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Chinese Tallow Trees As a Biodiesel Feedstock

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Biodiesel derived from renewable vegetable and animal fats is attractive as a substitute or additive for petroleum diesel because of its high energy return, simplicity of manufacturing, high lubricity and capacity to substantially reduce most exhaust pollutants. Currently, biodiesel production is severely limited by the availability of affordable feedstocks. The price of soy oil, the mainstay of the U.S. biodiesel industry, has risen beyond the point where biodiesel can compete with petroleum diesel, even with a $1 per gallon federal subsidy. To significantly affect our dependence on petroleum diesel, development of high-yielding alternative oilseed crops is essential. To minimize the effect of biofuel production on the world's food supply, these crops must be adaptable to land not currently used for food production.

Two years after transplanting, this Chinese tallow tree has grown to nearly 16 feet. The trunk diameter has increased from 1.1 to 5.1 inches, demonstrating the potential of the trees to sequester carbon. The tree is heavily laden with flowers and will produce a harvestable crop in its third season.

The Chinese tallow tree is perhaps the most promising oilseed crop adapted to the humid South and capable of producing a sufficient supply of feedstock to meet the needs of the U.S. biodiesel industry. The Chinese tallow tree is an introduced species that grows rapidly, spreads profusely and has become naturalized along the Gulf and southern Atlantic coasts between Texas and North Carolina where it is considered a noxious weed. It is also found in California.

In China, where this tree has been cultivated for more than 1,500 years, it is used to stabilize levees and stream banks. It also provides fertilizer to rice crops and is harvested for its oilseed. The seed of the tallow tree produces two distinctly different types of fats – a nontoxic "tallow," external to the seed coat, and a mildly toxic kernel oil, commonly called "stillingia oil."

A typical tallow tree two years after transplanting as a 1-year-old sapling. This tree has not yet produced flowers. Joe Kraska, in the photos, is a graduate assistant in the LSU AgCenter (Photos by Gary Breitenbeck)

In China, the tallow tree is reported to be grown without industrially produced fertilizers or pesticides, yet it is capable of producing 750 or more gallons per acre of waxes and oils used for multiple purposes, including lighting and heating oils, soaps and pharmaceuticals, as a substitute for cocoa butter in chocolate, and to produce dairy creamer substitutes. Other reports claim the tallow tree in managed systems is capable of producing seed yields of 12,500 pounds per acre, which contain about 300 gallons of kernel oil, 6,200 pounds (about 180 gallons) of tallow, 3,300 pounds of protein meal suitable for use as fertilizer, and 13 tons of fibrous and hard seedcoat.

LSU AgCenter scientists have confirmed that Chinese tallow trees growing

in favorable environments in Louisiana are capable of extraordinary yields. Hand harvesting of a single tree with a drip-line area of 380 square feet produced 68 pounds of seed. By extrapolation, this represents a seed yield of more than 7,800 pounds per acre containing 4,000 pounds of tallow and 3,750 pounds (about 420 gallons) of kernel oil. With appropriate management and continued research and development, sustainable yields of this magnitude are conceivable in commercial production.

Trait	Range
Seed yield/tree (less than 15 feet tall)	zero to 68 pounds
Percent aril	24 percent to 35 percent
Percent kernel	28 percent to 37 percent
Percent seed coat	34 percent to 44 percent
Percent lipids in aril	59 percent to 80 percent
Percent lipids in kernel	14 percent to 24 percent
Individual seed weight	97 to 185 milligrams
Average bushel weight	33.6 to 43.3 pounds
1st flowering date	Feb 10-March 30
Diameter of 4-year-old tree at 12 inches above ground	1-10 inches
Maturity	Sept. 21-Nov. 15
Number of catkins per branch	1 to 6
Seeds per capsule	2 to 4
Seed germination	zero to 85 percent

These high yields can lead to misconceptions regarding the amounts of seed produced in naturalized stands. In a half-acre area located in a highly dense stand of naturalized tallow trees, trees were scored based on seed load from zero to 4 for exceptional. The average score was 1.2, with most trees producing no seeds or only a few seeds at the top of the canopy. Rarely did a tree produce seeds throughout the canopy. Low seed yields are common when the tallow tree is heavily self-shaded or growing as an understory tree in a mixed forest. Even when provided with adequate light and water, however, most naturalized trees produce low amounts of seeds.

In a count of tallow trees growing in the fence row surrounding a pasture, only 27 percent were ranked as good or better. Seed production was considered exceptional in only one of 124 trees. In contrast to naturalized trees, nursery stock planted in full sun with adequate water and nutrients frequently produces high seed yields. In one stand of 12 landscape trees, seed production of every tree was rated good or exceptional.

Naturalized trees generally produce greater seed yields when growing along stream banks or drainage channels. While they tolerate continual flooding, they seem to produce better when flooded intermittently. Tallow trees are also extremely salt-tolerant. One tree with an exceptional seed load was growing in soil considered too saline for all but the most salt-tolerant plants. Shallow, less-saline groundwater may have benefited this tree.

Tallow trees are seldom found on drought-prone soils or in undisturbed mature forests. Fertility requirements are largely unknown, though limited evidence suggests they are low. These trees apparently attract few insects, and these few do not appear to affect the trees adversely. The trees develop occasional leaf lesions from fungal or bacterial infections, but these infections are invariably mild, affecting only a few leaves. The most common disorder of the tallow tree foliage causes cupping and dwarfing of leaves, usually near the base of the tree. This disorder does not appear to significantly affect tree health or productivity, however. The cause of this malady is under investigation.

Clearly, both genetics and environment interact to influence yields. LSU AgCenter researchers are documenting the differences in a random sampling of saplings collected across the Gulf Coast region and transplanted to a uniform environment. Only one or possibly two of these trees have displayed commercial potential. A primary research goal is to establish similar plantings of exceptional trees selected from the naturalized population. Because of the time required to breed and evaluate trees, collections are concentrating on "elite" ecotypes that display high yields and other characteristics desirable for commercial production. Table 1 shows some of the characteristics monitored in a collection of 26 elite trees located in Louisiana and Mississippi.

The key selection characteristic is exceptional seed production, though five trees were entered because of "good" seed set on trees with trunks less than 1 inch in diameter. Seed production by young trees – those shorter than 15 feet tall with a 6-inch diameter trunk at 12 inches above ground level – is extremely rare among naturalized trees. Early production may prove a critical characteristic in selecting a commercial variety.

In addition to seed yield, oil yield is a key consideration. The total amount of fats as well as the proportional distribution between tallow and kernel oil varies significantly among trees. The tallow layer consists primarily of palmitic, oleic and stearic acids. The kernel oil consists primarily of linoleic, linolenic and eleostearic acids. The considerable variation in the proportions of tallow and kernel oil as well as in the fatty acid composition within the fractions suggests it may be possible to select trees to meet specific end-use requirements.

Seed size and weight also vary. Some trees produce seeds weighing an average of 185 milligrams, whereas others produce seeds of approximately half that weight. This trait appears to be largely genetically determined – trees with large seeds have been seen growing in close proximity to trees with small seeds.

The variations in flowering are among the most distinct genetic differences among trees. While environmental factors undoubtedly play a role, some trees can flower as much as 30 days after others growing in the same general area. Flowering patterns vary as well. Most trees produce a single catkin containing six-12 female flowers at the base and a long tail of male flowers. Some produce two catkins per shoot but rarely as many as six. One unusual tree produces a single catkin early in spring and two others about three weeks later. This tree may be one of the few capable of significant self-pollination because female flowers are pollinated several days before the catkin's pollen matures. Flowers originate on a young shoot initiated in early spring, usually from a bud on a branch less than 0.5 inch in diameter. For this reason, careful pruning and harvesting are especially important. Pruning larger branches during harvesting can significantly reduce yields in the subsequent year.

Flowering is largely complete by mid-April, though trees will continue to produce an occasional catkin well into summer. Late flowers seldom set fruit. Fruit develops within a green, lobed capsule. Each capsule generally contains three embryos, a consistent trait, though an occasional capsule will contain two or four embryos. Capsule maturity varies among trees by as much as six weeks and within an individual tree by two to three weeks.

Unripe capsules cannot be harvested because the aril – the fleshy seed covering – is highly viscous until exposed to air and quickly clogs harvesting equipment. Although uneven maturity would seem to pose harvesting problems when unopened capsules are cut from the tree and left to dry on the ground, the capsules open and seeds harden within a few days. Once capsules open, they shed the husk, and the seeds are retained on elongated stalks. Seed retention varies among trees, and some trees are capable of retaining seed from the previous season until after the current season's fruit matures. Prolonged retention is not necessarily an attribute because after several weeks the waxy aril is colonized by fungi, turning the white seed black. While this does not appear to affect the amount of fats in the wax, it causes discoloration of the oil and may affect quality.

Seed germination rates vary greatly – from zero to 85 percent. The failure of the seed of some tallow trees to break dormancy may offer a first generation of trees with limited invasive potential because the spread of tallow trees is generally attributed to seed dispersal by birds.

To fully characterize the properties of elite trees, it is necessary to make side-by-side comparisons of trees growing in similar environments. Because seeds are heavily cross-pollinated, the trees do not breed true to their parents. Developing cloning techniques has proven surprisingly difficult given the natural vigor of this tree. Stem cutting will produce shoots but not vigorous root systems. Various combinations of rooting hormones have failed to produce more than a few fine roots less than 0.75 inches long. Root cuttings of various sizes invariably decay before they produce shoots. Various grafting techniques, including bud grafting, have proven marginally successful. Aside from the labor involved, grafting may not be an ideal method for commercial production given the tendency of tallow trees to copiously produce new shoots from

rootstock. Micropropagation techniques offer an attractive means of producing a large number, and research will continue to pursue this approach.

A three-year investigation has demonstrated that that the tallow tree has legitimate potential to supply the biodiesel industry with critical feedstock at low cost. Tallow trees readily adapt to soils too infertile, wet or saline for profitable agriculture; therefore, commercial production will not compete with food crops for limited land resources. Because of their high yield potential and oilseed value, tallow trees offer the possibility of restoring economic prosperity to some of the most impoverished areas of the South. For example, tallow trees continue to thrive in Plaquemines Parish, La., where soil salination caused by recent hurricanes has damaged the citrus industry.

Tallow trees represent a perennial crop that can be intercropped with forages until canopy closure. Because the soil is not cultivated, soil erosion is reduced, and water quality is improved, especially near stream banks. Naturalized tallow trees appear to have few insect or disease pests, and therefore would not require pesticide applications. While preliminary studies have shown that light fertilization can be beneficial during stand establishment, it is uncertain whether fertilizers would be necessary once commercial harvest begins, especially if the seed meal is returned as an organic fertilizer. It is likely that management may involve only a single pruning/harvesting operation in late fall. Because the waxy aril sheds water, seeds may not require drying before storage and processing. Most energy expenditures will be incurred at harvest or for post-harvest shipping and processing. Overall, the tallow tree has the potential to become our most energy-efficient and profitable oilseed crop.

Conversion to commercial production of 500,000 acres of noncrop uplands currently hosting dense stands of tallow trees in southwest Louisiana has the potential to produce 80 to 140 million barrels of biodiesel within a decade. In addition to the tallow tree's capacity to reduce the atmospheric burden of carbon dioxide by providing high yields of renewable hydrocarbons, commercial plantations of this fast-growing tree can sequester significant amounts of atmospheric carbon as standing biomass.

Read more about the Chinese tallow tree.

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