

## ***Economic Analysis of Sweet Sorghum for Biofuels Production in the Texas High Plains***

Steve Amosson<sup>1</sup>, Jnaneshwar Girase<sup>2</sup>, Brent Bean<sup>3</sup>, William Rooney<sup>4</sup>, and Jake Becker<sup>5</sup>

### **Introduction**

Sweet sorghum is a potential biofuel crop because it is capable of producing high yields of ethanol from a combination of easily fermentable sugars and lignocellulosic bagasse. The development of alternative forms of biofuels production is essential to meet the Renewable Fuel Standards (RFS) which calls for an annual production of 36 billion gallons of renewable fuels by 2022. Of the 36 billion gallons, 15 billion gallons is to come from grain based ethanol with the remaining 21 billion gallons coming from a combination of advanced biofuels and cellulosic ethanol production.

Research trials have been conducted in 2009 and 2010 at the Texas AgriLife Research Station - Bush Farm located 8 miles west of Amarillo, TX to evaluate the production potential of sweet sorghum in the Texas High Plains. In these trials, various varieties and seeding rates were evaluated. The objective of this study was to identify the costs associated with the production of sweet sorghum and to determine the cost per gallon of ethanol produced by using sweet sorghum as the input.

### **Data and Methods**

Scientists conducting the trials were asked to identify the Best Management Practices (BMPs) for growing sweet sorghum including farming operations performed. Enterprise budgets for irrigated and dryland sweet sorghum were developed utilizing the BMPs identified. These budgets include all costs up to the farm gate, therefore, hauling costs from the farm gate to the processing plant were not considered. Research on irrigated sweet sorghum was conducted using furrow irrigation. However, cultural practices were modified to reflect the more common pivot irrigation that is found on the Texas High Plains for budgeting purposes. A three year average of prices was utilized to evaluate direct expenses in order to dampen volatility caused by annual fluctuations in input prices due to market conditions. Harvest equipment and procedure for sweet sorghum was assumed to be the same as that used in corn silage. Texas AgriLife Extension Budgets were used to estimate the fixed and variable costs of farming operations generally performed by producers. Custom rates were utilized as a proxy for the cost of all other field and harvest operations.

Total ethanol production was calculated from adding the potential ethanol derived from sugar extracted from the sweet sorghum and the ethanol produced from the bagasse. Bagasse is the fibrous material (dry biomass) that remains after extracting sugar juice from sorghum stalks and is a good source of lignocellulosic biomass for ethanol production. The amount of bagasse

---

<sup>1</sup>Regents Fellow, Professor and Extension Economist, Texas A&M Agrilife Research and Extension Center, Amarillo, Phone: 806-677-5600, Email: samosson@ag.tamu.edu.

<sup>2</sup>Research Associate, Texas A&M Agrilife Research and Extension Center, Amarillo, Phone: 806-677-5600, Email: gopigirase@gmail.com

<sup>3</sup>Extension Agronomist, Texas A&M Agrilife Research and Extension Center, Amarillo, Phone: 806-677-5600, Email: bbean@ag.tamu.edu

<sup>4</sup>Professor, Plant Breeding and Genetics, Texas Agrilife Research, Texas A&M University, College Station, TX, Email: wlr@tamu.edu

<sup>5</sup>Research Assistant, Texas A&M Agrilife Research and Extension Center, Amarillo, Phone: 806-677-5600, Email: jdbecker@ag.tamu.edu

produced was estimated by converting the budgeted yields to dry matter using a 71% moisture level similar to what was observed in the research trials. The resultant ethanol produced from the bagasse was estimated at 80 gallons per dry ton.

## Results

Enterprise budgets were developed for both irrigated and dryland sweet sorghum production, Appendix A. The total cost per acre to produce sweet sorghum under irrigation was estimated at \$706.67 per acre, Table A1, including \$592.21 in direct expenses and \$114.46 in fixed costs. Fertilizer, harvest, and irrigation were the largest components of the direct cost accounting for 30.4%, 28.7%, and 12.9% of the direct expenses, respectively. Fixed costs consisted of the land rent (\$65.00/acre) and ownership expenses associated with the irrigation pivot (\$33.60/acre) and owned equipment (\$14.96/acre). The yield used in the irrigated sweet sorghum budget based on the trials was 28.75 wet tons per acre. This resulted in an estimated cost of production of \$24.58 per wet ton.

The sugar produced from the 28.75 tons was estimated to be 6021 lbs assuming a 95% sugar extraction rate which is similar to what is achieved in a sugar cane processing plant. Approximately, 483 gallons of ethanol can be produced from the 6021 lbs of sugar. An additional 667 gallons of ethanol can be produced from the remaining bagasse given 80 gallons per dry ton conversion rate. Therefore, the total ethanol yield considering both the sugar and bagasse production was 1150 gallons per acre. This resulted in an estimated cost of production of \$0.61 per gallon of ethanol produced, Table 1.

The total cost per acre to produce sweet sorghum under dryland conditions was estimated at \$303.17, Table A2. The dryland yield utilized in the budget based on the trials was 11.20 wet tons per acre resulting in a cost of \$27.07 per wet ton to produce the sweet sorghum. Fertilizer and harvest were the largest components of the direct cost (\$262.05) accounting for 34.3% and 25.3% of the direct expenses, respectively. The estimated sugar production and corresponding ethanol yield, assuming a 95% sugar extraction rate, were 2734 lbs of sugar/acre and 215 gallons of ethanol/acre, respectively. The ethanol yield from the remaining bagasse was calculated to be 259.84 gallons resulting in a total ethanol yield of 474.84 gallons per acre and a corresponding cost of \$0.64 per gallon of ethanol produced, Table 1.

**Table 1. Production Costs for Irrigated and Dryland Sweet Sorghum under Various Yields and 95% Extraction Rate**

<b>Irrigated Sweet Sorghum</b>							
<b>Yield</b>	<b>Wet tons</b>	<b>Total Cost (\$/wet ton)</b>	<b>Bagasse (tons/acre)</b>	<b>Ethanol gallons/Acre</b>			<b>Total Cost (\$/gallon)</b>
				<b>95%</b>	<b>Ethanol from Bagasse</b>	<b>Total</b>	
<b>75%</b>	21.56	30.80	6.25	362.25	500.25	862.50	0.77
<b>100%</b>	28.75	24.58	8.34	483.00	667.00	1150.00	0.61
<b>125%</b>	35.94	20.85	10.42	603.75	833.75	1437.50	0.52
<b>150%</b>	43.13	18.36	12.51	724.50	1000.50	1725.00	0.46

<b>Dryland Sweet Sorghum</b>							
<b>75%</b>	8.40	34.12	2.44	161.25	194.88	356.13	0.80
<b>100%</b>	11.20	27.07	3.25	215.00	259.84	474.84	0.64
<b>125%</b>	14.00	22.84	4.06	268.75	324.80	593.55	0.54
<b>150%</b>	16.80	20.02	4.87	322.50	389.76	712.26	0.47

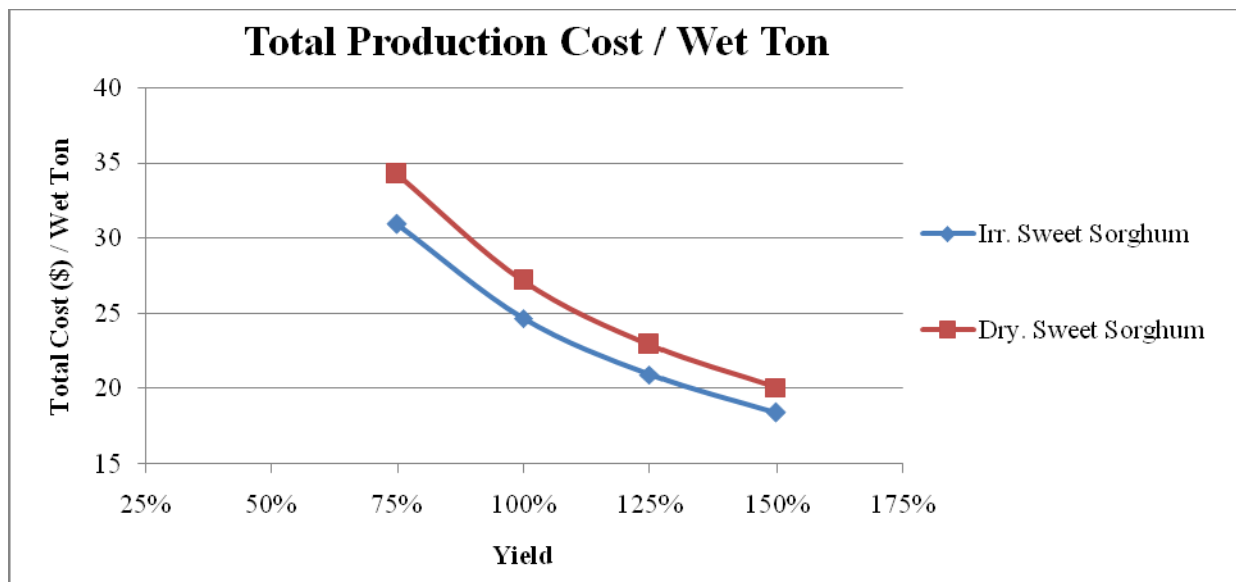
Note: 1) One ton of bagasse was estimated to produce 80 gallons of ethanol

2) Bagasse has calculated by adjusting 71% moisture from wet tons

### ***Yield Sensitivity Analysis***

Due to the yield variation between years, varieties and replicated plots, a sensitivity analyses was performed on yields for both irrigated sweet sorghum and dryland sweet sorghum. The budgeted yield was varied from 75% to 150% in the analysis, Table 1. The cost per wet ton of irrigated sweet sorghum decreased to \$18.36 and the corresponding cost to produce a gallon of ethanol at the 95% extraction rate fell to \$0.46 at the 150% production level (43.13 wet tons), Table 1 & Figure 1. Conversely, decreasing the yield to 75% of average led to an increase in the cost of production of \$30.80 per wet ton and \$0.77 per gallon of ethanol.

The yield sensitivity analysis performed on the dryland sweet sorghum yielded similar results to the irrigated analysis. Total cost per wet ton fell from \$27.07 to \$20.02 at the 150% production level and the corresponding cost as an input to produce a gallon of ethanol decreased from \$0.64 to \$0.47, Table 1 & Figure 1. Reducing the yield 25% increased the cost of production per wet ton and the production cost of a gallon of ethanol to \$34.12 and \$0.80 at the 95% extraction rate, respectively.



**Figure 1. Irrigated and Dryland Sweet Sorghum Total Production Cost per Wet Ton at Various Yields**

### ***Extraction Rate Sensitivity Analysis***

The sugar yield per ton of production can vary considerably depending on mill extraction efficiency. It can be as high as 95% in a processing facility that uses the same methods as a sugar cane mill. The cost of building this type of processing plant is expensive. Less expensive extraction techniques are being considered such as portable presses, but extraction efficiency drops significantly. A sensitivity analysis is performed to evaluate the change in costs from reducing the extraction rate from 95% to 65% or 40% over various yield scenarios.

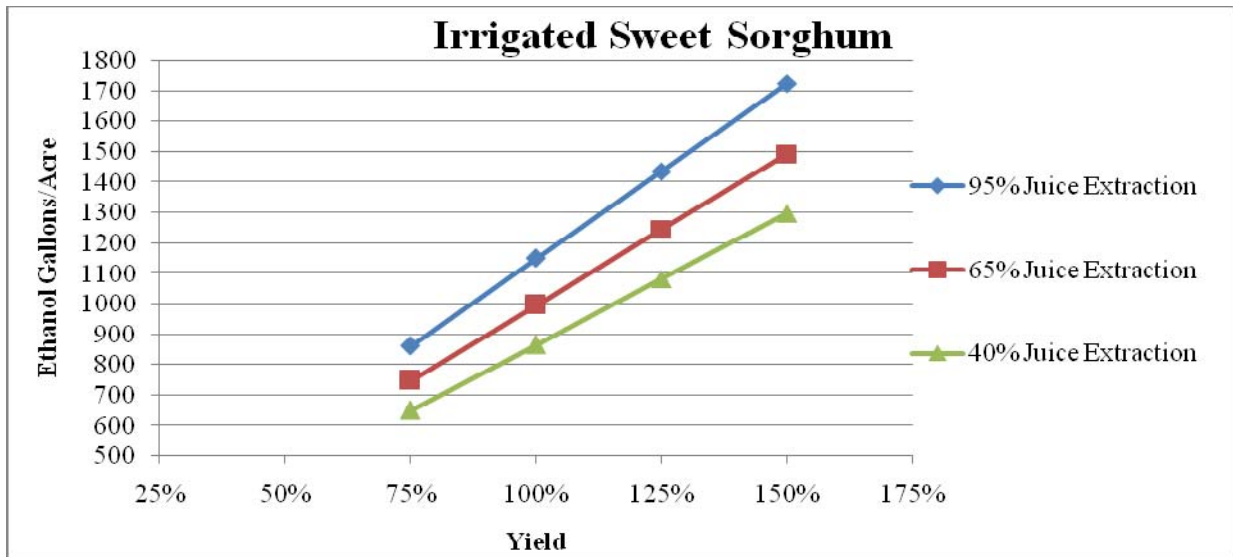
Varying the yield in irrigated sweet sorghum from 75% to 150% of budgeted production resulted in the estimated cost of producing a gallon of ethanol to range from \$0.46 to \$0.77 at the 95% extraction level, \$0.53 to \$0.89 at the 65% extraction rate, and \$0.61 to \$1.02 with a 40% extraction rate, Table 2.

**Table 2. Production Costs for Irrigated and Dryland Sweet Sorghum under Various Yields and Extraction Rates**

<b>Irrigated Sweet Sorghum</b>								
<b>Yield</b>	<b>Wet tons/Acre</b>	<b>TC (\$/wet ton)</b>	<b>Ethanol gallons/Acre (Sugar + Bagasse)</b>			<b>TC (\$/gallon)</b>		
			<b>95%</b>	<b>65%</b>	<b>40%</b>	<b>95%</b>	<b>65%</b>	<b>40%</b>
<b>75%</b>	21.56	30.80	862.50	747.00	649.50	0.77	0.89	1.02
<b>100%</b>	28.75	24.58	1150.00	996.00	866.00	0.61	0.71	0.82
<b>125%</b>	35.94	20.85	1437.50	1245.00	1082.50	0.52	0.60	0.69
<b>150%</b>	43.13	18.36	1725.00	1494.00	1299.00	0.46	0.53	0.61
<b>Dryland Sweet Sorghum</b>								
<b>75%</b>	8.40	34.12	356.13	308.36	259.38	0.80	0.93	1.11
<b>100%</b>	11.20	27.07	474.84	411.14	345.84	0.64	0.74	0.88
<b>125%</b>	14.00	22.84	593.55	513.93	432.3	0.54	0.62	0.74
<b>150%</b>	16.80	20.02	712.26	616.71	518.76	0.47	0.55	0.65

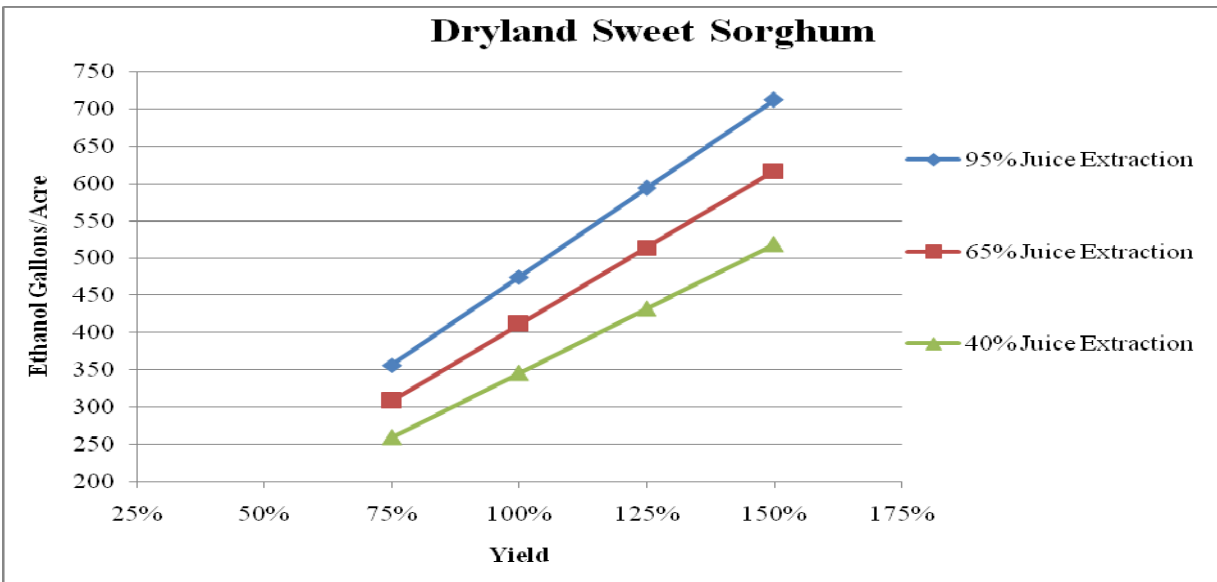
The sensitivity analysis performed on the dryland sweet sorghum indicated the cost of producing a gallon of ethanol rises from \$0.64 at the 95% extraction rate to \$0.88 at the 40% extraction level. Varying the yield and extraction rate resulted in extreme of \$0.47/gallon of ethanol at the combination of 150% production level and at the 95% extraction to a high of \$1.11/gallon at the 75% production level with a 40% extraction rate.

Reducing the extraction rate from 95% to 65% or 40% on the irrigated sweet sorghum at the 28.75 wet tons production level resulted in potential ethanol production falling from 1150 gallons per acre to 996 and 866 gallons, respectively, Table 2. The irrigated sweet sorghum relationship between yield and anticipated ethanol production for each of the extraction rates is illustrated in Figure 2.



**Figure 2. Irrigated Sweet Sorghum Ethanol Production per Acre for Three Different Juice Extraction Efficiencies and Various Yields**

Reducing the extraction rate from 95% to 65% or 40% on the dryland sweet sorghum at the 11.20 wet tons production level resulted in potential ethanol production falling from 474.84 gallons per acre to 411.14 and 345.84 gallons, respectively, Table 2. The dryland sweet sorghum relationship between yield and anticipated ethanol production for each of the extraction rates is illustrated in Figure 3.



**Figure 3. Dryland Sweet Sorghum Ethanol Yield per Acre for Three Different Juice Extraction Efficiencies and Various Yields**

## Appendix A.

Table A1. Estimated Cost of Sweet Sorghum Production per Acre, Sprinkler Irrigated Powered by Natural Gas, 2011

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
		dollars		
<b>PRODUCTION</b>				
Sweet sorghum	wet tons		28.75	
Sugar	lb.		6021.00	
Ethanol from sugar	gal		483.00	
Ethanol from bagasse	gal		667.00	
Total Ethanol	gal		1150.00	
<b>DIRECT EXPENSES</b>				
<b>SEED</b>				
Seed – sweet sorghum	lb.	8.50	6.25	53.13
<b>FERTILIZER</b>				
Fert (N) - liquid	lb.	0.58	218.50	126.73
Fert (P) - liquid	lb.	0.89	60.00	53.40
<b>HERBICIDE</b>				
Atrazine + appln.	acre	9.90	1.00	9.90
<b>CUSTOM</b>				
Fert appln.	acre	5.00	1.00	5.00
Silage harvest	ton	5.91	28.75	169.91
<b>FIELD OPERATIONS</b>				
Tandem disc	acre	12.00	1.00	12.00
Sweep plow	acre	6.84	1.00	6.84
Sweep plow	acre	6.84	1.00	6.84
Planted	acre	13.20	1.00	13.20
<b>HAND LABOR</b>				
Implements	hour	10.20	0.15	1.53
<b>IRRIGATION LABOR</b>				
Center Pivot	hour	10.20	0.90	9.18
<b>DIESEL FUEL</b>				
Tractors	gal	2.41	2.34	5.64
<b>GASOLINE</b>				
Pick Up	gal	2.60	2.01	5.23
<b>NATURAL GAS</b>				
Center Pivot	ac-in	7.60	10.05	76.38
<b>REPAIR &amp; MAINTENANCE</b>				
Implements	acre	5.75	1.00	5.75
Tractors	acre	4.75	1.00	4.75
Pick Up	acre	0.16	1.00	0.16
Center Pivot	ac-in	2.03	10.05	20.40
INTEREST ON OP. CAP.	acre	6.00%	1.00	6.24
<b>TOTAL DIRECT EXPENSES</b>				592.21
<b>FIXED EXPENSES</b>				
Implements	acre	8.80	1.00	8.80
Tractors	acre	6.82	1.00	6.82
Pick Up	acre	0.24	1.00	0.24
Center Pivot	acre	33.60	1.00	33.60
Cash rent – sweet sorghum	acre	65.00	1.00	65.00
<b>TOTAL FIXED EXPENSES</b>				114.46
<b>TOTAL SPECIFIED EXPENSES</b>				706.67

Table A2. Estimated Cost of Sweet Sorghum Production per Acre, Dryland, 2011

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
		dollars		
<b>PRODUCTION</b>				
Sweet sorghum	wet tons		11.20	
Sugar	lb.		2734.00	
Ethanol from sugar	gal		215.00	
Ethanol from bagasse	gal		259.84	
Total Ethanol	gal		474.84	
<b>DIRECT EXPENSES</b>				
<b>SEED</b>				
Seed - sweet sorghum	lb.	8.50	2.80	23.80
<b>FERTILIZER</b>				
Fert (N) - liquid	lb.	0.58	95.20	55.22
Fert (P) - liquid	lb.	0.89	39.20	34.89
<b>HERBICIDE</b>				
Atrazine + appln.	acre	9.90	1.00	9.90
<b>CUSTOM</b>				
Fert appln.	acre	5.00	1.00	5.00
Silage harvest	ton	5.91	11.20	66.19
<b>FIELD OPERATIONS</b>				
Tandem disc	acre	12.00	1.00	12.00
Sweep plow	acre	6.84	1.00	6.84
Sweep plow	acre	6.84	1.00	6.84
Planted	acre	13.20	1.00	13.20
<b>HAND LABOR</b>				
Implements	hour	10.20	0.31	3.16
<b>DIESEL FUEL</b>				
Tractors	gal	2.41	2.45	5.90
<b>GASOLINE</b>				
Pick Up	gal	2.60	2.01	5.23
<b>REPAIR &amp; MAINTENANCE</b>				
Implements	acre	5.81	1.00	5.81
Tractors	acre	5.02	1.00	5.02
Pick Up	acre	0.16	1.00	0.16
INTEREST ON OP. CAP.	acre	6.00%	1.00	2.89
<b>TOTAL DIRECT EXPENSES</b>				262.05
<b>FIXED EXPENSES</b>				
Implements	acre	8.66	1.00	8.66
Tractors	acre	7.22	1.00	7.22
Pick Up	acre	0.24	1.00	0.24
Cash rent – sweet sorghum	acre	25.00	1.00	25.00
<b>TOTAL FIXED EXPENSES</b>				41.12
<b>TOTAL SPECIFIED EXPENSES</b>				303.17