

Sweet Sorghum: an Alternative Feedstock for Bioethanol

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Abstract: Sweet sorghum is a rising crop for energy and being considered due to its merits of substituting fossil fuel with the ethanol that is extracted from it. It overcomes many of the shortcomings of other biofuel/energy (food) crops. To produce ethanol only the stalks of sweet sorghum are being used while the grain is saved for food or livestock feed. Also the grain is not in high demand in the global food market and thus has little impact on food prices and food security. Sweet sorghum is grown on already-farmed dry lands that are low in carbon storage capacity, so there are no concerns of clearing of rainforests. Sweet sorghum is easier and cheaper to grow than other biofuel crops and does not require much irrigation, so it is an important consideration in dry areas.

Key words: Sweet Sorghum % Bioethanol % Biomass % Agrowaste % Drought

INTRODUCTION

Sweet sorghum, (*Sorghum bicolor* (L) Moench) belongs to the Poaceae family and is one of the major varieties of sorghum that has high sugar content. It is similar to grain sorghum with sugar-rich stalks. It has various uses and is a key energy crop, which can be cultivated for simultaneous production of grain from its ear head as food; the juice from its stalk can be used for making syrup, molasses (“Gur”) or ethanol. The bagasse and green foliage are an excellent fodder for animal; moreover, it can be used as an organic fertilizer, or for manufacturing paper.

The plant will thrive under dry conditions and is primarily grown for forage, silage and sugar production [1]. Sweet Sorghum is considered as a new industrial energy crop as it is an alternative source of energy. It has the potential to be an important alternative feedstock for the production of ethanol.

Sweet sorghum is identified as a preferred biomass crop for fermentation into ethanol fuel. The plants stalks are used for producing biofuel by squeezing the juice and then fermenting it into ethanol. It is among the most widely adaptable cereal grasses potentially useful for biomass and fuel production.

Due to low water requirement for cultivation and processing, sweet sorghum can be grown throughout the temperate climate zones of Asia and the Americas.



Fig. 1: Sweet Sorghum Plant

Biology of Sweet Sorghum: Sweet sorghum belongs to C4 crop with high photosynthetic efficiency and high productivity. The plant grows to a height of about 14 feet. Seeds are produced by self-pollination from panicle, at the top of the plant and contain the male and female inflorescences. The plant lodging is more likely to occur in high population fields because

stalks become smaller in diameter due to competition. The plant can also be blown down in strong winds due to the heights.

Cultivation Technology: The plant can be grown on soils ranging from heavy clay to light sand. Loam and sandy loam soils generally allow the best syrup production. Good surface drainage is preferred although sweet sorghum can withstand long waterlogged condition; clay loam is preferred with soil acidity not lower than pH 6.

Sowing: Sowing can be done on ridges or in furrows at a spacing of 60 cm between rows and 15 cm within rows. Three to four seeds are dibbled in each planting hole and the seedlings are to be eventually thinned to one per hole. Sweet sorghum is not suitable for high density; the recommended density is about 7000 plants/ha. The plant is ideally shown during June to September, when soil can hold much water (deep). The crop does not prefer high rainfall as high soils moisture or continuous heavy rain after flowering may decrease sugar content in plants.

Setting of Furrow: Two planting seasons are possible for sweet sorghum. During the wet season, furrows are set 100 cm apart while the dry season planting are set 75 cm apart.

Fertilizer Application: The plant needs adequate nutrients to produce good yields. Quality of syrup is also affected by Fertilizer practices. The recommended dose of fertilizer for sweet sorghum is 80 kg of nitrogen, 60 kg of phosphorous and 40 kg of potassium per hectare. Half of N and whole of P and K are applied as basal. Remaining N is top-dressed during 25-35 days after germination, following weeding and inter-cultivated. Nitrogen fertilizer should not be applied in the field when sweet sorghum is grown immediately after a legume crop, as the soil contains nitrogen.

Intercropping: Sweet sorghum is suitable to intercropping with early maturing crops for its characteristics in growth and development. Sweet sorghum seedlings develop slowly at their early stage. It can be intercropped with potato, Maize, wheat etc.

Adaptation and Yield: It is relatively inexpensive to grow high yield sweet sorghum plants and can be used to produce a range of high value added products like ethanol, energy and dried grains [2]. It can produce approximately 30 tons/ ha per year of biomass on low quality soils with low inputs of fertilizer and limited water per ton of crop, half of that

required by sugar beet and a third of the requirement for sugar cane or corn [3].

Harvesting: The plant varieties mature between 115-125 days after plantation. To obtain high-quality syrup and high yields, the crop should be harvested when the seed is in the soft dough stage. Stalks can be harvested either along with the grain, or 4-5 weeks after the grain harvest. The ear-head and peduncle (between the base of the seed head and the top node) should be removed before processing the stalks.

Ear-heads may be dried and threshed so the seeds can be used for the next year's crop.

Ethanol Production: The juice of sweet sorghum contains sucrose, fructose and glucose, which can easily be made into ethanol.

To optimize ethanol yield, a juice extraction of at least 50% from the biomass stalks is needed. Extraction requires roller mill or diffuser equipment. The bagasse can be used to feed livestock or to produce electricity. The vinasse, a mixture of dead yeast and plant material after fermentation, can be composted and used as fertilizer.

A crop yielding 40 t fresh stalk/ha and 60% extractability would yield about 3.5 t syrup. The same stalk in fermentation may yield 2500 L of ethanol. The stalk residue left over after processing is about 12-15 t/ha, which may be used either as fuel or feed [4]. Excellent-quality syrup/juice can also be made without removing (stripping) the leaves. However, the stalks should not be crushed while the leaves are still wet. Delay milling for 3 to 5 days. This delay will allow the leaves to dry out, the stalks to lose some water and natural enzymes within the stalk to invert some of the sucrose. These changes will make the syrup easier to cook and less likely to crystallize.

Commercial Production of Ethanol and Utilization of Sweet Sorghum: Producing ethanol from sweet sorghum is relatively very simple. Press the juice from the stalk, add yeast, allow fermentation (the simple sugars derived from sweet sorghum have to be fermented immediate.) and get ethanol. To produce ethanol, the sorghum stalks are crushed yielding sweet juice that is distilled and transformed into biofuel, a clean burning fuel with a high octane rating. The grain is not involved in the ethanol process. It is used for food; mainly in flat breads and porridges. The crushed stalks are used for animal fodder [5]. New investors are getting into the commercial production of this crop which has multiple uses. Besides production of ethanol as biofuel there are many other important products that could be realized from sweet sorghum.

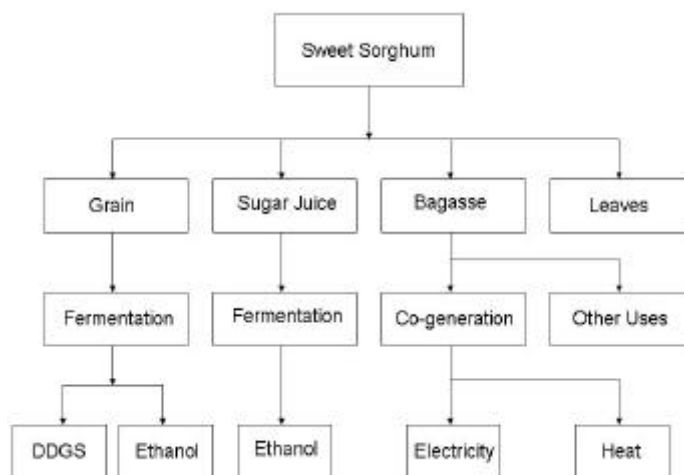


Fig. 2: Simplified diagram of Alternative Processes to Convert Sweet Sorghum to Energy Fuel

Table 1: Comparison of Sweet Sorghum with Sugarcane [3]

Parameters	Sugarcane	Sweet Sorghum
Harvesting cycle	9 -14 months	4 months
No of cycle in a year	One	Two
Water requirement	100%	65 -70%
Fertilizer requirement	100%	35 - 40%
Stalk production MT/Hectare/Cycle	65 - 80	42 - 55 for one cycle/year 84 - 110 for two cycles/ year
Fermentable sugar concentration in stalk (% W/W)	10.0 to 14.0	9.0 - 12.0
Yield of fermentable sugar, MT/Hectare/Cycle	6.0 to 10.5	3.6 to 6.2 for one cycle/year 7.2 to 12.4 for two cycles/year
Ethanol (100% basis) yield L/Hectare/Cycle	3400 to 6000	2020 to 3500 for one cycle/year 4000 to 7000 for two cycles/year
Bagasse MT/ Hectare/Cycle 50% w/w moisture	19 to 24 (30% on cane weight)	10 to 14 for one cycle/year (25% on stalk) 20 to 28 for two cycles /year

Sweet Sorghum is highly complementary to sugarcane in the expanding global need for renewable biofuel systems. It provides high biomass yield and ethanol with low irrigation and fertilizer requirements. Sugar cane ethanol, in contrast, requires significant amounts of water for growing and processing.

A comparison between the sugarcane and Sweet Sorghum is shown in the table.

Advantages of Using Sweet Sorghum for Alcohol Manufacturing:

- C It requires less water and fertilizers compared to sugarcane.
- C Harvesting & cultivation practices are easier and are identical to sugar cane.
- C Crop cycle is short- 3.5 to 4 months. Usually, two cycles are possible from same piece of land annually, provided irrigation is possible.
- C On crushing to extract juice, gives bagasse as by-product, which can be a principal source of

energy for operation of distillery in the form of boiler fuel. This practically makes alcohol production free of energy cost and improves possibility of operation in remote areas.

CONCLUSION

Sweet sorghum shows promise for small to mid-size farms as a directly fermentable sugar crop. The crop can also grow well on marginal soil with little supplemental nutrients and is drought tolerant. It also can be easily pressed for a sugar-rich juice that is directly fermentable without enzyme-based conversion of cellulose or starch.

Additionally, the cellulosic matter left after pressing juice from the plant has fuel value. Being a dedicated energy crop that is directly fermentable and the by-product, bagasse is distinguishes sweet sorghum from other candidate of ethanol crops. Its ability to grow on marginal land with minimal inputs is a significant factor that further differentiates it from other energy crops.

Hence, Sweet sorghum is a very promising biofuel crop with potential for cultivation due to relatively high drought tolerance, short growing season and easy propagation by seed.

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