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Production of Biofuel Crops in Florida: Sweet Sorghum[1]

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Introduction

The term 'sweet sorghum' is used to describe varieties of sorghum (*Sorghum bicolor* (L.) Moench), a summer annual, which have a high concentration of soluble sugars in the plant sap or juice. This crop is attractive because of the easy accessibility of readily fermentable sugars combined with very high yields of green biomass. In all varieties, the primary carbohydrate is sucrose, with variable amounts of reducible sugars and starch. Similar to sugarcane, the sap of sweet sorghum is extracted by milling. Once extracted, the sugars from sweet sorghum can be easily fermented to produce ethanol. Other products from sweet sorghum include syrup, molasses, and crystal sugar.

Current Potential for Use as Biofuel

Sweet sorghums have generated interest as a feedstock for ethanol production since the 1970s. Juice from sweet sorghum can be converted to ethanol using currently available, conventional fermentation technology (similar to ethanol produced from sugarcane juice in Brazil). The bagasse (crushed stalks) that remains after removal of the juice can be burnt to generate electricity or steam as part of a co-generation scheme. Additionally, the bagasse could be utilized as a feedstock if the technology for cellulosic ethanol production becomes viable on a commercial scale.

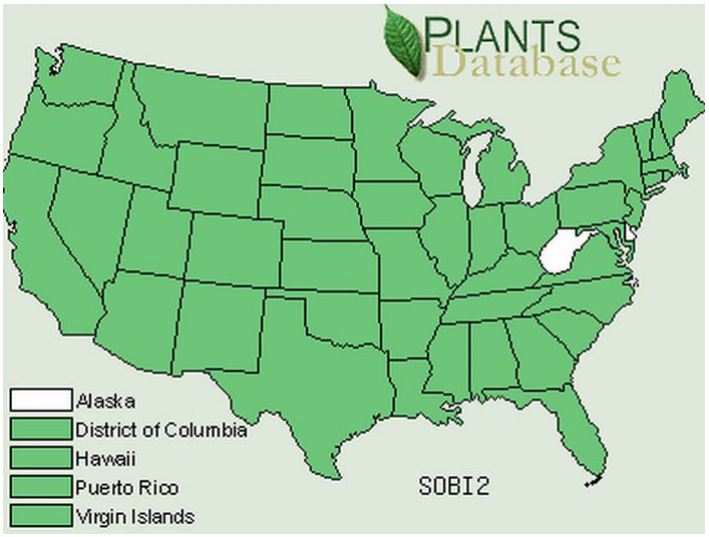

Figure 1. Occurrence of *Sorghum bicolor* in the U.S.

Credits: NRCS Plants Database

Typically, sweet sorghum varieties have low grain yield, but recently varieties with more balanced grain/sugar production have been developed in China and India. These varieties can be used as a dual-purpose crop, where the grain is harvested for human or animal consumption and the sugars are fermented to ethanol. Alternatively, these varieties can be used as a dedicated bioenergy crop, where both the sugars and the grain are used for ethanol production.

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Figure 2. Sweet sorghum planted in Florida

Credits: Forage Extension, Agronomy Department

Biology of Sweet Sorghum

Sorghum is an annual crop with considerable variability in growth characteristics. Heights range from 1.5 ft for grain sorghum types to over 16 ft tall for sweet and forage types. The thickness of stalks also varies, ranging between 0.5–1.5 inches. Brace or prop roots often grow from the lower nodes. Juice content of stalks at maturity is typically lower in grain and forage types compared to sweet types. Seeds are produced by self-pollination from a panicle that emerges at the top of the plant and contains both the male and female inflorescences. Sorghum seeds are small, round and may be white, yellow, brown, or red in color. Although sorghum is predominately self-pollinating, hybrids and crosses can be produced using male-sterile plants as the maternal parent. After harvesting the stalks, most varieties will regrow or ratoon. The ability to form a ratoon enables multiple harvests per season in certain environments, although yields typically decrease in ratoon crops. Sugar content in the juice increases with maturity and is low prior to seed development.

Production

Sweet sorghum is a warm-season crop that tolerates drought and high temperatures better than many crops, but it does not grow well under low temperatures. Optimal planting times in Florida will vary between locations, but soil temperatures at planting should be above 65°F. Late planted crops will mature more rapidly, but should be planted early enough to ensure that the crop matures before the first expected killing frost.

Proper variety selection will play a large role in the success of sweet sorghum production for ethanol. The ideal variety for a particular location should produce high yields with minimal inputs, have a high percentage of high quality and easily extractable juice, be disease and insect tolerant, and tolerate both drought and wet conditions.

Sweet sorghum can be produced in a wide variety of soil types, but yields are typically highest in deep, well-drained soils with good fertility. Sorghum grown in shallow soils or soils very low in organic matter may be more prone to drought stress. Although sorghum is more tolerant of drought stress than many other crops, ample moisture during the growing season is important for good yields of stalks and juice.

Soil tests should be taken to determine soil fertility requirements for sweet sorghum. Nitrogen typically has the greatest impact on yields and will likely be needed on most soils. UF/IFAS studies using currently available sweet sorghum varieties (e.g., M 81E) on sandy soils in Florida with low organic matter indicate that optimal sugar yields can be achieved with N fertilization rates between 80–120 lbs nitrogen (N) per acre for a single crop. Best results will be achieved if you apply N in two split applications. These same studies also indicate a crop needs about 40 lbs of P_2O_5 per acre per crop; however, P_2O_5 application rates should also be based on soil test recommendations. Recommended rates for K_2O are 100 lbs per acre per crop for soils with medium fertility levels (see http://edis.ifas.ufl.edu/ss163). Lime should be applied to soils with a pH below 6.0 to correct soil acidity.

Sweet sorghum is typically seeded in widely spaced rows (30–40 inches) using a corn planter. The ideal seeding rate for most sweet sorghum varieties is 3–4 seeds per linear ft of row with a final stand of 2–3 plants per linear ft of row. If plant populations are too high, the canes will be spindly and contain less juice than an equal tonnage of larger diameter canes.

Currently, the only commercially viable harvest method for sweet sorghum is removing the entire crop with a forage harvester and transporting it to a mill/ethanol facility. Using this method, transportation costs and proximity to the mill/ethanol facility will play a large role in determining where sweet sorghum production is profitable. Several research groups have developed prototype harvesters that extract the juice and leave the bagasse in the field, but it is unclear if this technology will become commercially viable.

Potential Yields

Sweet sorghum yields vary considerably depending on the cultivars/hybrids used, the location (soil, water, climate, pests, and diseases), inputs, and production practices. When considering sweet sorghum for ethanol production via conventional fermentation, biomass yield, juice yield, and sugar production per acre are the most important yield components. The concentration of soluble sugars in sorghum ranges widely depending upon variety. For example, some forage varieties have some sweet sorghum parental background to increase the palatability and energy value of the feed. While these forage types produce high amounts of biomass and some sucrose, they typically contain much less sucrose than dedicated sweet sorghum types (up to 20%).

UF/IFAS researchers have recently completed sweet sorghum field trials at locations across Florida to address a number of the production-related issues for our region. Plant crop green yields (without grain heads) for 'Dale', 'Topper 76-6', and 'M 81E' sweet sorghum cultivars across three spring planting dates from late March to mid-June averaged 31.3 tons per acre. Brix values (which measure sugar content) averaged about 14.8%, but were lower for all cultivars grown on muck soils in the Everglades Agricultural Area (EAA). We found limited opportunities for 'ratooning' these sweet sorghum cultivars, as ratoon crop yields were generally 1/3 to 1/2 as much as the plant crop yields, even in South Florida. These data resulted in estimated sugar yields of 5,075 lbs per acre (approximately 400 gallons of ethanol per acre) from a single crop.

UF/IFAS data are similar to data collected from multiple sources, with a wide range of genetic variability, production practices, and growing environments. These studies have shown that biomass yields of sweet sorghums can range from 8 to 48 tons per acre and juice content ranges from 65% to 80%. The combined sugar content of the juice varies between 9%–20%. Sugar yields vary from 1.6 to 6.9 tons per acre. The bagasse and leaves make up the remainder of the wet biomass. The bagasse represents approximately two-thirds of the dry matter. Fermentation of the sugar in the juice yields between 400–600 gallons of ethanol per acre.

Production Challenges

The costs associated with transportation of the crop to the mill will be the major limiting factor for where sweet sorghum can be grown profitably. Varieties that have higher sugar contents per ton of biomass will be more efficient to process and haul to the mill.

Currently, there is a limited number of varieties for which seed is commercially available. If sweet sorghum is widely and rapidly adopted as an energy crop, seed may become difficult to obtain. Disease and insect problems may also limit yield potentials because there are no sweet sorghum varieties that have been specifically bred for Florida growing conditions.

Estimated Production Costs

Currently, sweet sorghum is not produced in Florida on a commercial basis, so there is limited information on production costs. However, grain and silage/forage sorghum are produced in North Florida and their production costs are likely similar. Information can be found at http://nfrec.ifas.ufl.edu/programs/enterprise_budgets.shtml#field_crops.

Environmental Concerns

Compared to many other crops, sweet sorghum has high water- and nutrient-use efficiencies and is considered environmentally sustainable. Unlike some proposed high biomass energy crops, sweet sorghum is not a threat to become an invasive weed in Florida.

Summary

It should be noted that there are no commercial facilities converting sweet sorghum to ethanol currently operating in Florida. However, several conversion facilities are in the design, planning, or construction phase. Consequently, growing sweet sorghum for purposes other than research or a green manure crop is not recommended unless you have a legally binding contract with an ethanol facility.

Sources of Additional Information

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