ELEMENT STEWARDSHIP ABSTRACT

for

Sapium sebiferum

Chinese tallow-tree, Florida aspen, popcorn tree

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SCIENTIFIC NAME

Sapium sebiferum (L.) Roxb.

SYNONYMS

Triadica sinensis Lour., *Triadica sebifera* (L.) Small, *Croton sebiferum* L., *Stillingia sebifera* (L.) Michx., *Excoecaria sebifera* Müll. Arg.

COMMON NAME

Chinese tallowtree, popcorn tree, Florida aspen, white wax berry

The specific name "*sebiferum*" means wax-bearing. The common name "Chinese tallowtree" refers to its 1,500 year history of being used as a seed-oil crop in Asia, while "popcorn tree" refers to its persistent, white fruit.

DESCRIPTION AND DIAGNOSTIC CHARACTERISTICS

Sapium sebiferum is a tree in the spurge family (Euphorbiaceae). At maturity it typically reaches a maximum height of 15 m. Its bark is reddish-brown with wide fissures and narrow ridges, and it often peels off vertically in narrow strips. The branches, which begin relatively low on the trunk, are typically long and drooping. The twigs are slender and waxy. The simple aspen-like leaves are alternate and deciduous, broad rhombic to ovate, 3-8 cm long and 3-6 cm wide, and have a smooth margin. Leaf bases are wide-rounded, and the leaf blade terminates in a gradually tapering tip. The upper leaf surfaces are medium to dark green, and the lower somewhat paler. Leaf veins are yellow and conspicuous on both surfaces. Petioles are 2-5 cm long, with 2 swollen glands on the upper side immediately below the leaf blade. At the base of each petiole is a pair of stipule-like appendages approximately 3 mm long. In autumn, the leaves turn yellow, orange, and scarlet (Godfrey 1988).

S. sebiferum is monoecious (i.e. it produces separate male and female flowers on the same plant). The flowers are greenish-yellow in terminal spike-like inflorescences up to 20 cm long. The staminate (male) flowers occur in clusters at the upper nodes of the inflorescence, and the pistillate (female) flowers are solitary, located on short branches at the base of the spike. Each pistillate flower has a three-lobed ovary, three styles, and no petals.

Fruits are three-lobed, three-valved capsules about 1-2 cm long and 2 cm wide. As the capsules mature, their color changes from green to nearly black. The capsule walls fall away and expose three globose seeds with a white, tallow-containing covering. Seeds usually persist on the plants for several weeks. In North America, the flowers typically mature April-June and fruit ripens September-October (Godfrey 1988).

S. sebiferum has milky white sticky sap which may act as a skin irritant or as a diarrhetic (other members of the spurge family also frequently contain toxins). *S. sebiferum* is classified as a "noxious weed" in Florida and Louisiana.

STEWARDSHIP SUMMARY

S. sebiferum is native to China and Japan, and has been introduced into most of the subtropics. It is a locally abundant weed in the southern United States. Recently detected spreading in riparian areas in California, *S. sebiferum* thrives in mesic to hydric soil conditions and tolerates shade. *S. sebiferum* is capable of spreading into both disturbed and undisturbed environments and can alter the composition of

both terrestrial and wetland forest communities. It causes large-scale ecosystem modification by replacing native vegetation and changing community structure, and can also modify soil conditions by producing tannins and by increasing rates of eutrophication. *S. sebiferum* has the ability to invade wet prairies, bottomland forests, and the shorelines of water bodies.

Mechanical removal and grazing treatments control only small specimens of *S. sebiferum*, as large plants resprout readily. Its coppicing ability also restricts the usefulness of fire as a control measure, although studies have found that in areas with sufficient fuel such as in prairies with good grass cover, summer burns kill or top-kill trees as tall as three meters. The control of trees growing in wet sites where fuels are poor, however, is less effective.

Although several organisms occur with *S. sebiferum,* it is remarkably free of insect pests and serious pathogenic organisms. This lack of important pests may preclude the use of biological controls. Herbicides provide the best control of *S. sebiferum* so far. Basal bark application, which consists of spraying a band at least 15 cm wide around the lowest 30-60 cm (12-24 inches) of the trunk(s), is the most effective treatment. Triclopyr (brand names Garlon 3A, Garlon4, Pathfinder II, and others) at a concentration of about 15% (or up to 20% for larger trees) is most often and successfully used. Basal bark applications may be ineffective on large trees with thick bark; for such trees a cut-stump method may be necessary. For a cut-stump treatment, excellent results are reported with a 50% solution of triclopyr (Garlon 3A) or with a 10% solution of imazapyr (brand names Arsenal, Chopper and others). Other herbicides used to control *S. sebiferum* include the combined 2,4-D and picloram formulations (Grazon P+D and Grazon) applied to foliage, hexazinone (Velpar L) applied to soil near plants, or glyphosate (Rodeo, Roundup) as a frill treatment.

RANGE

S. sebiferum is native to Japan and to several provinces of central China, especially north of the Yangtze River Valley. *S. sebiferum* is also cultivated in its native locales and on Hainan Island, Hong Kong, Taiwan and in Korea. It was introduced to Sri Lanka, Indochina, Bengal, India, Sudan, Martinique, southern France, Algeria, South Africa, and the southern United States. *S. sebiferum* was introduced to the U.S. in Charleston, South Carolina in the late 1700s. It has since spread to every coastal state from North Carolina to Texas, and inland to Arkansas. In Florida it occurs as far south as Tampa. It is most likely to spread to wildlands adjacent to or downstream from areas landscaped with *S. sebiferum*. Occurrences *of S. sebiferum* in North America have been reported in the following states: Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, and Texas (U.S.D.A. 1999). *S. sebiferum* has most recently been reported as invading into wetlands and riparian areas in central California (Meyers-Rice et al., in review).

IMPACTS AND THREATS POSED BY *SAPIUM SEBIFERUM*

S. sebiferum can invade wildland areas and swiftly replace natural communities with nearly monospecific stands. It alters natural soil conditions, creating an inhospitable environment for many native species. In Texas, invasion by *S. sebiferum* marked a dramatic transformation of community structure from graminoids (grasses) and forbs to trees and shrubs as *S. sebiferum* shaded out herbaceous species. A similar replacement of native grasses by *S. sebiferum* occurred in the coastal prairies of Texas (Bruce et al. 1997).

S. sebiferum is characteristic of a woody invader, in that it grows rapidly, begins reproduction when young (after only 3 years), produces abundant viable seed, and can reproduce from cuttings. It produces seeds soon after establishment, leading to a rapid increase in stem and cover density. *S. sebiferum* was documented in a Florida wetland as becoming a co-dominant species twenty years after its introduction (based on tree age), and was found to reproduce from seedlings and vegetative sprouts much more prolifically than the local native species (Jubinsky and Anderson 1996). Additionally, *S. sebiferum* is able to become widely established following natural disturbances such as hurricanes or other storm events that eliminate or damage the canopy layer (Smith et al. 1997). Seeds are spread by birds and may also float for great distances.

S. sebiferum is able to alter nutrient cycles. It may enhance productivity (or encourage eutrophication) in ecosystems by the addition of nutrients (mainly nitrogen and phosphorous) from the rapid decay of its leaves (Cameron and Spencer 1989). These leaves produce tannins, but it is unclear if *S. sebiferum* produces other allelopathic compounds that may interfere with the germination of native North American species (Conway 1997). Further, the presence of *S. sebiferum* seems to favor non-native arthropods (Miller and Cameron 1983) that may also negatively impact the native ecosystem.

The milky, white sap of *S. sebiferum* may also be a skin irritant or diarrhetic in humans.

HABITAT

S. sebiferum is adapted to a variety of disturbed sites and a wide range of soil conditions (alkaline, saline, or acid soils). It does best in alluvial forests, on low alluvial plains, and on rich leaf-molds, preferring well-drained clay-peat soils.

BIOLOGY AND ECOLOGY

Light, temperature and moisture

S. sebiferum possesses characteristics typical of an invasive species: it grows quickly, fruits at an early age, produces abundant seeds, is resistant to native pests, grows in a wide range of soils, invades both disturbed and undisturbed habitats, and has characteristics useful to humans who promote and distribute it (Jubinsky 1995). Once established, removal of *S. sebiferum* requires major eradication and restoration efforts (Bruce et al. 1995).

S. sebiferum can grow rapidly in full sunlight as well as establish under closed canopies (Jones and McLeod 1989). Growth experiments indicate that in full sunlight, *S. sebiferum* grows more rapidly than Carolina ash (*Fraxinus caroliniana*) and southern red oak (*Quercus falcata*), and equaled the rates of growth of American sycamore (*Platanus occidentalis*, known for its rapid growth rate in full sun) (Jones and McLeod 1989, 1990).

S. sebiferum prefers mean air temperatures of 12.5° to 30.1°C and annual precipitation of 13 to 37 dm. Average minimum temperatures must be above -12° to -15°C. *S. sebiferum* is a subtropical to warm temperate plant, hardy and able to withstand light frosts, but unripened twigs are susceptible to frost injury. It typically occurs at elevations of 0 to 800 m (Duke et al. 1997).

S. sebiferum is tolerant of flooding in fresh, brackish, or saltwater. The trees survive flooded conditions by producing hypertrophied lenticels and adventitious roots. In saline water, *S. sebiferum* seedlings can survive up to 6 weeks, although rates of growth become negatively impacted (Conner 1994).

Reproduction

In the southern United States, *S. sebiferum* initiates growth in February, and flowers from March through May. Fruits ripen from August to November. Trees generally live 15-25 years with a potential maximum age of 100, though rootstocks may live much longer (Jubinsky 1995).

S. sebiferum can begin flowering and fruiting when the plant is one meter tall or approximately three years old (Jubinsky 1995). In the southern U.S., catkins appear from March to June. *S. sebiferum* produces two types of inflorescences that are composed of two different types of seed clusters, commonly called “grape" and "eagle claw." The "grape" form, on which the female flowers mature first, produces pedicelled pods, usually three seeds to a pod, spirally arranged around a fruiting terminal branchlet. The "eagle claw” form, on which the male flowers mature first, produces pedicelled pods arranged around two or more short stems that branch from the terminal branchlet. This highly unusual flowering strategy, called dichogamy, involves

differential flowering times and requires two subpopulations, but ensures cross-pollination (Bruce et al. 1997). This characteristic contributes to the high genetic diversity observed within stands of the species (Conway 1997). *S. sebiferum* fruits are usually a three-lobed capsule, about 1 cm long and broad, and superficially resembles popcorn (Bruce et al. 1997).

S. sebiferum plants have tremendous reproductive potential. They may reach reproductive age in as little as three years, and in greenhouse experiments, seedlings flowered in their first year of growth. A mature tree may annually produce an average of 100,000 seeds that are dispersed primarily by birds and water (Duke 1983; Jubinsky and Anderson 1996). Under favorable conditions, a mature stand of trees can produce 4,500 kg of seeds per hectare per year. Trees can remain productive for 100 years. Tree stumps have the ability to resprout, and roots fragments can readily develop shoots (Conway 1997).

Seed Dispersal

S. sebiferum seeds disperse mainly by birds and water (Duke 1983; Jones et al. 1989). In Florida, pileated woodpeckers (*Dryocopus pileatus*) and boat-tailed grackles (*Quicalus major*) (Jubinsky 1993) are common dispersers of *S. sebiferum* seeds. Seeds have also been documented along riverbanks in central and north Florida after heavy rains, indicating they floated or were washed to the area (Jubinsky and Anderson 1996).

The viability of seeds averages 95% and germination is 26%-65% in the laboratory. Germination is highest in January and February and lowest in late fall and early spring. Ten to 50% of seeds were viable after one year in Louisiana soil. Seeds in sealed metal cans remained viable 7 years, with maximum germination rates continuing even after 1-2 years of storage (Bruce et al. 1997).

ECONOMIC USES

The outer covering of the seeds contains a solid fat known as Chinese vegetable tallow, and the kernels produce a drying oil called stillingia oil. Candles, soap, cloth dressing, and fuel are made from the tallow. The oil is used in machine oils, as a crude lamp oil, in making varnishes and paints (because of its quick-drying properties), and as a substitute for linseed oil. The oil is also reportedly used in Chinese medicine as an emetic or purgative, but overdoses can cause violent sickness and perhaps death (Duke 1983). *S. sebiferum* may represent an industrial toxic hazard in terms of both pro-inflammatory and tumor-promoting effects (Brooks et al. 1987). After the seeds have been processed, the residual cakes are often used as fertilizer/green manure. A black dye can be made by boiling leaves of *S. sebiferum* in alum water (Duke 1983). Tallow wood is white and close-grained, suitable for carving and for making blocks in Chinese printing. The wood is also used for furniture making and incense.

In the early 1900s, the Foreign Plant Introduction Division of the U.S. Department of Agriculture introduced *S. sebiferum* into Texas and other parts of the Gulf Coast states in order to establish a local soap industry (Scheld and Cowles 1981). In the 1970s and early 1980s, *S. sebiferum* was regarded as a promising biomass candidate in the Gulf Coast region of the United States because of its ability to resprout, its rapid growth rate, and its drought and salt tolerance (Scheld and Cowles 1981). Field trials demonstrate that it can produce six times as much woody biomass as cottonwoods and aspens (*Populus* spp.) in Wisconsin (Scheld and Cowles 1981). *S. sebiferum* can be easily grown by conventional agricultural methods and can provide woody biomass for direct burning or for conversion into charcoal, ethanol, or methanol (Scheld and Cowles 1981).

Oil from *S. sebiferum* seeds can potentially be a substitute for petroleum. Scheld et al. (1980) reports yields of *S. sebiferum* seeds ranging from 4,000 to 10,000 kg/ha, and estimates that 25 barrels of oil per year can be produced as a source of energy. In addition to its biomass and energy value, *S. sebiferum* has been extensively planted and propagated for ornamental purposes (Duke 1983).

MANAGEMENT

Potential for Restoration of Invaded Sites

As with all prolific invaders, the key is to successful control is to prevent new infestations or to control them as soon as possible. *S. sebiferum* has a high degree of reproductive vigor, a wide range of adaptability, and few pests and predators. It produces a large number of viable seeds that are readily dispersed by birds and by water, and which germinate at high rates in a wide range of conditions. If controlled during the early stages of invasion, the potential for successful management is high. The potential for large-scale restoration of wildlands where *S. sebiferum* has become established, is probably low.

Manual and Mechanical Control

Hand removal of trees is usually limited to trees less than three feet tall or to small infestations. Sawing down large trees will help to remove seed sources. Fruit should be removed from fallen trees in order to reduce the number of seeds present. In order to prevent resprouting, however, cut-stumps will require an herbicide application. Heavy equipment can be effectively used to control tallow trees on canal banks and in areas where soil disturbance and selective species removal are not important considerations. Stumps remaining following such treatment will require herbicide application to prevent regrowth from cut surfaces. In some agricultural areas, bulldozing and disking have been effective in the control of *S. sebiferum* (Bruce et al. 1997). Trees standing in water may be successfully killed by cutting them below the water line.

Grazing

Sheep and goats will eat the leaves of *S. sebiferum*, but toxicity to cattle limits their effectiveness as a control agent. Cattle will eat seedlings less than 6 cm tall (Bruce et al.1997).

Flooding

Flooding is not effective in controlling *S. sebiferum*, as it is adapted to flooding in fresh, brackish, and saltwater.

Prescribed Burning

The use of prescribed fire can be used to control *S. sebiferum*. Fire has various effects on tallow trees: (1) complete kill (preliminary data suggest that this is unlikely); (2) top-kill where the aerial portions of the trees are killed but resprouting occurs from the base, and (3) incomplete top-kill where the crown can resprout after fire. In areas with sufficient fuel, such as in prairies with good grass cover, summer burns killed or top-killed trees as tall as three meters. The control of trees growing in wet sites where fuels were poor, however, was much less effective. Burning during the dormant season (December), followed by burning or mowing during the growing season (July-August) seems to be the most effective. Additional experimental work is being done on the effect of fire on tallow trees (J.B. Grace, personal communication, Federal Wetlands Laboratory, USGS, Lafayette, LA).

Herbicides

The most effective method for the control of *S. sebiferum* is the basal bark application of herbicide. Several organizations, including the Florida Department of Environmental Protection, the Florida Exotic Pest Plant Council, Florida Native Plant Society, the Florida Nature Conservancy, the Louisiana Nature Conservancy, and the Texas Nature Conservancy, have adopted this method of treatment (Jubinsky and Anderson, 1996; Randall and Meyers-Rice, unpublished). Effective treatment consists of spraying a band at least 15 cm wide around the lowest 30-60 cm of the trunks with triclopyr (brand names Garlon 3A, Garlon4, Pathfinder II and others) at a concentration of approximately 15%. Concentrations up to 20% might be required for larger trees. Vegetable oil and other similar products are effective surfactants. Basal bark applications may be ineffective on large trees with thick bark; for such trees a cut-stump method may be necessary. For a cut-stump treatment, excellent results are reported with a 50% solution of the triclopyr formulation Garlon 3A or with a 10% solution of the herbicide imazapyr (brand names Arsenal, Chopper and others). Imazapyr is a soil-active herbicide that requires careful use when applied near desirable plants or trees to prevent it from

killing them. Other herbicides that have successfully controlled *S. sebiferum* include the combined 2,4-D and picloram formulations (Grazon P+D and Grazon) applied to foliage, or hexazinone (Velpar L) applied to soil near plants (Bruce et al. 1997; Jubinsky and Anderson 1996). Frilling using glyphosate (Rodeo) is also an effective control method. Bergen (1998, pers. comm.) reports from Texas that the most effective time to apply herbicide to minimize seed spread is in late summer to early fall.

Biological Control

There are currently no biocontrol agents identified for control of Chinese tallow. *S. sebiferum* trees are generally free of insect pests and serious pathogenic organisms. A few organisms known to associate with *S. sebiferum* (potential agents) include a bagworm, *Eumeta* sp., which feeds on the leaves, and the root-knot nematode *Meloidogyne javanica*. Fungi known to attack this tree include *Cercospora stillingiae*, *Clitocybe tabescens*, *Dendrophthoe falcata*, *Phyllactina corylea*, *Phyllosticta stillingiae*, and *Phymatotrichum omnivorum* (Duke 1983). Adult and juvenile leaf-footed bugs (*Lepotglossus zonatus*) have been observed feeding on fruits of *S. sebiferum* at Brazoria National Wildlife Refuge in Texas (Johnson and Allain 1998).

EXAMPLES OF MANAGEMENT PROGRAMS FOR *SAPIUM SEBIFERUM*

Prescribed fire has been used at Brazoria National Wildlife Refuge in Texas to control *S. sebiferum*. Jim Grace reports that prescribed fire was somewhat effective in top-killing trees and killing seedlings, but many resprouts were observed afterwards (Grace 1998). Several other studies on the effectiveness of different control methods on *S. sebiferum* have been completed or are in progress by the Brazoria County Extension Service.

On TNC preserves, several herbicides have been used successfully to control *S. sebiferum*. Mark Dumesnil (Mad Island Marsh Preserve, Texas) reports that cutting and pulling are somewhat effective in the short-term for controlling *S. sebiferum*, but an herbicide application following cutting is necessary for good control. He applied a 1% foliar application of Arsenal (imazapyr) in the fall and obtained excellent control results. Tom Ledbetter also found that a 1.5% foliar spray of Arsenal was effective at the Galveston Bay Prairie Preserve in Texas. Additionally, he found that a 30% formulation of triclopyr (Garlon4) with oil worked well as a basal bark application. Richard Martin similarly used Garlon4, but as a 10% basal spray, and also obtained excellent control results.

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MONITORING

Following control treatments, further control efforts and monitoring are needed annually for at least 3-5 years due to the ability of *S. sebiferum* to resprout, the viability of seeds in the seedbank, or the likelihood of reinvasion from nearby sources of propagules (Bruce et al. 1997). In natural areas management, monitoring programs will likely combine assessment of changes in abundance of *S. sebiferum* with changes in abundance of species or changes in community attributes that are the targets of management. Such programs should have explicit objectives that can be measured with statistical significance, and that are meaningful from both a biological and management standpoint. In addition, increasing regeneration of native species may be an important objective. Monitoring the status of other conservation targets such as invertebrates dependent on specific nectar sources, may be more important than tracking invasive plant species abundance. In general, the objectives of monitoring should track those of management.

In terms of effort (number of plots established and monitored), transects or long, linear plots laid across notable environmental gradients are more effective in providing sufficient statistical power to determine change than square or broadly rectangular or otherwise regularly shaped quadrats. Analyses of plant species composition and abundance can be simplified by (1) collecting data on abundance of dominant species; (2) collecting data on all species and pooling data on less abundant species; and (3) pooling data on species by placing them in guilds (invasive grasses, invasive legumes, native grasses, etc.).

While generally a research technique, measuring change, or lack thereof, in control (unmanaged) areas can be an effective way of assuring that any changes detected in treated areas are actually the result of management actions and not from other factors. In forest communities that are in early successional stages or recently disturbed, declines in abundance of *S. sebiferum* may occur without management.

Research Needs

Work is needed on possible allelopathic properties of *S. sebiferum*; long term successional dynamics of systems invaded by *S. sebiferum* to determine if native species become established and regain dominance absent of management; and viability of *S. sebiferum* seeds in the seed bank under varying soil conditions (e.g., nutrient availability, soil moisture, light, temperature).

The following research topics need attention: 1) What are the mechanisms of *S. sebiferum* invasion and spread in a variety of forest landscapes? 2) What is the light environment of disturbed forests and the corresponding tolerance limits for *S. sebiferum* reproduction and survival? 3) To what extent does alteration

of water level fluctuation foster invasion by *S. sebiferum*? 4) What are the effects of *S. sebiferum* on herb layer species? 5) To what extent are deer a factor in fostering invasion by *S. sebiferum*? 6) Which if any biocontrols are effective in the native ranges of *S. sebiferum*? 7) What roles do logging and other forestry practices play in the successful spread of *S. sebiferum*? 8) How could forestry operations be carried out to prevent invasion by *S. sebiferum*? 9) Which species replace *S. sebiferum* when control succeeds? 10) What is the effectiveness of prescribed burning on this species and encouraging regeneration of native species in forest types that are fire-influenced?

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