from "eagle claw" inflorescences was 0.112 g and from "grape like" inflorescences was 0.121 g, giving an approximate average seed production of 100,000 seeds from a 20-year-old tree [112]. In northern India seed production ranged from 3,276 seeds in a tree with a diameter of 2.4 inches (6 cm) to 45,276 seeds in a tree with a diameter of 8.0 inches (20.4 cm) [174].

Mean Chinese tallow seed crop in a 16,900-foot<sup>2</sup> (1,570 m<sup>2</sup>) area of coastal South Carolina was estimated at 1,681,000 seeds [151]. In a Chinese tallow-dominated forest in southeastern Texas, estimated Chinese tallow seed production was 327,670 seeds/year or 273 seeds/m<sup>2</sup>/year. Dominance in seed input may explain Chinese tallow's dominance in the understory, since Chinese tallow had a lower seedling establishment rate (seedling:seed) than native species [186]. In 2007, Chinese tallow trees on a riparian site in central California had fruit loads similar to those of horticultural trees in Davis, Woodland, and West Sacramento, California, averaging 39,538 seeds/tree. Viability of evaluated seeds from horticultural trees was 95% [15]. According to the Woody Plant Seed Manual, Chinese tallow seed viability is 90% (Bonner 1974 cited in [14]).

**Seed dispersal:** Chinese tallow seeds are dispersed by water ([167], reviews by [20,92]) and birds [15,41,150,151,167]. Chinese tallow seeds soaked in water for 30 days had higher germination rates than unsoaked seeds. Chinese tallow germination rates in flooded northern Florida prairies were greater than those in nearby forested habitats that were not flooded, suggesting that water dispersal of Chinese tallow seeds may have contributed to Chinese tallow invasion of the prairie habitat [167]. Birds removed an estimated 675,000 (SD 56,000) Chinese tallow seeds (about 40% of the total seed crop) in a South Carolina study area [151].

Conway and others [41] observed 24 different bird species eating Chinese tallow seeds in coastal Texas; Renne and others [151] saw 14 species feeding on Chinese tallow seeds in South Carolina; and Samuels [167] reported 21 bird species dispersing Chinese tallow seeds away from parent trees in northern Florida. Red-bellied woodpeckers, northern cardinals, northern flickers, and red-winged blackbirds are common dispersal agents in the Southeast [41,150,151,167]. Eight species were observed consuming Chinese tallow fruits in riparian areas of central California, including American robins, European starlings, cedar waxwings, and northern flickers [15].

**Seed banking:** Chinese tallow apparently produces a seed bank that persists for at least a short period [69]. No significant difference in germination rates was observed between seeds buried for 1 year and those buried for 2 years. Germination rates of seeds that had been buried for 1 and 2 years ranged from about 15% to 55% across habitat types.

In the maritime evergreen forest, however, which has a comparatively open overstory of loblolly pine and live oak and high densities of shrubs and vines in the understory, seeds buried for 2 years had significantly ( $P=0.0077$ ) higher germination rates than seeds buried for 1 year [152]. In contrast, second-year germination did not occur at all on 4 of 8 sites in South Carolina, and only 2 sites had more than 1 seed germinate in the second year [139]. Jubinsky (Jubinsky unpublished data cited in [20]) observed Chinese tallow seedlings "emerging from seeds in the soil" 5 years after herbicide treatment of Chinese tallow began, suggesting persistence of Chinese tallow seeds in the soil seed bank. Chinese tallow seeds germinated in a greenhouse after 7 years of cold storage at 32 to 39 °F (0-4 °C), reaching a maximum germination rate after 2 years storage (see [table](#) below for more detail) [25]. Chinese tallow emergence declined significantly ( $P=0.0001$ ) after 1 year of storage in a paper bag placed in a sheltered area outdoors [152].

**Germination:** Chinese tallow germination and time to germination are influenced by season of planting, digestion by birds, site characteristics, and seed characteristics. This results in a wide range of reported germination rates both across and within studies. For instance, Conway and others [40] did not obtain germination rates higher than 10% from ripe seeds collected in fall that were either soaked in cold water, soaked and chilled, or not subject to any pretreatments, while germination rates observed by Cameron and others [25] ranged from 0% to 94%. Chinese tallow germination rates ranged from about 13% to 80% in a greenhouse experiment investigating the effects of bird consumption and seed burial on Chinese tallow germination [152]. Germination of Chinese tallow seeds in various treatments and at varying elevations above water level at a riparian site in central California ranged from 6.1% to 68.3%. Sixty-five percent of ungerminated seeds were viable at the end of the experiment, suggesting a longer experimental period would have resulted in greater germination rates [15].

Germination of native species is typically similar to or higher than Chinese tallow germination and may occur over a broader range of conditions [18,133]. However, regardless of comparatively low germination rates, including rates below 10% [40,41] or 15% [133], high seed production may cause difficulties in controlling Chinese tallow invasions [40]. In areas where Chinese tallow is already present, the possibility of increased germination of Chinese tallow seeds [39,42] compared to germination of seeds of native species causes additional concern. However, success of Chinese tallow seedlings in closed-canopy Chinese tallow woodlands may be low [18,186].

Digestion by birds likely enhances germination of Chinese tallow seeds [15,152,167,192]. In a greenhouse experiment, 51% of seeds that passed through an avian digestive tract germinated, significantly ( $P<0.0001$ ) more than the 22.5% germination rate of seeds that had no evidence of being manipulated by birds. There was an interaction between burial and digestion ( $P<0.0005$ ), with digested seeds that were buried exhibiting 81% germination compared to about 15% to 30% germination rates in other treatment combinations. Cumulative emergence of digested seeds was 76.5%, significantly ( $P\leq 0.0003$ ) greater than the 39.5% cumulative emergence of unmanipulated seeds [152]. Lack of a difference in germination between uneaten seeds collected after yellow-warbler feeding activities and those collected from trees [41] indicates that digestion of the seed, not manipulated by the birds, results in enhanced germination. Effects of digestion by birds on Chinese tallow seeds collected from areas around Davis, California was simulated by soaking in sulfuric acid. The germination rate of these seeds was significantly ( $P<0.05$ ) higher than germination of seeds removed from trees [15]. Sulfuric acid treatment also exhibited the fastest mean time for germination (36.4 days) of all treatments. However, exposure to sulfuric acid for more than 10 minutes resulted in significant ( $P<0.05$ ) decreases in germination compared to a 10-minute treatment. A 62.3% germination rate was observed in seeds that had their tallow coating completely removed, while seeds in the treatment where the coating was split exhibited 17.3% germination [192].

**Environmental factors:** Light availability, ambient temperature, water immersion, burial, and site characteristics likely influence Chinese tallow germination.

The effect of time of planting and associated light conditions on Chinese tallow germination differs between studies. Nijjer and others [133] note that germination of Chinese tallow seeds in the field peaks in April and May [133]. Similarly, seeds planted at Lake Jackson began germinating in February, and germination peaked in mid-March and in mid-April [21]. In contrast, germination of Chinese tallow seeds collected near the Pakistan-India border and planted either in February or in May was about 60% after 60 days [191]. In a greenhouse with "natural" photoperiod and temperature, average germination rates (58%-59%) observed 120 days after planting in January and February were significantly ( $P<0.001$ ) greater than rates seeds buried in early spring or late fall (21%-46%). Several benefits of

winter germination are suggested, including decreased activity of possible seed predators, increased light due to a more open canopy, and decreased interspecific competition for nutrients or light due to fewer annuals and dormancy in perennials [25]. However, about 15% germination was observed in light and dark treatments, significantly ( $P < 0.05$ ) higher than Chinese tallow germination [133].

Chinese tallow germination is likely greater under variable temperature regimes than with constant temperatures [133]. Given that temperature fluctuations occur more often in open areas, such as canopy gaps, it is suggested that Chinese tallow may have higher germination in disturbed habitats [133]. In the coastal prairie of eastern Texas, Chinese tallow seedling emergence was significantly higher ( $P < 0.05$ ) in experimental plots without mulch than on sites with 2 inches (5 cm) of Chinese tallow mulch. Cumulative seedling emergence on sites with 2 inches of mulch was greater ( $P < 0.05$ ) than on sites with 4 inches (10 cm) or 6 inches (15 cm) of mulch. From 9 April to 14 April, soil temperatures on sites with no mulch varied about 16 to 23 °F (11-13 °C) daily; temperatures on sites with 2 inches of Chinese tallow mulch varied about 5 to 10 °F (3-4 °C) daily; and those on sites with 4 or 6 inches of Chinese tallow mulch varied about 1 to 6 °F (1-3 °C) daily [49]. A complementary laboratory study found greater germination of Chinese tallow seeds subject to fluctuating temperature regimes compared to seeds exposed to constant temperatures, with no consistent trends related to mulch depths within temperature treatments (Donahue 2004 cited in [49]).

Studies investigating the impact of water immersion on Chinese tallow germination in which seeds were soaked for 192 hours or less did not find significant effects [40,192]. In contrast, Chinese tallow seeds soaked in water for 30 days and either placed in a shade-house or in prairie habitat in northern Florida had significantly ( $P < 0.001$ ) greater germination rates than acid-treated seeds in the shade-house or prairie habitat [167].

Burial increases germination of Chinese tallow seeds [152,167]. In a greenhouse experiment, seeds buried to a depth of 0.4 inch (1 cm) exhibited a 56% germination rate, while only 17.5% of seeds placed on the soil surface germinated ( $P < 0.0001$ ). Buried seeds began germinating after about 7 days, significantly ( $P < 0.05$ ) faster than digested surface-sown seeds (13.1 days) or unmanipulated surface-sown seeds (42.2 days) [152]. For information on the interaction of digestion and burial, see the paragraph on effects of [digestion](#). Germination of Chinese tallow seeds placed on the soil or litter surface following acid treatment ranged from 0% to 20%, depending on the habitat or soil source [167].

Several site factors likely influence Chinese tallow germination rates including elevation, soil temperature and moisture, community composition, and litter characteristics. In a central California riparian area, Chinese tallow germination was significantly ( $P < 0.05$ ) greater at elevations less than 7.5 feet (2.3 m) above water level compared to 15 feet (4.6 m) above water level. Soil temperature ( $P = 0.045$ ) and electrical conductivity ( $P = 0.039$ ) had significant positive effects on germination. Germination rates were lower ( $P = 0.042$ ) on south facing slopes, possibly due to drier soils [15]. In the Lake Jackson area of northern Florida, germination rates differed significantly ( $P < 0.001$ ) over a 3-foot (1 m) elevational gradient, with higher germination rates at high and intermediate portions of this gradient compared to the low end of the gradient. Although germination rates on sites with Chinese tallow in this area were slightly higher than those without Chinese tallow, the difference was not significant [21]. Chinese tallow germination was lower ( $P = 0.07$ ) on herbaceous marsh substrates than on soil from southern bayberry thickets from Barataria Preserve just south of New Orleans, Louisiana [11]. In a shade house, acid-treated seeds had significantly ( $P < 0.05$ ) higher germination in soils from prairie than in mixed pine-hardwood or oak hammock habitats of northern Florida. Acid-treated seed placed in shaded wet prairie had significantly ( $P < 0.05$ ) greater germination than acid-treated seeds placed on the litter in mixed pine-hardwood or oak hammock habitats. Samuels [167] suggested that the general trend of greater germination in prairie soil was primarily due to forest litter providing a drier germination substrate. Watering frequency had no significant effect on germination in a greenhouse experiment [18].

**Seed characteristics** Seed source has been shown to have a large effect on Chinese tallow germination rates. Seeds from 3 areas of northern India exhibited significant ( $P = 0.001$ ) differences in germination [192]. Germination rate of Chinese tallow seeds from Florida was significantly higher than seeds from the 4 other source locations investigated, while germination rates of seeds from Houston, Taiwan, and Georgia were significantly higher than those of seeds from South Carolina. Differences in developmental stage of seeds from plants at different latitudes and/or site factors are possible explanations for these trends. The following table displays total germination rates for seeds from these areas [25].

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Germination rates (SE) of Chinese tallow seed from different locations after 120 days [25]

Locality	<i>n</i>	Total percent germinated
Florida	9	52.4 (5.9)
Houston	53	24.3 (2.7)
Taiwan	36	28.8 (3.3)
Georgia	9	30.9 (6.3)
South Carolina	15	5.7 (3.1)

Chinese tallow seed size and length of time in storage also affect germination. Large seeds had significantly ( $P < 0.05$ ) higher germination rates ( $\geq 0.15$  g = 87.1%) than medium (0.1-0.14 g = 35.4%) and small seeds ( $< 0.1$  g = 10.4%) [192]. In a greenhouse experiment, 75.3% of freshly collected Chinese tallow seeds emerged, significantly ( $P = 0.0001$ ) more than the 44.5% cumulative emergence of 1-year-old seeds that had been stored in a paper bag in a sheltered outdoor location in northwestern South Carolina [152]. In another greenhouse experiment, length of seed storage has significant ( $P < 0.0001$ ) negative effects on Chinese tallow germination. After 4 to 5 years cold, dry, storage, mean germination rate started falling and by 7 years was 12% or less. The following table shows Chinese tallow germination rates for seeds of varying ages planted at different times of the year in a greenhouse; the interaction between these variables was significant ( $P < 0.0004$ ) [25].

Germination rates (SE) for Chinese tallow seed stored for 0 to 7 years 120 days after planting date [25]

Age (yrs) of seeds	Date of Planting					
	Nov 2	Nov 30	Jan 2	Feb 1	Mar 6	Apr 5
7	0	0	12 (3.7)	6 (2.5)	2 (2.0)	0
5	18 (8.0)	48 (5.8)	52 (13.6)	36 (22.3)	20 (3.2)	20 (5.5)
4	36 (9.3)	60 (8.4)	64 (5.1)	80 (4.5)	40 (5.5)	28 (7.3)
2	44 (9.3)	82 (3.7)	94 (2.5)	84 (4.0)	76 (7.5)	46 (7.5)
0	8 (5.8)	40 (4.5)	66 (6.8)	92 (5.8)	40 (8.4)	14 (4.0)

**Seedling establishment:** Chinese tallow seedlings are capable of quick growth and are able to survive in a variety of conditions. Seedlings that emerged up to 15 weeks after planting exhibited survival rates from 80% to 100% [34].

Presence of certain species on a site may influence Chinese tallow seedling success. Chinese tallow seedling emergence in the understory of Chinese tallow woodlands of coastal Texas averaged 4.3% of sown Chinese tallow seeds, and average survival of these seedlings was 19%, which was less than sugarberry [186]. In a pot experiment, survival and biomass of Chinese tallow seedlings were significantly ( $P < 0.05$ ) lower in soil collected near conspecifics in the Big Thicket National Preserve than in soil collected near different species in the same area. Success of Chinese tallow in Chinese tallow soil that was sterilized or had fungicide applied suggests that fungi in soil from Chinese tallow woodland reduced seedling performance [135]. Jones [88] found that after 42 days, the species growing with Chinese tallow had a significant ( $P < 0.01$ ) effect on Chinese tallow seedling biomass, with seedlings in Chinese tallow-only pots smaller than those in grown in mixed-species pots. After 96 days there was no longer a significant difference between Chinese tallow seedlings in inter- and intraspecific treatments [88]. In the Lake Jackson area of northern Florida, seedling survival was not significantly influenced by the presence of Chinese tallow [21]. Association with Chinese tallow plants does not consistently reduce growth, however. Chinese tallow had consistently higher germination and growth rates when exposed to Chinese tallow extracts in a laboratory experiment [42].

Planting Chinese tallow from Texas with Italian ryegrass (*Lolium multiflorum*) had no significant effect on shoot growth, shoot mass, or root mass of Chinese tallow seedlings [159]. Roots of nearby plants invading the area containing Chinese tallow roots resulted in a significant ( $P<0.05$ ) decrease in total Chinese tallow seedling mass, total height, and leaf area [91]. Chinese tallow seedling growth rates in greenhouses were significantly greater on substrates collected from southern bayberry thickets of southeast Louisiana than substrates from edges of these thickets ( $P=0.01$ ) or herbaceous marsh areas ( $P=0.05$ ) [11].

Timing of planting did not have a significant effect on seedling emergence or survival [152]. Chinese tallow seedlings emerged throughout the growing season in coastal forests with established Chinese tallow. Seeds planted in December and those planted in February showed no significant difference in total emergence ( $P=0.5308$ ) or number of Chinese tallow seedlings emerged by sampling date ( $P>0.10$ ). Similarly, there was no significant effect of planting date on seedling survival either across habitats ( $P=0.8851$ ) or within habitats ( $P>0.20$ ) [152].

In the Lake Jackson area of northern Florida, seedlings that germinated from seeds planted 82 feet (25 m) above sea level survived for significantly ( $P<0.03$ ) shorter periods than seedlings from seed planted 2 to 3 feet (0.6-1 m) higher. Significantly ( $P<0.017$ ) higher soil moisture at low elevation sites may have contributed to this trend [21].

Root damage (roots cut 2 inches (5 cm) below the soil surface) did not significantly affect stem growth, root mass, or shoot mass of 3- to 5-month-old Chinese tallow seedlings from Texas that were grown in a laboratory [159].

Information on the effects of site characteristics such as water and soil conditions on establishment of Chinese tallow are discussed in the [Site Characteristics](#) section below, while the effect of light is addressed in the [Shade tolerance](#) section.

**Plant growth:** Growth rate of Chinese tallow seedlings has been reported as equal to or greater than many native seedlings in most conditions [18,89,90] and is a factor in its success invading coastal prairies [18]. Growth rates of 0.03 inch (0.08 cm) per day were recorded in canopy gaps of Chinese tallow forest and coastal prairie, and up to 0.13 inch (0.33 cm) per day in cleared grassland plots. In all water treatments, Chinese tallow had one of the highest growth rates and one of the greatest total masses of the 5 species investigated [22]. Average height of Chinese tallow seedlings at the end of the 1991 growing season was 8.7 inches (22 cm) [18]. Chinese tallow planted on a southern Florida site when 10 to 12 inches (25-30 cm) tall grew to 13 feet (4 m) 1.7 years after planting. Coppiced Chinese tallow on the site grew over 26 feet (8 m) in 24 months [154]. Maximum heights of coppiced Chinese tallow in coastal Texas were 11 to 12 feet (3-4 m) 1 year after cutting and over 18 feet (>5.5 m) 2 years after cutting [170].

Invasive Chinese tallow may grow faster than Chinese tallow from its native range. Chinese tallow seedlings from the United States, grown in pot experiments in China, had greater total biomass ( $P<0.003$ ) after 120 days [217] and greater shoot biomass ( $P<0.0001$ ) after about 4 months [218] than Chinese tallow seedlings from China.

The following table shows the mean annual mortality and recruitment rates of small and large Chinese tallow saplings in a 10-acre (4 ha) floodplain forest site along the Neches River in the Big Thicket Preserve, Texas, over 14 years [73].

Mean annual mortality and recruitment rates (fraction of saplings/year) of small and large Chinese tallow saplings in the Big Thicket Preserve, Texas [73]		
	Small saplings (50-140 cm tall)	Large saplings ( $\geq 140$ cm)
Mortality rate	0.100	0.013
Recruitment rate	0.642	0.347

Chinese tallow spreads locally by root sprouts [69,126] and has strong sprouting

## Vegetative regeneration:

capabilities following damage [[20,38,69,126](#)]. Root sprouting up to 16 feet (5 m) from the tree trunk has been reported [[67](#)]. Near the coast in eastern Texas, Chinese tallow sprouted prolifically within a month of cutting [[170](#)]. On an abandoned agricultural field in southern Florida, experimentally planted Chinese tallow coppiced consistently and exhibited 37% survival after 36 months [[154](#)].

## SITE CHARACTERISTICS:

Chinese tallow is most successful in wet, open habitats. It is flood tolerant [[126](#)] and is often found along the shores of water bodies, in floodplains, and in swampy areas [[47,62,63,126,132,214](#)]. However, it also occurs in drier, upland habitats [[62,63,126,152,214](#)]. Chinese tallow invades intact habitats and is successful in disturbed areas [[35,132,193,214](#)]. Thin woodlands, canopy gaps, and open understory appear more easily colonized by Chinese tallow than closed-canopy forests [[52,77,132,138,183](#)]. Although Chinese tallow has been reported to withstand some exposure to freezing temperatures [[154](#)], substantial damage has been observed after 36 hours of below-freezing temperatures [[20](#)]. Chinese tallow distribution is likely limited by cold temperatures in the north [[20,93](#)].

Chinese tallow typically occurs at low elevations [[52,62,63,212](#)] but does grow at higher elevations. In forests of the southern United States, Chinese tallow is most common on low and flat lands. About 80% of invasive Chinese tallow populations in southern forests occur on sites below 165 feet (50 m) and with slopes less than 2°, and all invasive populations occur on sites below 540 feet (165 m) and with slopes of 18° or less [[58](#)]. In the Lake Jackson area of northern Florida, Chinese tallow cover was greatest, typically about 10%, at elevations of 84 to about 89 feet (25.5-27 m) above sea level, and cover was less than 5% outside of this elevational range [[21](#)]. In a southern New Mexico experimental planting, Chinese tallow survived and grew at 3,770 feet (1,150 m) [[100](#)]. Chinese tallow plantations occur at elevations from 1,300 to 2,300 feet (400-700 m) in Taiwan [[112](#)] and from 4,000 to 5,000 feet (1,200-1,600 m) in northern India [[174](#)].

- [Water](#)
- [Temperature](#)
- [Soil](#)
  - [Nutrient supplementation](#)

**Water** Chinese tallow has been reported on sites with average annual precipitation ranging from 9.6 to 147 inches (243-3,733 mm). Average annual precipitation in Chinese tallow-invaded habitats near Houston ranged from 42.1 to 55.9 inches (1,070-1,420 mm) [[183](#)]. In Taiwan average annual precipitation ranges from 52.6 inches to 147 inches (1,336-3,733 mm) in habitats where Chinese tallow occurs [[112](#)]. In plantations in New Mexico that receive average annual precipitation of 9.6 inches (243 mm), Chinese tallow that were irrigated for 2 months after transplanting exhibited 90.6% survival and grew to an average height of 55 inches (140 cm) over 2 growing seasons [[100](#)].

Chinese tallow apparently prefers wet sites, although it does grow in drier areas. Based on logistic regression from sites throughout the Southeast, the probability of invasion of forests by Chinese tallow increases with decreased distance to water. This is likely due to movement of seeds by water, occurrence of bird habitat around water, and soil moisture levels favorable for Chinese tallow establishment [[58](#)]. Chinese tallow exhibited significantly ( $P<0.01$ ) lower seedling survival in treatments with 23% soil moisture compared to treatments with  $\geq 31\%$  soil moisture [[18](#)]. Chinese tallow near the border of India and Pakistan grew taller, had larger stem diameters, and produced seed at an earlier age when planted on a waterlogged site compared to those planted on an agricultural site [[191](#)]. In central California, all Chinese tallow that had established on their own at North Davis Pond occurred within 23 feet (7 m) of the water's edge. Chinese tallow planted  $\geq 3.7$  feet (1.1 m) above the water level of Putah Creek did not survive more than 132 days, while 80% of those planted at water level survived a summer drought [[15](#)]. Chinese tallow was less abundant on dry sites in Gulf Coast forests [[77](#)] and in a dry pine-turkey oak community in coastal South Carolina [[152](#)] than on more moist sites or in communities nearby.

Chinese tallow can survive dry periods, although growth may be impacted. In eastern Texas coastal prairies, Chinese tallow that received ambient precipitation survived significantly ( $P<0.05$ ) longer than Chinese tallow in plots where pumps removed surface water following large rain events [[189](#)]. Chinese tallow in a greenhouse survived and grew

when watered monthly. However, significantly ( $P=0.0001$ ) larger total plant biomass was observed in more frequently watered plants [8]. In another greenhouse experiment, an intermittent drought treatment did not have significant impacts on growth rate or the total mass of Chinese tallow [22]. Scheld and Cowles [170] attribute Chinese tallow survival during dry periods to rapid taproot development.

Chinese tallow survives and grows in most flooding conditions, although Chinese tallow in drained soils generally have significantly ( $P<0.05$ ) smaller root biomass and significantly ( $P<0.05$ ) larger heights, stem diameters, and leaf biomass [31,32,34,91]. Chinese tallow may produce hypertrophied lenticels, adventitious roots, and thicker feeder roots when flooded [31,91]. Flooding duration did not have a significant effect on Chinese tallow survival ( $P>0.31$ ) or mass ( $P>0.35$ ) in a floodplain forest where flooding depths ranged from 8 to 20 inches (20-52 cm) and flooding duration ranged from 14 to 61 days [183]. Chinese tallow trees in drained soil exhibit significantly ( $P=0.0001$ ) increased photosynthesis compared to flooded (to 2.0 inches (5 cm) above the soil surface) plants [122]. The reduction in Chinese tallow size due to flooding to 1.0 inch (2.5 cm) above the soil surface was significantly ( $P<0.0001$ ) larger than the reduction in water tupelo under 100% light but not under 20% light ( $P>0.03$ ) [91]. In a greenhouse experiment, flooding to 0.4 to 1 inch (1-3 cm) for 16 weeks significantly ( $P<0.05$ ) decreased Chinese tallow growth rate. This and a treatment consisting of daily watering for 2 weeks followed by flooding for 2 weeks repeated over 16 weeks resulted in significant ( $P<0.05$ ) declines in Chinese tallow mass [22]. Greenhouse experiments in coastal Texas and east-central China showed that Chinese tallow seedling growth rate, leaf, shoot, and total biomass were significantly greater in soils that were not flooded compared to soils flooded to 0.4 inch (1 cm) above the soil surface [219].

Chinese tallow tolerates moderate levels of salinity [31,33,122], with younger plants [31,122], plants exposed for longer periods [31,33,122], and plants exposed to greater salinities the most negatively impacted [31,122]. All 4-month-old Chinese tallow trees died after 6 weeks exposure to 10 ppt saline water, while no mortality occurred over an 8-week period in a group of 5.5-month-old Chinese tallow trees exposed to the same conditions [31]. Chinese tallow was only slightly affected by saline (20-27 ppt) flooding of up to 2 days, and after 5 days survival was 60% [33]. No Chinese tallow mortality was reported following simulated storm surge treatments of 21 ppt salinity lasting 48 hours. Tip dieback did occur, mainly in plants that were flooded with freshwater before the simulation [31,32]. Chinese tallow watered with 10 ppt saline water had significantly ( $P<0.05$ ) reduced height [32], photosynthesis [122], and stem and root biomass [31] than those watered with less saline water (2 ppt) or freshwater.

**Temperature:** Chinese tallow establishment and persistence are restricted by freezing temperatures in the north [20,58,93]. The average extreme minimum January temperature was associated with the probability of invasion of southern forests, with no Chinese tallow invasion detected on sites with average extreme minimum January temperatures below 10 °F (-12 °C) [58]. In open-canopy habitats and closed-canopy uplands along the east coast, germination rates of Chinese tallow were positively correlated with mean minimum temperature in January 2001 ( $P<0.05$ ) [141]. Seeds from North Carolina planted in fall had higher germination rates than seed from South Carolina planted in fall. Seedlings from North Carolina were more likely to survive extended periods (6-384 hours) of freezing temperatures ((19 °F) -7 °C) ( $P=0.04$ ) and had significantly less height loss from November to April ( $P=0.02$ ) than Chinese tallow seedlings from South Carolina. However, seedlings from North Carolina and South Carolina did not differ in survival or date of budbreak. About 70% to 80% of Chinese tallow seedlings from North Carolina and South Carolina survived exposure to 23 °F (-5 °C) for 6 hours [139]. Rockwood and Geary [154] report Chinese tallow survival after a December 1983 freeze, and Grace and others [69] note Chinese tallow growth after damage from exposure to cold temperatures. However, Chinese tallow suffered substantial damage after exposure to freezing temperatures for 36 hours. From these observations and a distributional map, the authors conclude that the northern boundary of Chinese tallow spread is in the 7b zone (average minimum winter temps of 5 °F to 10 °F (-12 to -15 °C)) of the USDA Plant Hardiness Zone map [69].

A warming climate is expected to increase the range and severity of Chinese tallow invasion, especially if coupled with increased occurrence and intensity of disturbance. Based on Forest Inventory and Analysis data from southern forests, a 36 °F (2 °C) increase in temperature was projected to result in low levels of invasion into central and northern Alabama and Mississippi and further east into Texas and increased invasion rates in most of southern Louisiana and parts of southern Mississippi and southeastern Texas [58]. Based on the climate in Chinese tallow's native and introduced range and results of seeding and planting trials in the eastern United States, a CLIMEX model predicts that Chinese tallow's potential distribution would extend from New Jersey west through southern portions of Pennsylvania,

Ohio, Indiana, and Illinois to central Missouri and southeastern Kansas with a 2 °C increase in maximum and minimum daily temperatures [140].

**Soil:** Chinese tallow occurs in a wide range of soil types. It occupies sites with acidic to slightly basic soils. Soil pH ranged from 3.9 to 8.5 in Chinese tallow plantations in Taiwan [112]. Values of pH on sites with Chinese tallow in India [116,131], Texas [200], and soil used in an experiment [34] were within this range. Chinese tallow grows on a wide range of soil textures from clays [18,170] to loams [18,131] to sandy [84,145] soils. Nutrient levels in soil from Chinese tallow plantations in Taiwan [112] and India [116,131] are available.

Chinese tallow is tolerant of slightly saline soils [112,126,170]. Chinese tallow was present in a southeastern Louisiana community type with significantly ( $P<0.05$ ) greater soil salinity in 4 years of a 5-year study than in 3 community types where Chinese tallow did not occur. Salinity ranged from just over 1 ppt to over 4 ppt in a drought year [83]. In field experiments, Chinese tallow had lower mortality and better growth on eastern and central coastal prairie sites with electrical conductivities  $\mu\text{S}$  to 634  $\mu\text{S}$  compared to Chinese tallow on western sites with mean electrical conductivity of 3070  $\mu\text{S}$ . Although other factors may have influenced this pattern, a likely cause is high salinity on the western sites [8].

**Nutrient supplementation:** Fertilizer may increase Chinese tallow survival, occurrence, and size, which may facilitate establishment in areas where nutrients have been added [187,189]. In a tallgrass coastal prairie of Texas with encroaching woody species such as Chinese tallow and Rio Grande dewberry (*Rubus riograndis*), addition of fertilizer was positively associated ( $P=0.09$ ) with percentage of woody species [80]. In eastern Texas coastal prairie, Chinese tallow in plots fertilized with nitrogen, phosphorus, and potassium survived longer ( $P<0.05$ ) than in plots that were not fertilized [189]. However, in another study in the same area, nitrogen addition did not affect Chinese tallow survival [182,187]. Chinese tallow height [157,158,189], diameter [157], aboveground biomass [134,189], shoot mass [157,158], root mass [157], and individual plant mass [157,182] have been shown to increase with nutrient supplementation. Mean leaf area ( $P\leq 0.0006$ ) [156,158] and individual leaf mass ( $P<0.0001$ ) [156] were significantly increased with increased nitrogen. In contrast, in 2 greenhouse studies Chinese tallow shoot mass [158,159], root mass [159], diameter growth [158], and stem growth [159] were not significantly influenced by addition of fertilizer. The effects of nitrogen and shade have been the topic of several studies [157,158,182], and their results regarding the effect of shade and the interaction of nitrogen addition and shade are summarized in the [Shade tolerance](#) section.

#### SUCCESSIONAL STATUS:

Although Chinese tallow occurs in undisturbed areas, it is more common on disturbed sites. In forests of the southern United States, Chinese tallow is common adjacent to roadways, recently harvested sites, and sites disturbed by animals or wind. Based on logistic regression from sites throughout the Southeast, Chinese tallow is more likely to invade young than mature forests in that region [58].

It is probable that in some instances, high seed input of Chinese tallow maintains its dominance rather than seedling performance. Chinese tallow seedling emergence was lower than that of sugarberry in the understory of Chinese tallow woodlands in an area of coastal Texas that was previously dominated by coastal prairie. Native tree species may establish and increase in the understory of invasive Chinese tallow woodlands. However, distance to seed sources can be restrictive and creation of canopy openings would likely favor Chinese tallow [186].

**Shade tolerance:** Although Chinese tallow survives and grows in shade, it generally performs better in sunlight. In a floodplain forest in eastern Texas, Chinese tallow mortality increased from about 0.05% at 10% full sunlight to 5.3% at 0.1% full sunlight [111]. In a grassland field experiment, Chinese tallow seedling survival was significantly ( $P<0.01$ ) reduced in shade treatments and significantly ( $P<0.05$ ) increased in increased-light treatments [182]. Chinese tallow dry mass [89,90,91], height [90,91], basal diameter [91], root mass [158], and growth rate [11,90,219] have all shown increases with increasing light availability. Significant [158] have been observed with increasing light. Leaf area ( $P<0.0001$ ) and number ( $P\leq 0.019$ ) declined with increasing light [156,158]. In greenhouse experiments, Chinese tallow from Texas showed greater positive responses to higher light levels than Chinese tallow from China, including greater increases in leaf area, leaf biomass, and shoot biomass [219]. Net photosynthesis and dry mass of Chinese tallow were significantly greater than those of sycamore and cherrybark oak under 5% full sunlight [89], and absolute growth was greater than Carolina ash (*Fraxinus caroliniana*) under 5% and 100% full sunlight [90].

Chinese tallow's response to light may be moderated by other site characteristics. Siemann and Rogers [183] found a significant ( $P<0.05$ ) effect of light availability on Chinese tallow survival and growth in prairie sites, but not in mesic ( $P>0.16$ ) or floodplain ( $P>0.61$ ) forests.

Chinese tallow height growth may decrease at high light levels. Jones and McLeod [90] found that the tallest Chinese tallow trees occurred in the intermediate (53% and 20%) light treatments ( $P<0.05$ ). In greenhouse experiments, Chinese tallow seedling shoot and total biomass were significantly lower in ambient light than under an 87% shade cloth [219]. Chinese tallow grown in 37% and 12% sunlight had significantly ( $P<0.0001$ ) greater height growth than those grown in full sunlight. They suggest this may have been caused by photo inhibition or by temperature or water stress [157].

In the field, Chinese tallow seedlings perform much better in open than shaded habitats. Bruce [18] observed 100% mortality of Chinese tallow seedlings in a closed-canopy Chinese tallow forest, while Chinese tallow seedlings survived and grew, in some cases rapidly, in canopy gaps, grassland, and cleared sites. Chinese tallow was prevalent on the edges of Chenier woodland sites in Louisiana [132]. In southeastern Louisiana, Chinese tallow was present in a community type with significantly ( $P<0.05$ ) lower basal area, stem density, standing wood biomass, and bulk density than 3 other community types where Chinese tallow did not occur [83]. Increases in Chinese tallow were associated with canopy gaps in relatively closed-canopy, mixed-bottomland hardwood forest on the border of southern Louisiana and Mississippi following Hurricane Katrina in 2005 [29] and maritime forest on Bulls Island, South Carolina, following Hurricane Hugo in 1991 [36]. Chinese tallow basal area growth increased significantly following a large die-off of American hornbeam (*Carpinus caroliniana*) trees in a bottomland hardwood forest in eastern Texas. The authors suggest that increased light due to a more open canopy following American hornbeam mortality resulted in increased Chinese tallow growth [117]. Average relative growth rate was significantly greater ( $P=0.01$ ) in open herbaceous marsh than in sparse and dense southern bayberry thickets of southeastern Louisiana, despite greater growth of Chinese tallow in substrates from southern bayberry thickets in greenhouse experiments (see [Seedling establishment](#)) [11]. In several Atlantic coast and inland sites, Chinese tallow germination was greatest in open-canopy habitats where Chinese tallow had established and lowest in closed-canopy lowland habitats where Chinese tallow had not yet established. Growth rates of Chinese tallow seedlings were generally higher in open-canopy habitats than closed-canopy habitats, and Chinese tallow grew in all open areas, even those outside its current distribution [141]. Oliver [138] suggests that Chinese tallow dominance in part of her Harris County, Texas, study area may be explained by the relatively open canopy and/or greater moisture availability. In contrast, Chinese tallow typically occurred on transects that corresponded with high canopy cover and moderate soil moisture in an ordination of sites in the Lake Jackson area of northern Florida [21].

Chinese tallow's response to shade may vary with nitrogen availability. Chinese tallow growth was significantly ( $P<0.05$ ) greater in a shaded and nitrogen-added treatment than in other treatments. This result may be attributable to better performance of Chinese tallow than prairie vegetation under shaded, nitrogen-added conditions [182]. Petiole length showed a significant ( $P=0.0089$ ) nitrogen  $\times$  shade interaction, with more shade and nitrogen resulting in longer petioles [156]. Significant ( $P<0.05$ ) shade  $\times$  nitrogen interactions were also observed for Chinese tallow in pots placed on a rooftop. Increased nitrogen and intermediate shade were associated with increased stem diameter growth, and increased shade and nitrogen were associated with decreasing root:shoot ratio [157]. No significant interactions between nitrogen and shade were found in a paired greenhouse and field experiment on a coastal prairie site in eastern Texas [158]. Results regarding the effect of nutrient addition are discussed in the [nutrient supplementation](#) section.

Flood tolerance may vary with shading. Reduction of Chinese tallow growth due to flooding under 20% sunlight was not significantly different from that of water tupelo, while Chinese tallow growth reductions due to flooding under full light were significantly larger than those of water tupelo [91]. Quick seedling growth of flood-tolerant species may allow them to inhabit areas that would typically be occupied by more shade tolerant species [72,111].

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## FIRE EFFECTS AND MANAGEMENT

**SPECIES:** *Triadica sebifera*

- [FIRE EFFECTS](#)
- [FUELS AND FIRE REGIMES](#)
- [FIRE MANAGEMENT CONSIDERATIONS](#)



Chinese tallow burning in a prescribed fire in a tallgrass prairie at the Brazoria National Wildlife Refuge in Texas. Photo by Larry Allain, USGS

#### FIRE EFFECTS:

- [Immediate fire effect on plant](#)
- [Postfire regeneration strategy](#)
- [Fire adaptations and plant response to fire](#)

**Immediate fire effect on plant:** Mature Chinese tallow typically survives or is top-killed by fire. Small trees are more vulnerable than large trees [67,148]. As of 2010, there was no information regarding the effect of fire on Chinese tallow seed viability.

Chinese tallow seedlings are more susceptible to fire than adult trees. Observations at Armand Bayou Nature Center suggest that trees larger than 1 inch (2.5 cm) in diameter are difficult to top-kill with fire (personal communication [149]). The only immediate mortality Grace [67] observed after prescribed fire was that of 4-inch (10 cm) tall transplanted seedlings. [Grace and others](#) [68] reported generally decreasing mortality and decreasing top-kill with increasing height after prescribed fires in Texas coastal prairies [68]:

Approximate postfire mortality and top-kill rates of Chinese tallow as a function of tree size [68]			
Chinese tallow height class	Died (%)	Top-killed (%)	Survived (%)
<0.1 m	100	0	0
0.1-1.0 m	40	~25	~35
1-2 m	~15	~60	~25
2-3 m	~3	~36	~61
3-4 m	0	~8	~92

Fuel biomass and continuity influence the direct fire effects on Chinese tallow. More Chinese tallow trees were burned in a prairie site (73-100%) than in an abandoned rice field (24-73%) because fuel load and continuity were greater on the prairie site [67]. Observations at Armand Bayou Nature Center indicate that Chinese tallow trees of any size are more likely top-killed by fire when they have substantial fine fuels around the base of the tree (personal

communication [[149](#)]).

### Postfire regeneration strategy [[198](#)]:

Tree with [adventitious](#) buds or a sprouting [root crown](#)

[Crown residual colonizer](#) (on site, initial community)

[Secondary colonizer](#) (on- or off-site seed sources)

### Fire adaptations and plant response to fire:

Fire adaptations: Chinese tallow has the potential to respond positively to fire, given its ability to sprout following damage (see [Vegetative regeneration](#)), its association with disturbed areas (see [Plant communities](#)), and its response to increased sunlight (see [Shade tolerance](#)) and nutrients (see [nutrient supplementation](#)).

Chinese tallow has several adaptations to survive and persist after fire, even at frequent intervals. Bark that thickens with age insulates older trees. Chinese tallow top-killed by fire may produce vigorous basal sprouts, and roots are capable of sprouting up to 16 feet (5 m) from the original stem [[67](#)]. Chinese tallow has been observed sprouting after several years of annual burning (personal communication [[149](#)]). In addition, it is not prone to crown fires and typically ignites only when fires are intense. This and the lack of herbaceous fuels under Chinese tallow stands (see [Fuels](#), below) result in woodlands that are resistant to burning [[67](#)].

Information regarding colonization of burned sites is lacking. Surviving Chinese tallow trees are the most likely source of seed. However, no data address the ability of seeds in the seed bank to survive fire, and information is sparse regarding the ability of Chinese tallow seeds to establish on burned sites (see below).

Plant response to fire: In some instances fire in forested habitats may enhance Chinese tallow invasiveness. Chinese tallow was not invading a mixed-hardwood pine site in northern Florida where fire was excluded, but it was invading a similar habitat in South Carolina burned every 3 to 5 years. The unburned site had significantly ( $P=0.03$ ) greater litter depths than the South Carolina site, which was thought to reduce access to moist soil and impede Chinese tallow germination [[167](#)]. In counties already highly invaded by Chinese tallow, probability of invasion of forested areas was significantly greater ( $P<0.047$ ) where fire had damaged at least 25% of trees within the previous 5 years. Conversely, in counties that were not yet highly invaded, there was a negative relationship between fire damage and the probability of invasion, although the relationship was not significant ( $P=0.176$ ) [[58](#)].

Fire may reduce Chinese tallow recruitment in some circumstances. At Lake Jackson in northern Florida, Chinese tallow germination from February to May averaged 7.4% in unburned areas, which was significantly ( $P<0.001$ ) more than the average 1.0% germination rate in areas that were burned in early to mid-March [[21](#)]. According to an abstract from proceedings of a conference, annual spring burning reduced survival and growth of Chinese tallow seedlings in a coastal prairie in eastern Texas. A single spring fire had no impact on Chinese tallow invasion three years after burning [[162](#)].

Circumstantial evidence suggests that Chinese tallow density may be lower on burned than unburned sites. Smith and others [[193](#)] found more Chinese tallow in unburned than burned plots following prescribed burning in maritime forests in Cape Romain National Wildlife Refuge, South Carolina. Burns were conducted in winter and were of low severity, with most of the duff layer remaining unburned [[193](#)]. In a tallgrass coastal prairie of Texas with encroaching woody species, primarily Chinese tallow and Rio Grande dewberry, a late February fire had a significant ( $P=0.03$ ) negative impact on percentage of woody species [[80](#)]. Relative density of Chinese tallow was 41.5% on a site that was burned after clearcutting, compared to relative densities of 85% and 80% on larger tracts that had different postharvest treatments [[85](#)]. It is important to note that confounding factors, such as Chinese tallow seed availability or differences in site characteristics, were not eliminated as possible explanations for these observations.

Stage of development of a Chinese tallow stand is possibly the most important factor influencing its long-term response to fire, due the effects of [tree size](#) and [fuel characteristics](#) [[67,68](#)]. Repeated burning of stands with enough fuel to carry a fire may eventually lead to declines in Chinese tallow dominance [[67,68](#)]. However, as Chinese tallow stands age they become increasingly resilient due to increased ability of older trees to recover after fire (see [Immediate fire effect on plant](#)) and reduced severity of burns in woodlands with little fuel [[67](#)] (see [Fuels](#)). Grace and others [[69](#)]

report that repeated fires performed with adequate herbaceous fuel near Chinese tallow trunks killed large, isolated individuals. However, once a "critical stand density" is reached, burning will have little to no long-term impact on Chinese tallow stands [69]. This critical threshold is likely affected by season of burning and other fire and site characteristics [67,68,69].

Season of burning influences Chinese tallow's response to fire. Prescribed burns conducted during the growing season had greater long-term negative effects on growth and survival of Chinese tallow basal sprouts than those conducted when Chinese tallow was dormant [67]. Chinese tallow generally recovers more slowly from burning during the growing season [67,68].

Site conditions are likely to influence Chinese tallow's response to fire. The amount of clay in soils may affect Chinese tallow response by increasing water retention and insulating roots from the heat of a fire (personal communication [194]). In general, soil moisture influences the impact a fire has on plants [78,175,190].

#### FUELS AND FIRE REGIMES:

**Fuels:** In established Chinese tallow stands, fine fuel loads have been observed to decrease over time as Chinese tallow shades out understory grasses ([19,67,68], personal communication [149]). According to a comprehensive review [211], forbs increase in dominance in Chinese tallow stands compared to native wetland or upland grassland vegetation. This results in a patchier, discontinuous fuel layer comprised of less flammable species than the original community. Sometimes Chinese tallow seedlings establish at such high densities that fine fuels are lacking even in a stand of smaller trees (personal communication [149]). These changes in fuel characteristics result in patchier and/or less severe fires, which are less likely to impact Chinese tallow [67,211]. According to Grace [67], "it is common to watch a prescribed fire burn right up to the edge of a tallow stand and simply go out because of a lack of fuel."

Chinese tallow woodlands may generate or retain less litter than native woodlands. Areas with high densities of Chinese tallow in the understory and overstory had significantly lower daily litterfall ( $P \leq 0.038$ ) and lower cumulative litterfall ( $P \leq 0.035$ ) than areas of a bottomland hardwood forest with little Chinese tallow in the overstory [82]. There are exceptions, however. The average amount of leaf fall observed in a Chinese tallow woodland in coastal Texas, 382.6 g/m<sup>2</sup>/year, is typical for southern deciduous trees [27]. Chinese tallow litter decays quickly compared to that of native species [27,82,109] (see [Impacts](#)).

**Fire regimes:** There is a wide range of fire frequencies and severities in habitats where Chinese tallow occurs. Many of these habitats have evolved with short fire-return intervals. Observations suggest that sites with relatively infrequent or irregular fire frequencies may be more easily colonized by Chinese tallow [67,68,153,163], although data are lacking. Frequent burning may decrease Chinese tallow recruitment or prevent establishment of Chinese tallow woodlands in coastal prairies [67]. Burning or mowing at 1- to 3-year intervals has been effective at maintaining native prairie vegetation at Armand Bayou Nature Center in southern Texas [75]. Reintroduction of fire into native plant communities adapted to a regime of frequent fires may help slow establishment and spread of Chinese tallow while promoting native species.

In Chinese tallow woodlands, the moisture and fuel conditions necessary to ignite and carry a fire rarely occur [67]. The lack of fine fuel biomass and patchiness of fuels on sites invaded by Chinese tallow (see Fuels, above) likely reduce the probability of ignition and spread on those sites. Grace [67] suggests that "it is possible for tallow to render the ecosystem nonflammable".

See the [Fire Regime Table](#) for further information on fire regimes of vegetation communities in which Chinese tallow is important. This list is not inclusive for all plant communities in which Chinese tallow occurs.

#### FIRE MANAGEMENT CONSIDERATIONS:

**Potential for postfire establishment and spread:** The overall ability of Chinese tallow to establish in the postfire environment is unclear. Germination of Chinese tallow may be reduced by burning in certain circumstances [21]. However, in regions already experiencing high rates of Chinese tallow invasion, risk of invasion increased in stands where 25% of trees were damaged by fire [58]. Due to its ability to establish following other types of disturbance [35,132,193,214], Chinese tallow establishment following fire is a concern.

Preventing postfire establishment and spread: To some extent, repeated burning mitigates the risk of postfire colonization of Chinese tallow. Monitoring burned sites in areas where Chinese tallow occurs is recommended, especially in areas prone to invasion such as sites that are near water, naturally regenerated, and/or in areas with abundant seed sources [58].

Preventing invasive plants from establishing in weed-free burned areas is the most effective and least costly management method. This may be accomplished through early detection and eradication, careful monitoring and follow-up, and limiting dispersal of invasive plant propagules into burned areas. 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 that may alter soil nutrient availability, such as those 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: [4,16,17,65,206].

**Use of prescribed fire as a control agent:** Use of frequent prescribed fire in communities with short presettlement fire-return intervals is probably fire's most practical use in controlling Chinese tallow, since fire is most effective when used repeatedly and frequently. In addition to burning sprouts from Chinese tallow top-killed in previous fires and possibly causing increased damage to older trees [67,68], the susceptibility of young Chinese tallow [68] and the potential for lower germination rates [21] means repeated fires may decrease recruitment. However, the lack of fine fuel biomass and continuity in Chinese tallow-invaded sites may make prescribed burning difficult, and decrease fire intensity in the immediate vicinity of the trees such that they are not damaged by fire (personal communication [149]). Chemical and/or mechanical treatments may be used initially to increase fuels so prescribed fires can be conducted [48,49]. If conditions conducive to burning do not occur often enough to allow for a fire frequency that will reduce Chinese tallow dominance, other control methods are required. This will likely be the case in relatively mature Chinese tallow stands, wet areas, and sites where production of herbaceous fuels is low and/or patchy ([15,75,138], personal communication [149]). For example, repeated burning is used in combination with herbicides and mowing in the coastal prairie of the Armand Bayou Nature Center ([75,138], personal communication [149]). Occurrence of Chinese tallow in urban settings also limits the use of fire as a control method [15].

**Altered fuel characteristics:** Invasive populations of Chinese tallow may reduce the amount of fine [fuels](#) on a site, and Chinese tallow woodlands rarely burn (see [Fire regimes](#)). Due to these factors, prescribed fire may not be an effective [control agent](#) in established Chinese tallow woodlands.

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## MANAGEMENT CONSIDERATIONS

**SPECIES:** [Triadica sebifera](#)

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

#### FEDERAL LEGAL STATUS:

None

#### OTHER STATUS:

Chinese tallow is considered a noxious weed in Florida. Its sale there was prohibited in 1998 [204]. Sale of Chinese tallow is also prohibited in Texas [64]. The Southern Region of the Forest Service has listed it as a Category 1 weed species [205]. The Georgia Exotic Pest Plant Council [60] included it in the top 10 exotic pest plants of Georgia. Chinese tallow is considered a severe threat in the piedmont and coastal plain regions of South Carolina [196]. It is listed as an "alert" species in California by the California Invasive Plant Council [23,24]. Information on state-level noxious weed status of plants in the United States is available at [Plants Database](#).

#### IMPORTANCE TO WILDLIFE AND LIVESTOCK:

Although Chinese tallow leaves, fruit and sap are toxic to many animals including cattle, several bird species eat the fruits, and insects eat a limited amount of various parts.

**Palatability and/or nutritional value:** Chinese tallow is toxic to several species including humans [52,62,113,197]. Compounds from Chinese tallow roots may irritate skin and produce tumors [172]. The toxic effect of Chinese tallow leaves and fruit on cattle was demonstrated by Russell and others [165]. However, cattle have been reported to eat seedlings <2.4 inches (6.1 cm) tall (Kramer personal communication in [20]). Domestic sheep and goats are much less affected by Chinese tallow [165]. They have been reported to eat the leaves [3], although Sharma and others [174] note that domestic goats in northern India do not eat Chinese tallow.

Several bird species eat Chinese tallow seeds [41,124,150,151] and are important dispersal agents. Winter residents eat Chinese tallow seeds more often than other birds ( $P < 0.001$ ) [41,150]. Species commonly observed eating Chinese tallow seeds include northern cardinals, red-winged blackbirds, gray catbirds, and red-bellied woodpeckers [41,150,151]. Baltimore orioles and yellow-rumped warblers comprised 72% of the foraging observations in coastal Texas [41], while northern flickers and American robins were important in South Carolina [150,151]. Chinese tallow met the energy requirements of yellow-rumped warblers and American robins, but not northern cardinals in feeding trials. Chinese tallow occurrence may influence local winter distributions of yellow-rumped warblers [7]. Hermit thrushes ate Chinese tallow seeds in loblolly pine plantations that were 12 to 14 years old and 21 to 23 years old [201]. Given the importance of birds as dispersal agents and the possibility of competition with native plant species for dispersal agents [151], more research is needed on birds' preference for Chinese tallow seeds compared to native foods. Mammalian seed predators of Chinese tallow were observed in a prairie habitat of northern Florida and included marsh rabbit, eastern cottontail, and marsh rice rat [167].

Little information on the nutritional content of Chinese tallow is available. However, seeds have been reported to contain crude fat in quantities >25% of dry matter [177]. According to a review of nutritional content of edible plants of the Sikkim Himalaya, Chinese tallow is high in fat and protein [202].

Nutritional data (% dry matter) for Chinese tallow collected by Rockwood and included in a literature review by Rockwood and others [155]

Organic matter	Neutral detergent fiber, ash free	Digestibility by rumen microbes	Acid detergent fiber	Lignin	Nitrogen	Phosphorus
98.5	85.7	19.1	69.5	20.2	0.49	0.04

**Insect herbivory:** Few insects typically feed on Chinese tallow in the field. For example, much lower herbivory was observed in Chinese tallow (mean 3.3%; range 0-5% of total leaf area) than in green ash (mean, 25.8%; range 5-75%) [91]. Insect damage on Chinese tallow in coastal Texas was low, averaging 0.67% of leaf area removed [189]. In southeastern Texas, maximum loss of Chinese tallow to insect herbivores was significantly ( $P=0.002$ ) less than maximum loss of willows [28]. Chinese tallow woodland in this area had fewer insects [28] and a lower proportion of insect herbivores than native species [28,79]. Only 7% of arthropods collected in a Chinese tallow woodland near Houston, Texas, were herbivores, while predators and detritivores comprised 70% of arthropods collected. Herbivores comprised 49% to 67% of arthropods in several native communities surveyed in previous studies, including prairies, riparian habitats, and pastures [79]. In bottomland hardwood forest in southeastern Louisiana with high densities of Chinese tallow in the understory and overstory, primary and secondary terrestrial invertebrate consumers were less abundant than in less invaded areas [82]. See [Impacts](#) for more information on Chinese tallow's effects on invertebrates.

Experiments suggest that behavioral avoidance, as opposed to strong Chinese tallow defenses, may result in low herbivory. Siemann and Rogers [185] found increased rates with increased amounts Chinese tallow foliage consumed ( $P<0.05$ ) by grasshoppers. In laboratory trials, Lankau and others [108] found that grasshoppers preferred Chinese tallow over 3 native species ( $P<0.05$ ). Invasive Chinese tallow experienced greater herbivory than native Chinese tallow in a common garden in China [220], possibly due to lower levels of tannins in invasive Chinese tallow [28]. Several insects feed on Chinese tallow including leaf-footed bugs [87], leaf-cutting ants [171], fire ants [167], termites [99], yellow-striped army worms, and eri silkworms [173]. Insect loads in Chinese tallow woodlands have been shown to increase with time since establishment [28,188]. Despite this and other evidence for reduced defenses compared to Chinese tallow from China [28,181,184,185,220], Chinese tallow occurring in the southeastern United States do have some herbivory defense [119,161]. For instance, one terrestrial reducer ate leached and ground Chinese tallow leaves faster than unprocessed leaves [26], and terrestrial isopods ate Chinese tallow leaves once tannins were leached [109].

Much of the research on insect foraging on Chinese tallow has investigated the hypothesis that the evolution of reduced defenses in response to low herbivory has allowed Chinese tallow to allocate more resources to increasing performance [181,183,184,185,218,220]. Several studies show that invasive Chinese tallow has faster growth rates compared to Chinese tallow from its native range [216,217,218,219] (see [Plant growth](#)). Increased growth allows Chinese tallow in the United States to recover from herbivore damage faster than native Chinese tallow. Thus, invasive Chinese tallow has become less resistant to and more tolerant of herbivory than native Chinese tallow [160,218,220].

Chinese tallow response to herbivore exclusion is variable. Despite having lower herbivore damage than sugarberry, application of insecticide in coastal prairie, mesic forest, and floodplain forest in Texas resulted in greater increases in Chinese tallow survival and growth than observed in sugarberry [183]. Exclusion of invertebrate herbivores did not impact Chinese tallow seedling growth in open coastal prairies of eastern Texas [162] but resulted in significant increases in Chinese tallow seedling growth ( $P=0.01$ ) in an established Chinese tallow woodland [186]. Although Chinese tallow shows high tolerance to short-term herbivory, the amount of herbivory in the 1st year was negatively correlated with survival from the start to the end of the 2nd growing season [183]. Greenhouse experiments investigating the effect of herbivory have consistently found no effect of simulated insect herbivory on Chinese tallow from the southeastern United States under varying nutrient conditions [157,158,159].

**Cover value:** The value of Chinese tallow as cover is uncertain. Small mammals such as cotton rats and harvest mice in coastal Texas preferred other habitats over those containing Chinese tallow [97,98]. Chinese tallow woodlands had lower avian species diversity than bottomland hardwood forest in southwestern Louisiana. Only 3 species, American robin, gray catbird, and yellow-rumped warbler, were more common in Chinese tallow woodland than bottomland hardwood forest [7]. Use of specific layers of Chinese tallow forests by species of migrant birds, such as black-throated warblers and black and white warblers, suggest that Chinese tallow provides adequate cover for some bird species [43]. On coastal prairie sites in southeastern Texas, sedge wrens and swamp sparrows were more common in areas where Chinese tallow was present, while savanna sparrows were more common in areas where it was absent [6]. Of 45 American woodcock roost points in the Alazan Bayou Wildlife Management Area in eastern Texas, 29 occurred under sapling-sized Chinese tallow trees that had been treated with herbicide the previous summer [61]. In a tallgrass coastal prairie of Texas with encroaching woody species primarily Chinese tallow and Rio Grande dewberry, arthropod diversity was negatively associated with woody species cover and percent woody vegetation [80].

Chinese tallow leaf fall may affect terrestrial and aquatic invertebrate communities and aquatic vertebrates. Stress from tannin input from Chinese tallow leaves may be responsible for changes in microbial community characteristics [129]. Chinese tallow woodlands typically have fewer herbivores than native communities [28,79,82] (see [Palatability and/or nutritional value](#)), suggesting that Chinese tallow invasion alters litter food webs [82]. In the laboratory, 2 common aquatic invertebrates showed significantly ( $P<0.05$ ) higher mortality in treatments with sufficient food and Chinese tallow tannin than controls with sufficient food and distilled water [26]. In southeastern Louisiana, Chinese tallow impacted aquatic invertebrate community composition and negatively ( $P<0.001$ ) affected survival of Cajun chorus frog and southern toad tadpoles. In tallow litter, Cajun chorus frog tadpole survival was 0%, and southern toad tadpole survival was 2.2%. In litter from native trees, survival of Cajun chorus frog tadpoles ranged from 89.1% to 95.3%, and survival of southern toad tadpoles ranged from 51.3% to 61.1%. In contrast, survival of green treefrog tadpoles was not affected by Chinese tallow leaf litter. Effects of Chinese tallow litter on water quality included significantly lower dissolved oxygen than treatments with native litter ( $P<0.001$ ), and dissolved oxygen in Chinese tallow treatments did not increase over the course of the experiment as it did in native litter treatments ( $P=0.031$ ). The effect of leached tannins is likely to have a persistent effect on aquatic organisms and seasonal effects on terrestrial invertebrates [109].

Feral hogs use Chinese tallow woodlands, and their effects on Chinese tallow are equivocal. In a mixed pine-hardwood forest with abundant feral hogs in the Big Thick National Preserve in Texas, Chinese tallow was twice as numerous in areas affected by feral hogs than in areas where they were excluded ( $P<0.05$ ). Feral hogs disturbed an average of 22% of ground area within control plots [180]. In contrast, Chinese tallow saplings outside enclosures experienced 90% mortality over a 103-day experiment on a barrier island of the Georgia coast with high feral hog densities (24.7 hogs/km<sup>2</sup>). On a site near Jesup, Georgia, with a stable or increasing feral hog population, Chinese tallow saplings outside enclosures experienced 34.6% mortality. Mortality within enclosures was negligible at both sites [121].

#### OTHER USES:

Chinese tallow has many uses. The waxy seed coating is used in candles, soaps, and cosmetics in China and Japan [52,112,171,173,174,191]. It is also edible and may replace animal tallow when processed properly [51,174,191]. The seed oil is used in many applications. It is well known for its drying properties and is used in several products including varnishes, paints, and plastics [112,168,171,173,174]. In addition, Chinese tallow seed oil has potential as a biofuel [51,114,208], although the long-term effects of its use in engines has not been reported [1,166]. Meal from the seed kernel is high in protein and is used as animal feed, fertilizer, or refined into flour for human use [171,174]. The leaves are used as a silk dye and as a fertilizer [112,171,174]. Chinese tallow is also an important species in the honey industry [110,112,126,171,173]. Chinese tallow wood may be used in furniture [178], pallets, paneling [178], particleboard [179], or burned to produce heat [170,171]. Chinese tallow has medicinal properties [51,103,121]. Chinese tallow's use as an ornamental assists its spread into new areas [52,126]. Based on estimates of cost and profits made in 1979, planting Chinese tallow as a cash crop for vegetable tallow and oil was economically viable [169]. However, see Impacts below.

#### IMPACTS AND CONTROL:

**Impacts:** Invasion of coastal prairie and longleaf pine communities by Chinese tallow is a major concern, given the already limited distribution of these habitats [67,209]. The degree to which Chinese tallow establishes in these and other communities ([Distribution and Occurrence](#)), its probable impact on some wildlife species (see [Cover value](#)), and its potential to alter [fuels](#) and [fire regimes](#) have been addressed in previous sections of this review. A summary of the literature investigating [allelopathic effects](#) of Chinese tallow is also discussed.

Chinese tallow leaf litter decomposes quickly and potentially increases nutrient availability. Litter bags with either 0.7 or 1.2 ounces (20 or 35 g) of Chinese tallow leaf litter placed in the main channel of Abita Creek in southeastern Louisiana had decomposition rates 2.6 to 14.5 times that of red maple leaves, and litter bags with 35 g of leaf litter placed in 3 ephemeral ponds near Florenville, Louisiana, had average decomposition rates 16.5 times that of laurel oak leaves. In all experiments Chinese tallow leaf litter had completely broken down after no more than 64 days [109]. Chinese tallow leaves decay rapidly in terrestrial habitats [27,82]. On sites within a bottomland hardwood forest with varying degrees of Chinese tallow invasion, only 8% of 0.35-ounce (10-g) samples of Chinese tallow litter remained after 16 weeks on the forest floor, and none remained after 32 weeks. This decomposition rate was faster than that observed for sugarberry, red maple, sweetgum, live oak, or a mixture of sugarberry, red maple, and sweetgum litter.

Chinese tallow litter was considered "high quality" based on nitrogen and phosphorus content [82]. The lignin to initial nitrogen concentration ratio was lower in Chinese tallow than in native southern trees, which may partially explain Chinese tallow's rapid leaf decay. Concentrations of several nutrients, such as phosphorus, potassium, and zinc, were significantly ( $P<0.05$ ) higher in Chinese tallow woodland soil than in nearby prairie soil, while manganese and sodium concentrations were significantly ( $P<0.05$ ) lower [27]. In the Jackson Lake area of northern Florida, Chinese tallow was associated with sites with high soil magnesium content, possibly due to decomposition of Chinese tallow leaves increasing magnesium levels [21]. Cameron and Spencer [27] conclude that rapid leaf decay resulting in the release of nutrients may cause increased productivity in areas with Chinese tallow. Greater aboveground net primary productivity has been observed in Chinese tallow woodland (1,264 g/m<sup>2</sup> (SD 27 g/m<sup>2</sup>)) compared to unburned (462 g/m<sup>2</sup> (SD 49 g/m<sup>2</sup>)) and burned (624 g/m<sup>2</sup> (SD 63 g/m<sup>2</sup>)) grassland [76].

**Control:** Several reviews summarize different Chinese tallow control options [13,20,92,93,197]. Bruce and others [20] suggest that Chinese tallow control efforts should be maintained for 3 to 5 years, and managed sites must be monitored. Due to Chinese tallow's ability to sprout following top-kill [67,154,170], continued control and monitoring are recommended regardless of the method used. McCormick [121] provides a comprehensive review of control techniques and case studies of Chinese tallow removal. Ramsey and others [146,147] describe techniques for mapping Chinese tallow stands using remote sensing techniques.

**Fire:** For information on the use of prescribed fire to control this species, see [Fire Management Considerations](#).

**Prevention:** Fire and mowing are used to prevent Chinese tallow establishment in prairies. For details regarding the effects of fire on Chinese tallow, see the [Fire Effects](#) section. Regular mowing is used to prevent Chinese tallow invasion in the coastal prairie of Texas [75,138,183]. Chinese tallow seedlings did not occur on sites near Natchitoches, Louisiana, that were regularly mowed but did occur in adjacent edges and ditches that were not regularly mowed [5].

Monitoring can be focused in areas where Chinese tallow is likely to establish, such as areas downstream from Chinese tallow seed sources where water is likely to deposit seeds and seedlings are likely to survive [15]. Results of logistic regression of data from forested sites throughout the Southeast suggest that monitoring should focus on low, flat areas near water or roads that were recently disturbed or are vegetated by young, naturally regenerated forests. Prompt restoration of harvested or disturbed sites that incorporates Chinese tallow control would likely be a cost-effective way to prevent invasions [58]. Monitoring may also include fertilized lands (see [Nutrient supplementation](#)).

General recommendations to prevent the spread of invasive species in Florida included strengthening legislation that prohibits the sale of invasive species, having a mandatory quarantine period for livestock moved from infested to uninfested areas, and implementing public education programs [66]. Gan and others [58] recommend efforts to educate public landowners and encourage their participation in Chinese tallow control efforts and prevention of Chinese tallow establishment because Chinese tallow establishment is more common on private than public lands.

Educating the public about the consequences of using Chinese tallow as an ornamental, encouraging planting of native species, and removing Chinese tallow from nurseries are important steps to reduce seed sources [120,144]. Langeland [106] includes a list of ornamental species that are good alternatives to Chinese tallow in areas with an annual minimum temperature of 15 °F (-9.4 °C) or higher.

**Cultural control:** No information is available on this topic.

**Physical or mechanical control:** As mentioned in [Prevention](#), mowing may prevent establishment of Chinese tallow. High-impact mechanical control techniques are practical only in certain situations [92]. They are typically used on heavily impacted sites, such as rights-of-way [13,93] and canal banks [208]. Mulching live Chinese tallow trees in invaded prairies may be a viable method of restoration in some areas and allow for future management through mowing or prescribed burning [49]. In central Louisiana, small (<1 foot (0.3 m)) Chinese tallow trees cut in autumn had higher mortality than small, uncut trees ( $P<0.05$ ). No mortality was observed in larger Chinese tallow trees, regardless of cutting treatment [5]. In sensitive areas, mechanical treatment typically involves manual removal of

seedlings and felling trees in place [20]. Due to the ability of Chinese tallow to sprout, mechanical techniques have the potential to exacerbate Chinese tallow invasions [92] and are almost always accompanied by herbicide application. Conway and others [44] conclude that mechanical harvest is best done during seed formation because this is when total nonstructural carbohydrate concentrations in Chinese tallow roots are the lowest. Cutting during flowering [197] and removing fruit from fallen trees [13] would help minimize seed left on newly cleared sites (see [Shade tolerance](#)).

Flooding is not typically used to control Chinese tallow, given its tolerance. However, cutting below the water level may kill Chinese tallow [13]. Smith (personal communication [194]) has observed successful control of Chinese tallow with constant flooding for 36 months.

Biological control: Only preliminary surveys of the feasibility of biological control of Chinese tallow had been undertaken as of 2010 [45,143,197,213].

Grazing has been noted to prevent establishment of Chinese tallow [138]. However, in a personal communication cited by Bruce and others [20], Kramer reports that short-term rotation of high-density cattle herds is less successful in controlling Chinese tallow than in controlling groundsel-tree, despite cattle eating Chinese tallow less than 2.4 inches (6.1 cm) tall.

Chemical control: Herbicides are widely used for controlling Chinese tallow [20,46,67,101,197], and guidance specifically for property owners is available [106]. Application of herbicide following cutting is a typical application method [54,107,208]. Langeland and others [107] provide direction on the application of herbicides to cut Chinese tallow. Basal bark applications are preferred by many organizations including The Nature Conservancy and the Florida Department of Environmental Protection [13,20,208]. Conway and others [44] conclude that the period from "seed maturation until leaf fall" is the best time for foliar herbicide application, since the chemicals would be moved downward into the root system during this time, resulting in a higher probability of the death of the entire plant. McCormick [121] provides detailed descriptions of herbicide treatments for small- and large-scale Chinese tallow control projects.

Integrated management: No information is available on this topic.

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## APPENDIX: FIRE REGIME TABLE

### SPECIES: *Triadica sebifera*

The following table provides fire regime information that may be relevant to Chinese tallow 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 below, see the [Expanded Fire Regime Table](#).

<p>Fire regime information on vegetation communities in which Chinese tallow is important. This information is taken from the <a href="#">LANDFIRE Rapid Assessment Vegetation Models</a> [105], 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.</p>
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<a href="#">California</a>	<a href="#">South-central US</a>	<a href="#">Southern Appalachians</a>	<a href="#">Southeast</a>
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#### California

- [California Grassland](#)
- [California Woodland](#)

Vegetation Community ( <a href="#">Potential Natural Vegetation</a> Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
California Grassland					
<a href="#">California grassland</a>	Replacement	100%	2	1	3
California Woodland					
<a href="#">California oak woodlands</a>	Replacement	8%	120		
	Mixed	2%	500		
	Surface or low	91%	10		
<b>South-central US</b>					
<ul style="list-style-type: none"> <li><a href="#">South-central US Grassland</a></li> <li><a href="#">South-central US Woodland</a></li> <li><a href="#">South-central US Forested</a></li> </ul>					
Vegetation Community ( <a href="#">Potential Natural Vegetation</a> Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
South-central US Grassland					
<a href="#">Bluestem-sacahuista</a>	Replacement	70%	3.6	1	
	Mixed	30%	7.7	2	
<a href="#">Blackland prairie</a>	Replacement	96%	4		
	Surface or low	4%	100		
South-central US Forested					
<a href="#">Gulf Coastal Plain pine flatwoods</a>	Replacement	2%	190		
	Mixed	3%	170		
	Surface or low	95%	5		
<a href="#">West Gulf Coastal plain pine (uplands and flatwoods)</a>	Replacement	4%	100	50	200
	Mixed	4%	100	50	
	Surface or low	93%	4	4	10
<a href="#">West Gulf Coastal Plain pine-hardwood woodland or forest upland</a>	Replacement	3%	100	20	200
	Mixed	3%	100	25	
	Surface or	94%	3	3	5

	low				
<a href="#">Southern floodplain</a>	Replacement	42%	140		
	Surface or low	58%	100		
<a href="#">Southern floodplain (rare fire)</a>	Replacement	42%	≥1,000		
	Surface or low	58%	714		
<b>Southern Appalachians</b>					
<ul style="list-style-type: none"> <li><a href="#">Southern Appalachians Forested</a></li> </ul>					
Vegetation Community ( <a href="#">Potential Natural Vegetation</a> Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Southern Appalachians Forested					
<a href="#">Bottomland hardwood forest</a>	Replacement	25%	435	200	≥1,000
	Mixed	24%	455	150	500
	Surface or low	51%	210	50	250
<b>Southeast</b>					
<ul style="list-style-type: none"> <li><a href="#">Southeast Grassland</a></li> <li><a href="#">Southeast Woodland</a></li> <li><a href="#">Southeast Forested</a></li> </ul>					
Vegetation Community ( <a href="#">Potential Natural Vegetation</a> Group)	Fire severity*	Fire regime characteristics			
		Percent of fires	Mean interval (years)	Minimum interval (years)	Maximum interval (years)
Southeast Grassland					
<a href="#">Southeast Gulf Coastal Plain Blackland prairie and woodland</a>	Replacement	22%	7		
	Mixed	78%	2.2		
<a href="#">Floodplain marsh</a>	Replacement	100%	4	3	30
<a href="#">Southern tidal brackish to freshwater marsh</a>	Replacement	100%	5		
<a href="#">Gulf Coast wet pine savanna</a>	Replacement	2%	165	10	500
	Mixed	1%	500		
	Surface or low	98%	3	1	10

Southeast Woodland					
<a href="#">Longleaf pine/bluestem</a>	Replacement	3%	130		
	Surface or low	97%	4	1	5
<a href="#">Longleaf pine (mesic uplands)</a>	Replacement	3%	110	40	200
	Surface or low	97%	3	1	5
<a href="#">Longleaf pine-Sandhills prairie</a>	Replacement	3%	130	25	500
	Surface or low	97%	4	1	10
<a href="#">Atlantic wet pine savanna</a>	Replacement	4%	100		
	Mixed	2%	175		
	Surface or low	94%	4		
Southeast Forested					
<a href="#">Coastal Plain pine-oak-hickory</a>	Replacement	4%	200		
	Mixed	7%	100		
	Surface or low	89%	8		
<a href="#">Maritime forest</a>	Replacement	18%	40		500
	Mixed	2%	310	100	500
	Surface or low	80%	9	3	50
<a href="#">Mesic-dry flatwoods</a>	Replacement	3%	65	5	150
	Surface or low	97%	2	1	8
<a href="#">Loess bluff and plain forest</a>	Replacement	7%	476		
	Mixed	9%	385		
	Surface or low	85%	39		
<a href="#">Southern floodplain</a>	Replacement	7%	900		
	Surface or low	93%	63		
*Fire Severities—					
<b>Replacement:</b> 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.					
<b>Mixed:</b> 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.					
<b>Surface or low:</b> 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 [74,104].					

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