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Economic Viability of Grain Sorghum and Corn as a Function of Irrigation Capacity

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Introduction

Grain sorghum is often hailed as a crop with high water use efficiency and low input costs. For example, NRCS irrigation guide (NRCS, 2010) suggests that at Goodwell, Okla., optimum production of corn requires 20 inches of irrigation water, while grain sorghum only requires 15.5 inches. This suggests that as water availability in the Panhandle region declines, grain sorghum may become a more viable crop for irrigation. In addition, it is very well adapted to the southern plains and has a feed value that is comparable to corn (Chen et al. 1994). In fact, the energy content is approximately 90 to 95 percent of that for corn and the crude protein is 20 to 30 percent higher than corn. The 10-year average price for grain sorghum received by producers in the U.S. is $4.17 per bushel, compared to $4.39 per bushel for corn. Despite the higher water use efficiency of grain sorghum, its production in the southern high plains under irrigation is still dwarfed by irrigated corn production. Specifically, in the three Oklahoma Panhandle counties of Beaver, Texas and Cimarron, there has been an average of 107,935 acres of irrigated corn in the past 10 years, compared to only 37,561 acres of grain sorghum. This suggests a potential for the expansion of irrigated grain sorghum in the future as water availability declines.

This disparity between corn- and grain sorghum-irrigated acres along with declining irrigation capacity in the region prompted the effort to conduct an economic analysis to determine the short-term and long-term profitability of corn and grain sorghum at irrigation capacities ranging from 6.4 to 0.8 gallons per miniute per acre. This analysis was conducted using simulated crop yields and irrigation estimates produced by the EPIC crop model. The model was calibrated using variety performance data collected from the OSU corn and sorghum variety performance trials conducted in the Oklahoma panhandle. It was also validated with data collected at the Oklahoma Panhandle Research and Extension Center.

Crop Yield as a Function of Irrigation Capacity

The yield and irrigation water applied presented in Tables 1 and 2 are the result of model simulations in which irrigation was applied at 1.4 inches per application event at a frequency constrained by irrigation capacity and/or a soil moisture depletion. Specifically, the data presented shows the outcome of irrigation triggered when the soil moisture is depleted to 50, 70 or 90 percent of the plant available water capacity.

As expected, this analysis shows that grain yields for both crops are maximized when soil moisture is maintained at 90 percent of plant available water-holding capacity with 6.4 gallons per miniute per acre irrigation capacity (i.e. when moisture was not a constraining factor). In this scenario, the sorghum and corn crops received 15.6 and 22.5 inches of irrigation water, respectively. This is comparable to the NRCS estimates for average crop requirement. In every scenario presented, the irrigation use efficiency is higher for grain sorghum than corn, as is expected. These yields may be compared to average yields reported by NASS in Texas County between 2000 and 2008 (172 bushels per acre for irrigated corn and 82 bushels per acre for grain sorghum). Based on this comparison, average corn yields from NASS are on average 20 percent below expected yields with 6.4 gallons per minute per acre irrigation capacity. In contrast, average grain sorghum yields from NASS are on average 50 percent of the simulated yields at 6.4 gallons per minute per acre. The 10-year average corn and sorghum yields from performance trials conducted in Texas County of 200 bushels per acre and 141 bushels per acre, respectively, produced with an average of 21 and 8 inches of water (Table 3), respectively, suggests that the model may underestimate the efficiency of grain sorghum, while it provides outcomes that are consistent with trial data for corn. Furthermore, the variety performance data also demonstrate

Table 1. Results from EPIC Simulation of Irrigated Sorghum Yields and Irrigation rates and irrigation use efficiency using Center Pivot System when irrigation was triggered when soil moisture is depleted to 50, 70 or 90 percent of plant-available water capacity.

Irrigation Capacity	*Yield (bu/acre) Soil Moisture Trigger*			*Irrigation Applied (inches/acre) Soil Moisture Trigger*			*Irrigation Use Efficiency (bu/inch) Soil Moisture Trigger*		
GPM/acre	*50%*	*70%*	*90%*	*50%*	*70%*	*90%*	*50%*	*70%*	*90%*
6.4	129	149	163	9.2	12.6	15.6	14	12	10
5.6	129	145	156	9.1	11.8	14.1	14	12	11
4.8	129	140	148	9	10.7	12.6	14	13	12
4	126	134	141	8.8	9.8	11.3	14	14	12
3.2	122	129	134	8.3	9.4	10.4	15	14	13
2.4	109	112	117	7.1	7.6	8.3	15	15	14
1.6	90	91	92	3.2	3.4	4.1	28	27	22
0.8	88	88	89	2.4	2.5	2.8	37	35	32

Table 2. Results from EPIC Simulation of Irrigated Corn Yields, Irrigation rates and irrigation use efficiency using Center Pivot System when irrigation was triggered when soil moisture is depleted to 50, 70 or 90 percent of plant available water capacity.

Irrigation Capacity	*Yield (bu/acre) Soil Moisture Trigger*			*Irrigation Applied (inches/acre) Soil Moisture Trigger*			*Irrigation Use Efficiency (bu/inch) Soil Moisture Trigger*		
GPM/acre	*50%*	*70%*	*90%*	*50%*	*70%*	*90%*	*50%*	*70%*	*90%*
6.4	167	194	213	16.2	21.5	22.5	10	9	9
5.6	165	186	199	16.1	20.4	23.1	10	9	9
4.8	163	177	187	15.9	19	21.6	10	9	9
4	158	168	175	15.3	17.4	19.5	10	10	9
3.2	152	158	164	14.4	15.9	17.6	11	10	9
2.4	137	139	143	11.8	12.8	13.9	12	11	10
1.6	119	120	122	9.1	9.7	10.3	13	12	12
0.8	98	98	99	5.7	5.9	6.1	17	17	16

Table 3. Average corn and sorghum yields, and irrigation water applied to hybrid performance trials located in Texas County.

Year	*Corn†*		*Sorghum††*	
	Average bu/ac	*Irrigation inches*	*Average bu/ac*	*Irrigation inches*
2005	196	17	149	10
2006	183	20	143	5
2007	178	20	92	4
2008	246	21	115	6
2009	226	21	148	9
2010	179	18	145	8
2011	85	21	166	10
2012	240	26	152	11
2013	236	26	145	10
2014	228	18	159	9
Average	200	21	141	8

† Corn average yields were measured at Joe Webb's farm.
†† Sorghum average yields were measured at OPREC.

that on average, the county corn yields are 14 percent below those achieved in the performance trial and the county grain sorghum yields are 41 percent below what is achieved in the performance trial.

Economic analysis based on Model Simulated Yields

Tables 4 and 5 contain the production budgets and estimated net revenue for corn and sorghum, respectively, when irrigated to maintain soil moisture at 90 percent of plant available water. This soil moisture threshold was selected because the lower yields resulting from lower soil moisture thresholds did not increase short term profit. However, utilization of drier thresholds did show promise in maximizing the long-term net present value of irrigation water.

As expected, corn generates greater profit when irrigation capacity is equal to or greater than 5.0 gallons per minute per acre. Furthermore, it maximizes net revenue at all irrigation capacities because of the greater yield that can be achieved. However, this greater yield comes at a higher variable cost of production. This analysis suggests that although high-yielding corn may be an economically superior option when

Table 4. Estimated net revenue over variable cost for grain sorghum irrigated by central pivot when irrigation occurs at the 90 percent soil moisture trigger by well capacity for a 120-acre pivot.

Well Capacity	*GPM/acre*	*6.7*	*5.8*	*5*	*4.2*	*3.3*	*2.5*	*1.7*	*0.8*
Yield	bu/ac	163	156	148	141	134	117	92	89
Nitrogen	lbs/ac	181.6	173.6	165.5	157.3	149.2	130.7	102.5	98.7
Phosphorous	lbs/ac	29.4	28.1	26.8	25.4	24.1	21.1	16.6	16.0
Irrigation†	acre-inch	15.6	14.1	12.6	11.3	10.4	8.3	4.1	2.8
Net Revenue ($4.16/bu)	$	677.4	647.7	617.3	586.8	556.5	487.6	382.6	368.2
Fertilizer-Nitrogen	$	99.9	95.5	91.0	86.5	82.0	71.9	56.4	54.3
Fertilizer-Phosphorous	$	15.3	14.6	13.9	13.2	12.5	11.0	8.6	8.3
Seed Cost	$	16.1	16.1	16.1	16.1	16.1	16.1	16.1	16.1
Herbicide Cost	$	52.4	52.4	52.4	52.4	52.4	52.4	52.4	52.4
Insecticide Cost	$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crop Consulting	$	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Drying	$	21.2	20.2	19.3	18.3	17.4	15.2	12.0	11.5
Miscelleneous	$	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Custom Hire	$	132.5	129.4	126.2	122.9	119.7	112.5	101.3	99.8
Non Machinery Labor	$	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
Interest	$	15.7	15.1	14.4	13.8	13.1	11.7	9.5	9.2
Irrigation Cost	$	90.4	79.8	70.3	62.6	56.8	44.9	21.9	14.8
Sub Total	$	477.7	457.3	437.9	420.1	404.4	369.9	312.5	300.7
Crop Insurance	$	22.9	22.0	21.0	20.2	19.4	17.8	15.0	14.4
Total Variable Cost	$	500.6	479.3	458.9	440.3	423.8	387.7	327.5	315.1
Net Revenue-Var Cost	$	176.8	168.4	158.4	146.5	132.7	100.0	55.1	53.1

† Irrigation is the depth of water applied with a center pivot irrigation system assuming that only 85% of water is delivered to root zone. Irrigation depth also reflects depth of water to be applied under intensive irrigation scheduling management.

Table 5. Estimated net revenue over variable cost for corn irrigated by central pivot when irrigation occurs at the 90 percent soil moisture trigger by well capacity for a 120-acre pivot.

Well Capacity	*GPM/acre*	*6.7*	*5.8*	*5*	*4.2*	*3.3*	*2.5*	*1.7*	*0.8*
Yield	bu/ac	213	199	187	175	164	143	122	99
Nitrogen	lbs/ac	196.8	183.0	171.9	160.9	151.0	130.9	112.1	90.9
Phosphorous	lbs/ac	28.5	26.5	25.0	23.4	21.9	19.0	16.3	13.2
Irrigation	acre-inch	22.5	23.1	21.6	19.5	17.6	13.9	10.3	6.1
Net Revenue ($4.48/bu)	$	956.1	890.9	837.3	784.0	736.4	639.0	547.6	443.9
Fertilizer-Nitrogen	$	108.2	100.7	94.6	88.5	83.0	72.0	61.7	50.0
Fertilizer-Phosphorous	$	14.8	13.8	13.0	12.1	11.4	9.9	8.5	6.9
Seed Cost	$	112.6	112.6	112.6	112.6	112.6	112.6	112.6	112.6
Herbicide Cost	$	61.0	61.0	61.0	61.0	61.0	61.0	61.0	61.0
Insecticide Cost	$	16.0	15.7	15.5	15.2	15.0	14.6	14.1	13.6
Crop Consulting	$	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Drying	$	27.7	25.9	24.3	22.7	21.4	18.5	15.9	12.9
Miscelleneous	$	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Custom Hire	$	161.5	155.1	149.9	144.7	140.0	130.5	121.5	111.4
Non Machinery Labor	$	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0
Interest	$	20.0	19.0	18.1	17.3	16.5	14.9	13.4	11.8
Irrigation Cost	$	130.0	130.5	120.4	107.4	96.1	75.3	55.5	32.7
Sub Total	$	686.5	668.8	643.9	616.0	591.6	543.8	498.8	447.4
Crop Insurance	$	33.0	32.1	30.9	29.6	28.4	26.1	23.9	21.5
Total Varible Cost	$	719.4	700.9	674.8	645.6	620.0	569.9	522.7	468.8
Net Revenue-Var Cost	$	236.6	190.0	162.5	138.4	116.4	69.1	24.9	-25.0

† Irrigation is the depth of water applied with a center pivot irrigation system assuming that only 85% of water is delivered to root zone. Irrigation depth also reflects depth of water to be applied under intensive irrigation scheduling management.

ample water is available, the production of lower-cost crops with greater water use efficiency characteristics should be considered in situations with limited irrigation water.

Limitations to Irrigated Grain Sorghum Production

There are certainly practical limitations to the extensive production of irrigated grain sorghum in the Oklahoma panhandle. For example, grain sorghum does not currently contain the crop protection genetics contained in corn, making it more challenging to manage pests such as weeds and insects. As such, grain sorghum will need to be incorporated as a component of a crop rotation system to succeed. Work conducted at the Oklahoma Panhandle Research and Extension Center has shown that both corn and grain sorghum production can be improved when they are produced in rotation. The sugarcane aphid also presents a new uncertainty as to its long-term impact on grain sorghum production costs. As such, producers should adjust the production budgets presented to include their costs associated with managing the new pest.

It is unlikely that grain sorghum will gain production acres in excess of the corn acres. However, this research adds to the body of evidence suggesting that both economic and agronomic benefits could be realized if at least a portion of the 107,935 acres of corn were planted to grain sorghum in situations where irrigation capacities are below 5 gallons per minute per acre.

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