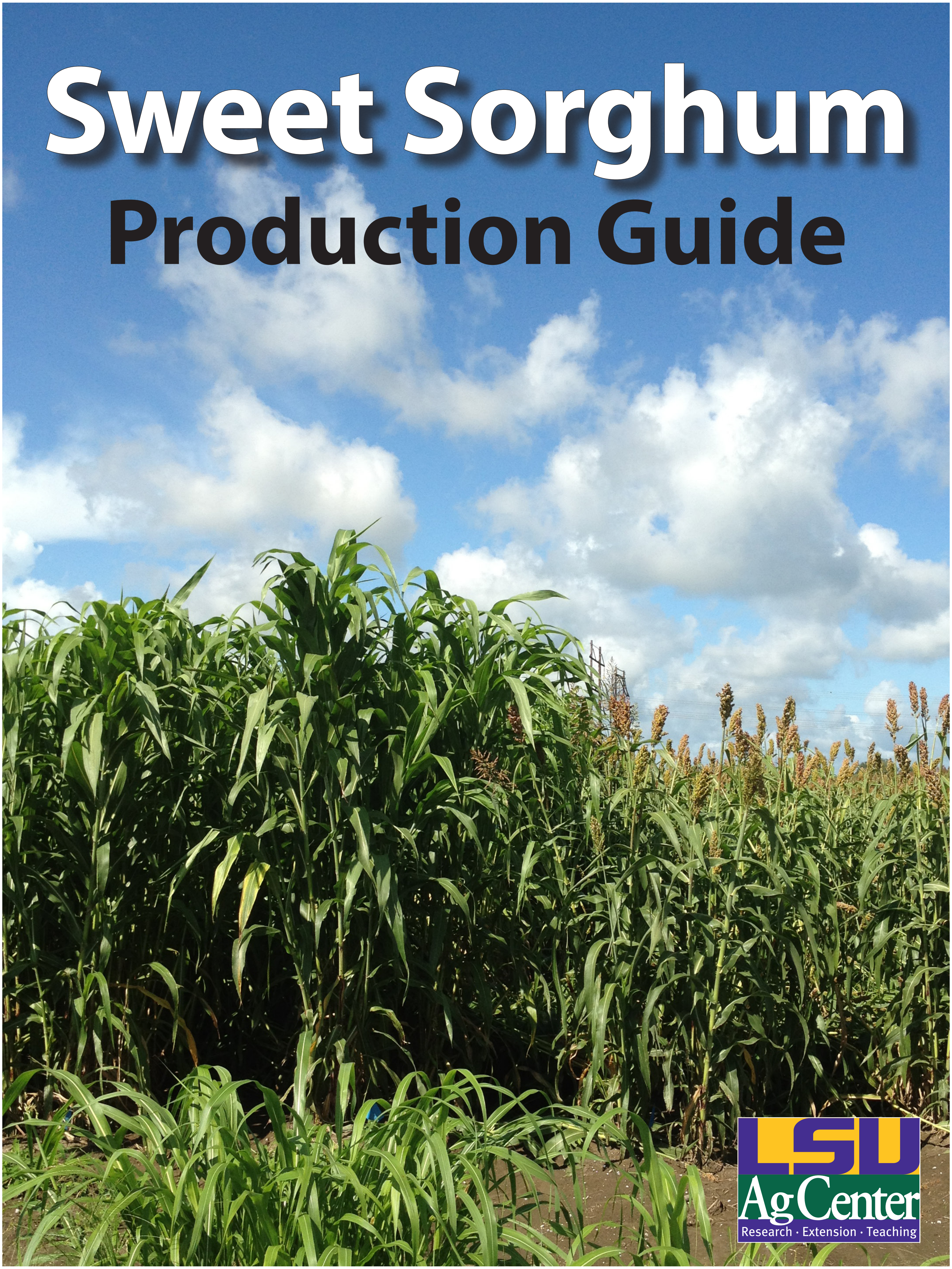
Sweet Sorghum Production Guide



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Introduction

The U.S. Energy Independence and Security Act of 2007 renewed interest in use of agricultural crops as a feedstock for biofuel.

Among them, sweet sorghum has received attention as a potential biofuel crop because the sap from the plant is relatively high in fermentable sugars. Sweet sorghum is related to grain sorghum but has been developed for greater production of sugar and biomass (Figure 1).

Sweet sorghum is an annual crop, and plants can reach heights of 12 to 14 feet. It can be planted and managed using the same equipment typically used in row crop production. It can be processed (juice extracted) through roller-mills or diffusion processes currently used for sugarcane. The bagasse (fiber) that remains after milling is suitable for use as a lignocellulose feed-stock in biochemical or advanced biofuel production. Bagasse also is suitable to use as fuel for operation of the mills. Sugar yield currently is the most important aspect of sweet sorghum on which to base management decisions for potential use in the emerging biochemical/biofuel industry.

Figure 1. Sweet sorghum beginning to head.

Planting

Sweet sorghum seed is similar to that of grain sorghum, so planting equipment is interchangeable between the two types of sorghum. Seeds with good germination and purity characteristics should be used when planting sweet sorghum. Research has shown seeding rates should be between 40,000 and 80,000 seeds per acre. This represents a seeding rate of approximately 2.5 to 4.5 pounds per acre. Limited research indicates it would be beneficial to have irrigation when planting at the lower seeding rate – particularly when soil moisture is limited.

Sweet sorghum can be planted into a fully prepared seedbed or by using minimum- or no-tillage practices. Prepared seedbeds should be thoroughly prepared to a depth of 4 to 6 inches and allowed to settle and store sufficient moisture to germinate the seeds. Because it is important the seeds be placed in the soil, it is necessary to use planters that are capable of cutting through existing residue when planting using minimum- or no-tillage practices. Seeds should be placed at a depth of 0.5 to 1 inch, with the deeper placement in sandy/light-textured soil and shallower in clay soil with heavier texture.

Recent research in Louisiana indicates sweet sorghum can be planted from mid-March until at least early July. Optimum planting period appeared to be mid-April to early May. Biomass and sugar production tended to be greater when planted during this period than from earlier or later plantings.

Low soil temperatures delay seedling emergence and limit plant growth rate, so waiting until April before planting would be advantageous. Planting should be delayed until soil temperature at the 2-inch depth averages at least 60 degrees Fahrenheit for several days, with ideal germinating temperature occurring at 70 F. Sweet sorghum growth will be halted by frost, so extremely late planting should be minimized because of the risk of frost damage occurring before plants reach maturity and peak sugar concentration.

Fertilization

Just as all crops do, sweet sorghum requires adequate soil nutrient levels to be productive. Soil test results should be used to base application levels of phosphorous, potassium, lime and other crop nutrients. It is suggested soil pH be at least 5.8 for profitable production of sweet sorghum.

LSU AgCenter scientists recently have evaluated nitrogen rates for production of sweet sorghum for biofuel in Louisiana (Figure 2). There were differences in response of sweet sorghum to nitrogen fertilization across regions.

Sweet sorghum biomass and sugar yield exhibited the greatest increase with the initial nitrogen application of approximately 40 to 50 pounds of nitrogen per acre. Nitrogen rates above that level did not enhance production of biomass or fermentable sugar from nonirrigated sweet sorghum. There is an indication biomass and sugar production from irrigated sweet sorghum will increase somewhat as nitrogen rate is increased from 45 to 90 pounds per acre.

Figure 2. Response of sweet sorghum to nitrogen fertilization, without (left) and with (right) nitrogen fertilizer application.

Cultivars (Varieties)

Some earlier developed cultivars (varieties) of sweet sorghum have been evaluated by scientists with the LSU AgCenter for use as biofuel/biochemical crops. Cultivars Dale, M81E, Theis and Topper 76-6 provided similar fermentable sugar yields at several locations in Louisiana.

Although sugar yields were similar among cultivars, there were differences in yield among locations. The range in total fermentable sugar production in extracted juice varied from 2.5 to 3.6 tons per acre among locations and years. The cultivar Dale tended to have higher Brix levels (sugar concentration) but lower stem yield when compared to several other cultivars, although total sugar production from land area tended to be similar among the cultivars.

The renewed interest in plant feedstocks for biofuel production since passage of the U.S. Energy Independence and Security Act of 2007 has inspired commercial breeding efforts in development of new sweet sorghum germplasm (mostly hybrids). Some of these newer germplasms have been evaluated at LSU AgCenter locations. Certain hybrids have consistently produced more than 4 tons of fermentable sugar per acre at the LSU AgCenter's Iberia Research Station and its Sugar Research Station. LSU AgCenter scientists are continuing to evaluate this more recently developed sweet sorghum material.

Brief descriptions of cultivars recently evaluated in Louisiana:

- **Dale** is a medium maturing variety developed at the U.S. Sugar Crops Field Station near Meridian, Mississippi, during the 1960s. Dale is resistant to leaf anthracnose and red stalk rot caused by Colletotrichum graminicola. Stalks are medium sized and erect growing.

- **M8IE** is a late-maturing variety that matures a few days later than Dale. It was released from the U.S. Sugar Crops Field Station at Meridian, Mississippi, in 1981. It is similar to Dale in height and lodging resistance. Resistant to leaf anthracnose and red stalk rot is noted as an attribute of M81E, but it is susceptible to maize dwarf mosaic. It is noted to be more susceptible to a light frost than other varieties.

- **Theis** is a late-maturing variety developed at the U.S. Sugar Crops Field Station at Meridian, Mississippi, and released in 1974. Theis may grow 12 to 16 feet tall, but it has good lodging resistance. It was developed with a high resistance to leaf anthracnose and red stalk rot, moderate resistance to downy mildew and tolerance to maize dwarf mosaic virus.

- **Topper 76-6** was released jointly by The University of Georgia and Mississippi State University in 1994. Initial crosses were made at the U.S. Sugar Crops Field Station near Meridian, Mississippi. It was developed for very good disease resistance to anthracnose and Fusarium stalk-rot and leaf blight.

Harvest

Research results indicate sweet sorghum harvest should be delayed until seeds reach the hard dough stage of development. This appears to be the time of maximum sugar content, as measured by Brix, and maximum fresh yield. Varieties and hybrids range in maturity, since maturity is a function of photoperiod sensitivity (day length) and the interaction of day length and variation in temperature (Figure 3). Under Louisiana growing conditions, early maturing sweet sorghums, which are photoperiod insensitive, typically mature in approximately 90 days. Certain full-season varieties or hybrids can take more than 150 days to mature.

It has not proven feasible to manage for ratoon cropping of sweet sorghum. Early harvest results in lower plant yield and lower sugar level. Ratoon growth is inconsistent because it is dependent on late-season rainfall, which is often lacking with dry land planting (Figure 4). Sugar production from ratoon growth has shown to be less than 1 ton per acre in studies that had successful regrowth. Varying planting date to provide biomass or fermentable sugar over a longer period appears to be a better alternative than depending on ratoon cropping of sweet sorghum.

Whole plant harvest is necessary for processing. Research has shown equipment commonly used for sugarcane harvest (billet harvesters) can be used effectively for sweet sorghum harvest (Figure 5). Combine harvesters currently used in the sugarcane industry are configured to harvest a basic 6-foot sugarcane rows at a harvest rate of approximately 50 to 70 tons of plant material per hour. Harvest efficiency for sweet sorghum using these harvesters is being evaluated. A complement of tractors and harvest wagons also would be required to collect and transport plant material from the field to a nearby transport site.

Figure 3. Sweet sorghum hybrids of different maturity.

Figure 4. Failed ratoon crop of sweet sorghum grown under dry land conditions in northeast Louisiana.

Processing

Because biofuel production potential depends on the total fermentable sugars, the ratio of sugars – glucose, sucrose and fructose – is not of utmost importance. Sucrose appears to be the predominant sugar in sweet sorghum juice. The relationship of sucrose to fructose appears to change as the plant matures, with the proportion of fructose being greater shortly after plant heading. Sucrose proportion becomes greater as the plant reaches hard dough seed stage. Planting date does not appear to affect the proportion of glucose, sucrose and fructose.

It would be beneficial to have a mechanism to evaluate plant sugar concentration and plant fiber components relatively quickly. This tool would be useful for determining optimum harvest timing and possibly provide a basis for crop value. Near infrared spectroscopy, or NIR, is being evaluated as a means of providing an instant measure of feedstock quality with minimal sample preparation. NIR is, however, a secondary evaluation method that requires calibration with data from laboratory analysis methods.

Calibration models for NIR are being developed for sweet sorghum with varying maturity profiles (early, medium and late). Juice and fiber percentages of the sorghum stalk can be quantified with NIR. Brix, sucrose, glucose, fructose and ash percentages of juice also can be determined using NIR, and NIR can be used to determine cellulose, hemicellulose, lignin and ash percentages of fiber. Starch present in both juice and fiber is of interest and can be quantified using NIR calibration methods.

It is evident that NIR can be used to quickly evaluate a sorghum plant sample for content of sugars immediately available for fermentation as well as sugars in the fibrous biomass that could be available with further processing. This technology is continuing to be evaluated for potential quality evaluations of sweet sorghum biomass targeted for use in the biofuel and bio-based chemical industry.

Figure 5. Combine harvesting of sweet sorghum.

Economics

Primary economic considerations associated with the production of sweet sorghum as a biofuel feedstock crop are related to land preparation, crop harvest and transportation of the harvested crop to a processing facility.

Land preparation and planting operations generally can be performed with traditional agricultural equipment. Costs for these production practices should not differ from typical row-crop enterprises. The extent of land preparation operations and costs vary, depending on the area of the state in which production occurs as well as other agricultural crops that might be grown in rotation with sweet sorghum. Other crop production costs associated with producing sweet sorghum as a feedstock crop would be similar to, and in some cases lower, than production costs of more traditional agricultural crops.

As this industry develops, research will continue to identify and refine best management practices for sweet sorghum to be used in a bio-based economy. Research has indicated sweet sorghum potentially would have lower fertilization requirements, specifically in nitrogen, than similar types of agricultural field crops such as grain sorghum, corn or sugarcane. Those lower requirements could provide some cost advantages.

Crop harvest and transportation to a processing facility will be significant cost items associated with sweet sorghum production as a biofuel feedstock crop. Sugarcane harvest machinery probably would be necessary for sweet sorghum harvest as well as tractors and equipment to transport the crop from the field. If harvested sweet sorghum crops were hauled to central processing facilities, the expected transportation costs would be similar to that of harvested sugarcane. Since crop transportation costs are estimated on a mileage basis, total transportation cost per truckload from the field to the processing facility would be directly related to the distance traveled between the two locations.

As the biofuel industry develops, it could be possible that some type of initial in-field or at-farm level crop processing technology could be developed to initially process the plant material prior to transportation to the final processing facility, thereby lowering total crop transportation costs.

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This production guide was funded by:

U.S. Department of Agriculture AFRI-CAP grant

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Pub. 3357 (online only) 7/14