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Growing Bamboo for Commercial Purposes in the Southeastern U.S.: FAQs

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Introduction

Golden bamboo (*Phyllostachys aurea*), planted as an ornamental and historically for use as fishing poles, is a familiar sight spreading beyond old homesteads. Sometimes confused with native river canes (*Arundinaria* spp.), golden bamboo is one of over 1,400 species of fast-growing, woody, evergreen grasses in the subfamily Bambusoideae (Poaceae)[3]. Bamboos range in size from short ground covers to timber bamboos which can reach heights of 75 feet and diameters of 5 inches or more.

In recent years there has been renewed interest in promoting bamboo as a sustainable cash crop. Bamboo has been called "green gold" and "the most useful plant in the world", with uses ranging from structural materials to industrial products, fencing, and even food. Still, many questions remain about the use of bamboo as a crop in the southeastern U.S. The purpose of this bulletin is to address some of these questions and to provide some basic information about the growth and biology of bamboo.

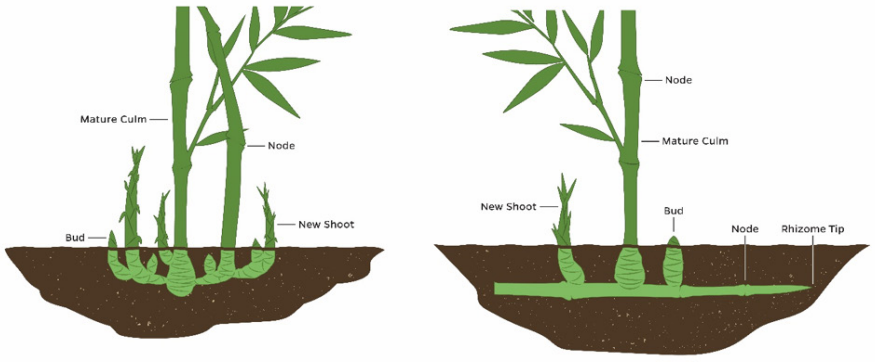
HOW DOES BAMBOO GROW?

Bamboo has an interesting growth pattern. Bamboo creates groves, in which all of the culms (stems) are clones of the original planting. Bamboo culms emerge from a dense rhizome system which is generally located within the upper 12 inches of soil. Rhizomes are modified underground stems that function similarly to roots. As new culms emerge from the ground they elongate very rapidly. This rapid growth (or 'shooting') is a result of redistribution of stored carbohydrates (stored energy) from the previous growing season and not new growth from current photosynthesis. Culms remain the same diameter from emergence to maturity and individual culms do not increase in diameter over time. However, there is an overall increase in the diameter of new culms as a bamboo grove matures. Likewise, an individual culm will not increase in height after the first season, but culms emerging in subsequent years will be taller. Culms can put on additional branches over time, thereby increasing the amount of leaves available for photosynthesis and growth of the grove. Self-shading will eventually limit this potential increase in carbon gain from photosynthesis. Culm walls continue to harden for several years until reaching maturity. Bamboos flower irregularly, sometimes decades apart. Many species flower gregariously (meaning all the culms on a single clonal plant, and all the plants of the same species around them, flower and produce seed at the same time) while others flower sporadically. Seeding is often followed by death of the clonal grove[2,14].

WHAT IS THE DIFFERENCE BETWEEN CLUMPING AND RUNNING BAMBOOS?

There are two major types of bamboo: clump forming and running[17] (Fig. 1). The rhizomes of clumping bamboos grow radially and produce very little horizontal

Fig. 1. Rhizome structure of clumping and running bamboo. From Lieurance et al. 2018.



growth before they turn upwards and produce a culm. As a result, they spread rather slowly, forming dense clumps with minimal spatial spread. Most clumping bamboos are from subtropical/tropical regions of Asia, Africa and South America, and are not very cold tolerant (though this varies among the different bamboo species). With the exception of bamboos in the genus *Fargesia*, clumping bamboos generally do not grow well in temperate climates, which encompasses most of the southeastern U.S.[23]

The rhizomes of running bamboos produce more horizontal growth and send up multiple culms along the rhizome, resulting in significantly greater spatial spread. Running bamboos can spread up to 15 feet a year. Running bamboos tend to be more tolerant of cold than clumping bamboos and are generally better suited for temperate climates. Our native river canes (*Arundinaria* spp.) are in the running bamboo category.

WHAT SPECIES ARE BEING PROMOTED FOR COMMERCIAL USE?

Two species of running bamboo originating from temperate areas in Asia are being promoted for commercial use in several southeastern states: moso bamboo (*Phyllostachys edulis*) and rubro bamboo (*Phyllostachys rubromarginata*). Because it is more suitable for sub-tropical climates, a clumping bamboo (*Dendrocalamus asper*) is also being promoted for cultivation in Florida.

IS THERE A DEMAND FOR BAMBOO PRODUCTS IN THE U.S.?

The annual market value of bamboo products world-wide is estimated to be $60 billion[13]. International trade accounts for a minor proportion ($1.7 billion in 2016, or < 5%, of the total market value), but the U.S. was the second largest importer of bamboo. Bamboo imports reached $336 million, which was 23% of the global import total. Bamboo furniture, bamboo plywood, and bamboo basketwork accounted for about 70% of the imported products, and bamboo shoots for food consumption accounted for about 10%. The flooring market is the most important category for the bamboo products, but new markets such as veneer and panels for interior decorations are also rapidly developing. However, markets for bamboo raw materials in the southeastern U.S. are not yet well established.

WHAT ARE THE PRIMARY BAMBOO PRODUCTS?

Most bamboo products are secondary products, such as engineered bamboo materials (e.g. bamboo flooring), woven bamboo materials (e.g. fabric), bamboo/rattan furniture, and paper pulp. Bamboo is also being turned into biochar and used as a soil amendment[27] and has potential as a biofuel[16]. Additionally, bamboo shoots can be harvested for food.

WHERE CAN A GROWER SELL BAMBOO?

Few commercial markets for raw bamboo currently exist in the southeastern U.S., though there may be some demand from smaller niche markets for things like bamboo shoots (food) or art and craft supplies (e.g. brush handles). Currently, in anticipation of developing markets, the companies promoting commercial planting of bamboo appear to be the primary market for raw bamboo materials (i.e., the companies selling nursery stock and often times financing planting will purchase the bamboo from the grower). This appears to be primarily contract-based, and it is unclear what would happen to the market should the company no longer continue to buy bamboo (i.e., if the anticipated markets fail to materialize or if the company folds).

WHERE IS BAMBOO BEING PROMOTED?

Bamboo is being promoted throughout the southeastern U.S., especially in areas where previous crops have failed. For instance, where the citrus greening epidemic has impacted Florida citrus growers, bamboo is being marketed to landowners as a viable crop in the post-citrus era. In Alabama, the focus is on the 'Black Belt' region where economic opportunity is depressed.

WHAT ARE THE ECONOMIC CONSIDERATIONS FOR GROWING BAMBOO?

Many factors play a role in the economics of growing bamboo commercially, including the following factors:

1. Markets: Are there established facilities in your local area that accept bamboo raw material in a sustained manner? If the company selling the bamboo plants is also the buyer, do they have guaranteed pricing and sustained demand?

2. Site Preparation: Getting a site ready for planting – which may include vegetation removal, tillage, and herbicides – can cost several hundred dollars per acre. The addition of an irrigation system, if needed, will substantially increase these costs.

3. Plant material: Planting material for bamboo may be available as rhizomes or young plants. Young plants from nurseries are preferred as they establish more successfully and more quickly than rhizomes. Cost per plant will vary depending on availability and species, but may be over $40 per plant. Also, 100% survival is not likely[25] so extra plants may be needed to get a fully established site to avoid waiting longer to reach grove maturity.

4. Labor: A significant amount of manual labor is typically involved with planting, growing and harvesting bamboo. These costs will vary depending on the grower's methods and equipment/personnel resources, and there are no published data documenting current bamboo propagation and harvest costs.

5. Transportation: What will it cost to get harvested bamboo to market? Distance to the processing facility is a primary factor. In southeastern U.S. forestry operations, due to transportation costs, wood typically is not transported more an average of 90 miles to the mill[4]. In some instances, if the grower is working under contract with a bamboo company, transport of the bamboo from the grower to the market or processing facility may be covered under the contract, but this will likely depend on with which company the grower enters an agreement.

6. Containment: For running species, there are costs associated with spread prevention. Repeated mowing, herbicide applications, the installation of physical barriers, or excavating a ditch around the perimeter of the grove are methods that can be used to contain running bamboo. All have associated costs – some only in labor, some in labor and materials.

7. Time: It may take a decade or more to harvest certain bamboo products, during which time the grower may not see any revenue from the planting.

8. Conversion out of bamboo: If a determination is made down the road that growing bamboo is no longer desirable, the costs of conversion to other uses (e.g., forestry or agricultural uses) could be high because mechanical and chemical means (multiple herbicide applications) are typically needed to completely eradicate bamboo from a site. In cases where there is a contract with a bamboo company, there may be penalties for early departure from a contract.

HOW DOES BAMBOO HANDLE INCLEMENT WEATHER AND FIRE?

While bamboo is known to be a very strong construction material[10,20], there is evidence that bamboo is not particularly hardy in certain environmental conditions. Specifically, ice storms can (but do not always) damage bamboo stands, with reports of nearly 60% of the culms bent, broken, or uprooted after a single ice storm[29,30]. In young (1-year-old) culms, the damage rate was about 70%. Ice storms are somewhat common in many states in the southern U.S. and may pose a threat to the establishment and health of bamboo plantings. In addition, bamboo does not hold up well when subjected to frequently rising and falling temperatures, as it may result in mechanical damage which would likely reduce the value of the bamboo[26].

There is little information regarding bamboo's ability to withstand high winds, but anecdotal reports (personal observations and newspaper articles) following recent hurricanes in the southeastern U.S. suggest it is not very tolerant. Bamboo has a shallow root system, which makes it relatively top-heavy and therefore more easily blown over[24].

Bamboo can be a fire hazard as the woody stems and thick layer of dead leaves on the ground are quite flammable. Bamboo also retains dead twigs, which can further serve as fuel and as fire ladders taking fire into the canopy. In some cases, fire can reduce bamboo clump growth by leading to culm mortality following a fire[9].

IS BAMBOO EASY TO GROW ON A COMMERCIAL SCALE?

Newly planted bamboo plants are not tolerant of competing vegetation. Fairly extensive site preparation, including land clearing and herbicide application, may be necessary before planting. Studies show that young bamboo responds well to fertilization and fertilization at planting with a complete fertilizer (e.g., 80 lbs N, 35 lbs P, and 50 lbs K per acre) is recommended, as this will increase productivity[1]. Soil tests may help determine appropriate fertilizer application types, formulations, and frequencies. During the first year, bamboo plants should be watered every 7-10 days (if it doesn't rain). This may require installation of an irrigation system, depending on the size of the plantation. Young plants should also be protected from competing vegetation[25] and in some cases from herbivory by deer or other animals.

Growth is strongly influenced by environmental factors and can be highly variable from year to year[1]. Growing bamboo takes time, and little can be done to speed up initial grove development. In the southeastern U.S. it will typically take over a decade for a grove to reach harvestable size[25]. Given that wall thickness and culm quality changes with age, it may take several years for individual culms to reach the desired maturity for particular end products. As new culms will continually grow an area, it may be necessary to mark individual culms in order to keep track of their age. Thinning the grove will help maintain product quality and grove health[25]. Once established, a bamboo plantation will probably be viable for several decades before it would start to decline and need to be replaced. However, data on expected grove life and productivity with different harvesting regimes is not currently available.

DO EFFORTS NEED TO BE MADE TO CONTAIN BAMBOO?

Both running and clumping bamboo require management to keep plantings contained, with at least a 20 ft. buffer between the bamboo planting and a natural area. Buffer areas around bamboo plantings can be mowed to prevent bamboo from spreading. Mowing will need to be done on a schedule (as you would your lawn) during 'shooting'. Young bamboo culms are fairly fragile and can also be

Table 1. Summary of approaches and techniques to control species of running bamboo. There are few published studies for many of these techniques.

Approach	Technique	Comments
Prevention	Increasing awareness/ Education[a]	Recognize that many individuals are still unaware of the problems bamboo can cause. Proactive education can help prevent "learning by mistake."
	Do not plant - use suitable alternatives[b]	Avoid using running bamboos for privacy screens, living fences or other risky ornamental plantings. Native replacements include giant cane (*Arundinaria gigantea*), or other dense hedges such as eastern red cedar (*Juniperus virginana*). Other shorter but robust native grasses include switchgrass (*Panicum virgatum*) and Eastern gamagrass (*Tripsacum dactyloides*).
	Trenching[c-f]	When bamboo is present nearby, trenching can eliminate rhizome encroachment across property lines. Trenches should be dug to a depth below the rhizome depth of the species. New rhizomes will grow to the trench wall, initiate vertical growth and produce a new shoot at the trench interface - these will require occasional removal. Several trenching/barrier installation guides are available online from commercial bamboo nursery operations. However, there has been little trenching/barrier research published to verify these.
	Rhizome barriers[c-f]	In addition to trenching, polyethylene plastic barriers are effective in preventing rhizome spread if properly installed. Critical issues are plastic thickness and angle and depth of installation. Several trenching/barrier installation guides are available online from commercial bamboo nursery operations. However, there has been little trenching/barrier research published to verify these.
Physical control	Rhizome excavation	Heavy equipment such as a backhoe or root rake can remove much of the rhizome system if complete soil disturbance is feasible. Any rhizome pieces left in the soil can resprout and follow-up removal will be required.
	Hand pulling/ weed wrench	Not feasible for running bamboo in most situations. Woody stems cannot be hand pulled and weed wrenches will crush stems or break them off near the soil surface, leaving intact rhizomes.
	Burning[11]	Not well studied but unlikely to control bamboo as a standalone technique. Anecdotal observations indicate rapid regeneration of new shoots from rhizomes. Accumulation of fine fuels and dead stems may allow fire to carry through dense stands. When burned, stems make loud popping noises due to hollow stems.
	Cutting/mowing	In theory, repeated cutting or mowing should gradually exhaust energy reserves in the rhizomes. The frequency to accomplish this has not been studied but is likely several years.
	New sprout elimination	A suppressive technique to reduce patch expansion. New shoots are extremely high in water content and can be easily broken off/mowed/crushed in the spring during the shooting period. This technique will not reduce the existing stand but can reduce spread. Timing is critical and must be done before shoots begin to harden off. This technique has not been well studied.
Biological control	Grazing[12]	All classes of livestock will graze the leaves, but hardened stems will not be eaten. Repeated, intensive grazing of new shoots probably won't suppress bamboo growth and spread over time. Historically, native bamboo (*Arundinaria* spp.) likely declined across the southeast as woodland grazing by livestock increased. However, grazing prescriptions for invasive bamboos have not been well studied.
	Classical biocontrol	There are no insects or diseases that have been utilized for classical biological control. Historically, invasive grasses have had very few successful biocontrol programs.
Chemical Control	Foliar[5,7,18]	Glyphosate: 5% v/v as a backpack or high-volume handgun treatment (using a 41% ai formulation or higher). Broadcast treatments of 120 oz/A will result in suppression and follow-up treatments will be needed. Foliar glyphosate treatments are most effective as a follow-up to cutting, when shoots have regrown to 3-4 feet in height. Multiple treatments over a few years will be required. Homeowners should avoid any RTU (Ready to use formulations of glyphosate) as they are too low in concentration to provide control. This is a non-selective treatment that will injure or kill other plants that are sprayed during bamboo treatment. Imazapyr: 2% v/v (using a 27% ai formulation) or 1% (using the 54% ai formulation common in forestry) as a backpack or high-volume handgun treatment. Broadcast treatments of 64 or 32 oz/A for the 27 and 54% ai formulations respectively. Imazapyr is the most effective
	Basal bark	Anecdotal reports of control when using triclopyr ester at 20% v/v applied to the lower 18 inches of each woody stem. This is a spot treatment only as high stem densities would result in reaching the maximum label use rate per acre on even small patches. Not confirmed in any published research. Imazapyr formulations compatible with basal oils are effective. However, this approach has not been well tested.
	Cut stem (Cut stump)	Not well tested for running bamboo.
	Woody stem injection	This treatment, which was developed for hollow stemmed species such as giant reed (*Arundo donax*) and Japanese knotweed, has not been tested on running bamboo.
	Granular	Granular formulations of imazapyr have been observed to control running bamboo. However, uniform treatment of large stands is difficult with ground equipment.

manually removed in areas where they are not desired simply by knocking them over (with a kick, shovel, etc.).

Belowground physical barriers (such as metal or landscape cloth sheeting) can be installed to stop rhizome expansion. These must be buried to at least a 28 inch depth to prevent roots from growing underneath the barrier. A trench (approximately 12 in. deep by 12 in. wide) can also be dug around the grove. Trenches should be monitored so that bamboo roots that emerge into the trench can be pruned off. Chemicals can also be used to remove new bamboo shoots (see Table 1) but applicators should not apply an herbicide that could impact or kill the remainder of the grove.

HOW IS BAMBOO HARVESTED?

Due to the growth pattern of bamboo, culms within the grove will vary in size (culms may be marked to keep track of age/size) and will get larger as the grove matures – so, the smallest culms are often the oldest. Different sized culms are used for different end products, so hand labor is currently the most effective method of product removal from the field. Strip harvesting has been used in the past[25], but this method yields culms of different sizes and might result in cutting of culms that are not the proper size for the intended end products. Strip cutting also results in slower plant recovery. Harvesting culms for food, requires the manual cutting of a culm when it is roughly 12 inches tall, then peeling the outer vegetative layers to expose the inside[23] (similar to peeling an onion). Information on how often culms can be harvested, and how many can be harvested at a time without impacting subsequent harvests, is not available.

IS BAMBOO INVASIVE?

Many of the species of running bamboos evaluated with University of Florida's IFAS plant risk assessment (http://assessment.ifas.ufl.edu/) were deemed to have a high probability of becoming invasive. Except for clumping bamboos, all bamboo species currently under consideration for commercial use are predicted to be invasive[15]. Several state invasive plant councils (including Alabama, Florida, Georgia, Kentucky, North Carolina, South Carolina, and Tennessee, as of February 2019) have listed golden bamboo (*Phyllostachys aurea)* as invasive. Golden bamboo is an ornamental species of running bamboo which is closely related to moso and rubro bamboos.

Since many bamboo species take a very long time to reach reproductive maturity, spread by seed is a minor concern, but cannot be completely ruled out. Due to the growth habit of clumping bamboos, most generally do not spread quickly. However, if not contained, running bamboos will spread. Over time a grove can extend well beyond the area it was first planted. Bamboo, like many non-native invasive plants, can grow into native vegetation, outcompeting it, often resulting in the complete conversion of natural areas into bamboo groves (Fig. 2). Once established, bamboos are very difficult to control (see Table 1) which is also a consideration when determining invasiveness.

DO NON-NATIVE BAMBOOS PROVIDE WILDLIFE HABITAT OR OTHER ECOSYSTEM SERVICES?

When planted densely for commercial purposes, bamboo plantations support very little wildlife or native plant habitat due to the dense growth and heavy leaf litter which prevents much else from growing in the understory. In areas where bamboo has invaded and become the dominant vegetation, bamboo leaf litter can also significantly influence stream chemistry and dynamics leading to impacts on aquatic species[19]. However, when grown at a wider spacing, bamboo plantings can be desirable for some bird species[8]. Research from the Pacific Northwest showed field mice readily ate the seeds of two non-native bamboo species, and bamboo masting events could potentially lead to increases in rodent populations[22]. Bamboo can also be a fire hazard and could potentially alter fire regimes which could cause long-term ecological harm.

IS GROWING BAMBOO A GOOD WAY TO SEQUESTER CO_2?

Some studies conducted in China suggest that bamboo may sequester CO_2 at higher rates than conifer or hardwood forests[28]. However, the reported sequestration rates are comparable to those reported for pine plantations in the Southeast[21]. Further research is required to accurately compare growth and carbon sequestration rates and to determine overall carbon inputs associated with cultivated bamboo growing in the Southeast.

WHAT HAPPENS IF A GROWER WANTS TO STOP GROWING BAMBOO?

Once established, a bamboo grove can be very difficult to eradicate (Table 1). In open areas, bamboo plants can be dug up and removed with heavy equipment as the rhizomes tend to be fairly shallow. Frequent cutting of the entire grove can reduce underground reserves and eventually control the stand. This could take several years depending on the species and on the health and size of the grove and is not likely to fully eradicate the grove.

Cut stems can be treated with systemic herbicides such as glyphosate or imazapyr, but multiple applications are typically required. Foliar sprays may suppress growth but are difficult to apply to mature stands and rarely result in complete control. Granular formulations of imazapyr have been effective but must be used very carefully due to potential non-target injury of other plants. In all cases, control or eradication is labor intensive and expensive[6].

Figure 2. Golden bamboo can even outcompete and crowd out Chinese privet, another invasive species prevalent throughout the southeastern U.S., and one known for forming dense thickets.

SUMMARY

While some bamboos may exhibit excellent growth rates, there is as yet little information regarding the economic costs and benefits of growing bamboo commercially in the Southeast. Information on how to best manage groves for optimal harvests is lacking, as are established markets for bamboo raw materials. Extension and peer-support systems are also lacking. Furthermore, the species of bamboo being promoted for commercial cultivation in the southeastern U.S. are non-native and pose a risk of becoming invasive. Care should be taken if these species are planted, and proper mitigation procedures should be followed, keeping in mind that once established, bamboo is very difficult to control.

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Resources

For the location and phone numbers of state agencies in the southeastern U.S. providing forestry assistance and information, see the following websites:

Alabama Forestry Commission: http://www.forestry.alabama.gov/

Arkansas Forestry Commission:
http://forestry.arkansas.gov/Pages/default.aspx

Florida Forest Service: http://www.floridaforestservice.com/

Georgia Forestry Commission: http://www.gatrees.org/

Kentucky Division of Forestry:
http://forestry.ky.gov/Pages/default.aspx

Louisiana Department of Agriculture and Forestry:
http://www.ldaf.state.la.us/

Mississippi Forestry Commission: http://www.mfc.ms.gov/

North Carolina Forest Service: http://www.ncforestservice.gov/

Oklahoma Forestry Services: http://www.forestry.ok.gov/

South Carolina Forestry Commission:
http://www.state.sc.us/forest/

Tennessee Division of Forestry:
https://www.tn.gov/agriculture/section/forests

Texas A&M Forest Service: http://texasforestservice.tamu.edu/

Virginia Department of Forestry: http://www.dof.virginia.gov/

For the location and phone numbers of University Extension personnel in the southeastern U.S. providing forestry assistance and information, see the following websites:

Alabama Cooperative Extension System:
http://www.aces.edu/

University of Arkansas Cooperative Extension Service:
http://www.uaex.edu/

University of Florida's Institute of Food and Agricultural Sciences (UF/IFAS):
http://solutionsforyourlife.ufl.edu/

University of Georgia Extension: http://extension.uga.edu/

Kentucky Cooperative Extension Service:
https://extension.ca.uky.edu/

Louisiana Cooperative Extension Service:
http://www.lsuagcenter.com/

Mississippi State University Extension Service:
http://extension.msstate.edu/

North Carolina Cooperative Extension:
https://www.ces.ncsu.edu/

Oklahoma Cooperative Extension Service:
http://www.oces.okstate.edu/

Clemson Cooperative Extension (South Carolina):
http://www.clemson.edu/extension/

University of Tennessee Extension:

https://extension.tennessee.edu/

Texas A&M AgriLife Extension: http://agrilifeextension.tamu.edu/

Virginia Cooperative Extension: http://www.ext.vt.edu/

To locate a consulting forester:

Association of Consulting Foresters:
http://www.acf-foresters.org/acfweb.

Click on "Find a Forester", then select your state in the "People Search – Public" search page.

For more information on how to select a consulting forester, go to:

http://msucares.com/pubs/publications/p2718.pdf

http://texashelp.tamu.edu/011-disaster-by-stage/pdfs/recovery/ER-038-Selecting-a-Consulting-Forester.pdf

http://www.uaex.edu/environment-nature/forestry/FSA-5019.pdf

Additional information on bamboo is available at:

American Bamboo Society:
https://www.bamboo.org/

Southeast Chapter of the American Bamboo Society:
http://www.sec-bamboo.org/?sRes=1

World Bamboo Organization: https://worldbamboo.net/

Bamboo Farming USA: https://www.bamboofarmingusa.com/bamboo-scams

EcoPlanet Bamboo: https://www.ecoplanetbambooplantations.com/

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Figure 1: From Lieurance et al. 2018 (reference 15).

Figure 2: Nancy Loewenstein, Auburn University.

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