SORGHUM YIELD RESPONSE TO WATER AND IRRIGATION MANAGEMENT

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INTRODUCTION

Grain Sorghum is one of the major irrigated crops in Kansas. Irrigators are faced with the problem of declining well capacities due to water withdrawals from the Ogallala aquifer for irrigation exceeding mean annual recharge. In addition to limited well capacities, public policy may also impose limits on total amounts of water that can be pumped. For example the 20% reduction in pumped water that is being implemented as part of a Local Enhanced Management Area (LEMA) policy in parts of Groundwater Management District (GMD) 4 and several Water Conservation Areas (WCAs) that have been implemented in GMD 3. The drought tolerance attributes of grain sorghum make it a good choice for limited irrigation. However, increase in grain sorghum irrigated area has lagged those of other irrigated crops in Kansas mainly corn and soybean. One of the major challenges facing irrigated grain sorghum producers in Kansas is how to increase yields under declining well capacities or limited water supplies.

To develop limited irrigation management strategies for grain sorghum, we evaluated yield response under well-watered conditions as well as under very limited water supplies. The purpose of the study was to determine the top-end grain sorghum yield potential under well-watered conditions (100%ET) at three locations in western Kansas (Colby, Garden City, and Tribune) and the effect of growth stage based irrigation timing on grain sorghum yields, water productivity and yield components with water supplies limited to 6 or 10 inches total.

METHODS AND MATERIALS

Experimental description

The study was conducted at three locations in western Kansas including; 1) the Kansas State University, Southwest Research-Extension Center (SWREC) near Garden City, 2) SWREC, near Tribune and 3) the Northwest Research-Extension Center (NWREC), near Colby. The soil type at Tribune and Garden City is Ulysses silt loam while that at Colby is a Keith silt loam. The climate at

the three locations is semi-arid with mean annual rainfall of 17, 18, and 19 inches for Tribune, Garden City, and Colby respectively. Cumulative rainfall and reference evapotranspiration during the 2015 and 2016 growing seasons at each location are shown in Figure 1. The experimental design was a randomized complete block design with four replications at each location.

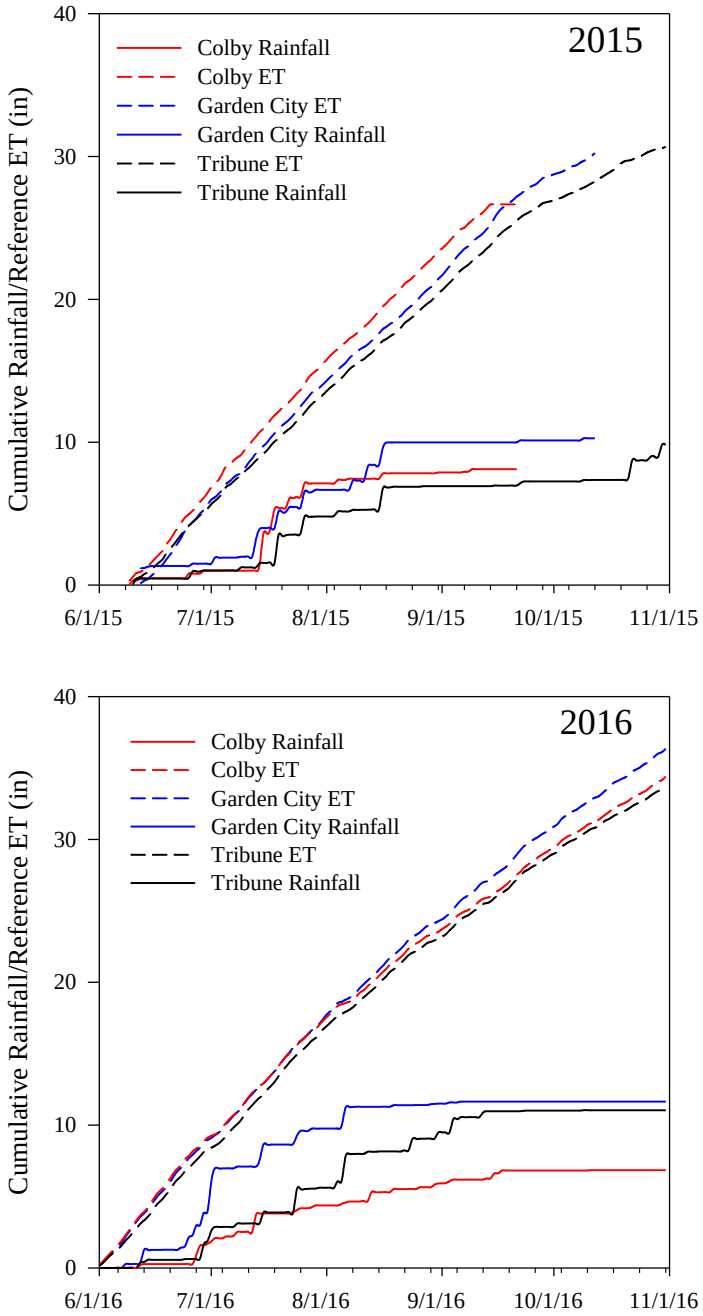


Figure 1. Cumulative rainfall and reference evapotranspiration at Colby, Garden City and Tribune, Kansas during the 2015 and 2016 grain sorghum growing seasons.

Irrigation management

At each of the three locations, the study was conducted under a lateral move sprinkler irrigation system modified to apply irrigation water in any desired treatment combination. The irrigation treatments included the following:

1. Full irrigation 100%ET
2. 50% ET prior to booting of grain sorghum and 100% ET after boot and total irrigation limited to 10 inches
3. 100% ET limited to 10 inches
4. 50% ET prior to booting of grain sorghum and 100% ET after boot and total irrigation limited to 6 inches
5. 100% ET limited to 6 inches
6. Dryland (only for Garden City and Colby sites)

As a case study, two limitations on total irrigation, 6 and 10 inches (Treatments 2-5) were compared to full irrigation. The fully irrigated treatment was managed as a non-water limiting crop with 100% ET replenishment. Soil water in the 8.0 feet soil profile was measured as a check for adequacy of the ET-based irrigation scheduling and for determination of crop water use. Soil water measurements were made using neutron scattering technique (neutron probe). In-season irrigation events were adjusted to account for rainfall amounts received during the growing season. Irrigation application dates and amounts at each location during the 2015 and 2016 grain sorghum growing seasons are shown in Tables 1 to 3.

Table 1. Sorghum Commission Study Irrigation at Tribune, KS, 2015 and 2016.

Irrigation (inches)					
Date	Treatment*				
	1	2	3	4	5
26-Jun-2015	1.58	1.58	1.58	1.58	1.58
6-Jul-2015	1.48		1.48		1.48
13-Jul-2015	1.48		1.48		1.48
23-Jul-2015	1.48		1.48		1.48
31-Jul-2015	1.47	1.47	1.47	1.47	
8-Aug-2015	1.80	1.80	1.80	1.80	
26-Aug-2015	0.92	0.92	0.92	0.92	
2-Sep-2015	1.53	1.53			
TOTAL-2015	***11.74***	***7.30***	***10.21***	***5.77***	***6.02***
13-Jul	2.02		2.02		2.02
29-Jul	1.14		1.14		1.14
11-Aug	1.52	1.52	1.52	1.52	1.52
20-Aug	1.54	1.54	1.54	1.54	1.54
02-Sep	1.48	1.48	1.48	1.48	1.48
12-Sep	1.56	1.56	1.56	1.56	1.56
TOTAL-2016	***9.26***	***6.10***	***9.26***	***6.10***	***9.26***

1 = 100% ET
2 = 50% ET to boot then 100% ET to 10" total
3 = 100% ET to 10" total
4 = 50% ET to boot then 100% ET to 6" total
5 = 100% ET to 6" total

Table 2. Sorghum Commission Study Irrigation at Garden City, KS, 2015 and 2016.

Irrigation (inches)						
Date	Treatment*					
	1	2	3	4	5	6
*07-Apr-2015	0.75	0.75	0.75	0.75	0.75	0.75
13-Jul-2015	1.00					
5-Aug-2015	1.00	1.00	1.00	1.00	1.00	
10-Aug-2015	1.00	1.00	1.00	1.00	1.00	
24-Aug-2015	1.00	1.00	1.00	1.00	1.00	
31-Aug-2015	1.00	1.00	1.00	1.00	1.00	
10-Sep-2015	1.00	1.00	1.00	1.00	1.00	1.00
18-Sep-2015	1.00	1.00	1.00	1.00	1.00	
TOTAL-2015	***7.75***	***6.75***	***6.75***	***6.75***	***6.75***	***1.75***
19-May-2016	0.75	0.75	0.75	0.75	0.75	0.75
28-Jul-2016	1.00		1.00		1.00	
01-Aug-2016	1.00		1.00		1.000	
15-Aug-2016	1.00	1.00	1.00	1.00	1.00	
18-Aug-2016	1.00	1.00	1.00	1.00	1.00	
22-Aug-2016	1.00	1.00	1.00	1.00	1.00	
29-Aug-2016	1.00	1.00	1.00	1.00	1.00	
01-Sep-2016	1.00	1.00	1.00	1.00		
06-Sep-2016	1.00	1.00	1.00	1.00		
09-Sep-2016	1.00	1.00	1.00			
TOTAL-2016	***9.75***	***7.75***	***9.75***	***6.75***	***7.75***	***0.75***

1 = 100% ET
2 = 50% ET to boot then 100% ET to 10" total
3 = 100% ET to 10" total
4 = 50% ET to boot then 100% ET to 6" total
5 = 100% ET to 6" total
6 = Dryland

Table 3. Sorghum Commission Study Irrigation at Colby, KS, 2015 and 2016.

Irrigation (inches)						
Date	Treatment*					
	1	2	3	4	5	6
07-Jul-2015	0.96		0.96		0.96	
12-Jul-2015	0.96		0.96		0.96	
01-Aug-2015	0.96		0.96		0.96	
04-Aug-2015	0.96	0.96	0.96	0.96	0.96	
10-Aug-2015	0.96	0.96	0.96	0.96	0.96	
17-Aug-2015	0.96	0.96	0.96	0.96	0.96	
20-Aug-2015	0.96	0.96	0.96	0.96		
24-Aug-2015	0.96	0.96	0.96	0.96		
29-Aug-2015	0.96	0.96	0.96	0.96		
02-Sep-2015	0.96	0.96	0.96			
06-Sep-2015	0.96	0.96				
TOTAL-2015	***10.56***	***7.68***	***9.60***	***5.76***	***5.76***	***0.00***
23-Jun-2016	0.56		0.56		0.56	
25-Jun-2016	0.96		0.96		0.96	
12-Jul-2016	0.96		0.96		0.96	
22-Jul-2016	0.96	0.96	0.96	0.96	0.96	
24-Jul-2016	0.96		0.96		0.96	
29-Jul-2016	0.96	0.96	0.96	0.96	0.96	
2-Aug-2016	0.96	0.96	0.96	0.96	0.96	
5-Aug-2016	0.96	0.96	0.96	0.96		
11-Aug-2016	0.96	0.96	0.96	0.96		
17-Aug-2016	0.96	0.96	0.96	0.96		
25-Aug-2016	0.96	0.96	0.96			
9-Sep-2016	0.96	0.96				
TOTAL-2016	***11.12***	***7.68***	***10.16***	***5.76***	***6.32***	***0.0***

1 = 100% ET
2 = 50% ET to boot then 100% ET to 10" total
3 = 100% ET to 10" total
4 = 50% ET to boot then 100% ET to 6" total
5 = 100% ET to 6" total
6 = Dryland

Agronomic management

The hybrid used at all the three locations was Pioneer 84G62 because it is full season and well adapted under both irrigated and dryland environments. Grain sorghum was planted at seeding rate of 100,000 seeds per acre on June 04, 2015, June 04, 2015 and June 02, 2015 at Tribune, Garden City, and Colby respectively. In 2016, grain sorghum was planted on June 01, 2016, May 23, 2016, and May 25 at Tribune, Garden City, and Colby, respectively. Best management practices for fertilizer and weed control for high yielding grain sorghum were followed. For example, at planting 10:34:0 was applied at a rate of 10 gal/ac and at least 160 lb N/a was applied. Some of the

herbicides used for weed control included Atrazine 4L at rate of 32 oz/ac and Lumax EZ at a rate of 80 oz/ac. Grain Sorghum was hand harvested on November 12, 2015, October 20, 2015 and October 20, 2015 at Tribune, Garden City and Colby respectively. In 2016 grain sorghum was harvested on October 19, October 13, and October 6 at Tribune, Garden City, and Colby respectively. At Tribune the previous crop was fallow (2014), at Garden City the previous crop was corn (2014) at Colby the previous crop was sunflower (2014). In 2016, at Tribune the previous crop was grain sorghum, at Garden City the previous crop was corn and at Colby the previous crop was sunflower.

RESULTS AND DISCUSSIONS

Grain sorghum yield and yield components

There were no significant differences in grain yield between irrigation treatments at Tribune, Garden City and Colby for the 2015 grain sorghum growing season (Tables 4 to 9). This is probably due to the above normal rainfall received during the 2015 grain sorghum growing season (Figure 1). In 2015, it was shown that the top-end yield potential could exceed 190 bu/ac (Table 4). The grain yield results are within range of K-State variety trials data that have shown grain sorghum to have a potential yield of higher than 200 bu/ac. The highest grain sorghum yields were recorded at Tribune, followed by Garden City and Colby as shown in Tables 4 to 9. Kernels per head, which greatly influences yield, was highest at Tribune. There were more heads per acre at Garden City and Colby compared to Tribune, but Tribune had higher yields implying the effect of kernel number per head, which was highest at Tribune, might exert a strong influence on grain yield compared to heads per acre (Tables 4 to 9). Kernel weight was similar between the three locations in 2015 (Tables 4 to 9).

The study was repeated in 2016, grain yield was not significantly different across all irrigation treatments in Tribune, but yields were significantly different among treatments in Garden City and Colby locations as shown in Tables 7 and 9. Averaged across treatments, grain yields were 17.9%, and 5.3% lower in Tribune and Garden City in 2016 compared to 2015. Averaged across treatments, grain yields were 18.4%, higher in Colby in 2016 compared to 2015. The differences could be attributed to seasonal variations in weather such as rainfall amount and distribution, environment and management. It is worth noting that the fully irrigated treatment (100% ET) was not significantly different from deficit irrigated treatments in both years at the three locations (Tables 4 to 9). In addition, there is no substantial differences in yield between irrigation management limited to 6 and 10 inches of water per season and between growth stage based irrigation treatments. Dryland treatments resulted in yield reduction of more than 25 bu/ac in Colby in 2016, which was drier than normal. In fact at Colby in 2016 all irrigated treatments produced significantly higher yield than the dryland treatment (p-value= 0.003). At Garden City dryland treatment resulted in yield reduction ranging from 2 to 21 bu/ac. Grain sorghum appears to be a suitable crop for limited irrigation with very little water needed to obtain maximum yield in a normal to wet year like 2015 and 2016. However, in drought years of 2011 and 2012 Klocke et al. (2014) showed that there was a strong relationship between in grain yield and irrigation applied.

Table 4. Sorghum Commission Study. Crop parameters as affected by irrigation timing and amount at Tribune, KS, 2015.

Treatment	Grain yield, bu/a	WUE[1], lb/a-in.	Heads, 10^3/a	Seeds /lb	1000 seed, oz	Kernels /head	Kernels /ft^2	Heads /ft^2
100% ET	190	422 b	69.0	16119	0.99	2497	3931	1.6
50/100%ET to 10"	181	447 ab	71.9	16691	0.96	2346	3847	1.7
100%ET to 10"	186	419 b	70.6	15937	1.00	2352	3800	1.6
50/100%ET to 6"	185	479 a	67.4	16198	0.99	2508	3832	1.5
50/100%ET to 10"	182	478 a	69.7	16341	0.98	2383	3803	1.6
LSD $_{0.05}$	17	50	10.7	834	0.05	354	379	0.2
ANOVA (P>F) Trt.	0.738	0.046	0.918	0.417	0.431	0.766	0.945	0.918

[1]WUE = water use efficiency
[2]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Table 5. Sorghum Commission Study. Crop parameters as affected by irrigation timing and amount at Tribune, KS, 2016.

Treatment	Grain yield, bu/a	WUE[1], lb/a-in.	Heads, 10^3/a	Seeds /lb	1000 seed, oz	Kernels /head	Kernels /ft^2	Heads /ft^2
100% ET	154	347 ab	108	17840	0.90	1911	3540	1.79
50/100%ET to 10"	153	379 b	104	17693	0.91	1961	3475	1.79
100%ET to 10"	149	334 a	104	18122	0.89	1933	3455	1.79
50/100%ET to 6"	153	379 b	110	17799	0.90	1866	3502	1.89
50/100%ET to 10"	150	328 a	104	17710	0.90	1911	3408	1.78
LSD $_{0.05}$	16	38.8	10.9	1183	0.06	315	346	0.19
ANOVA (P>F) Trt.	0.94	0.03	0.67	0.94	0.94	0.94	0.94	0.67

[1]WUE = water use efficiency
[2]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Table 6. Sorghum Commission Study. Crop parameters as affected by irrigation timing and amount at Garden City, KS, 2015.

Treatment	Grain yield, bu/a	WUE[1], lb/a-in.	Heads, 10^3/a	Seeds /lb	1000 seed, oz	Kernels /head	Kernels /ft^2	Heads /ft^2
100% ET	157	426	89.7	17971	0.89	1826	3835	2.1
50/100%ET to 10"	157	436	90.6	16676	0.96	1640	3445	2.1
100%ET to 10"	150	403	88.0	16434	0.97	1541	3236	2.1
50/100%ET to 6"	160	461	88.9	16393	0.98	1623	3373	2.1
50/100%ET to 10"	149	444	86.2	16505	0.97	1579	3156	2.0
Dryland	145	490	88.2	18120	0.88	1661	3321	2.0
LSD $_{0.05}$	19	63	13.6	3152	0.13	464	977	0.3
ANOVA (P>F) Trt.	0.59	0.095	0.997	0.492	0.409	0.844	0.756	0.997

[1]WUE = water use efficiency
[2]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Table 7. Sorghum Commission Study. Crop parameters as affected by irrigation timing and amount at Garden City, KS, 2016.

Treatment	Grain yield, bu/a	WUE[1], lb/a-in.	Heads, 10^3/a	Seeds /lb	1000 seed, oz	Kernels /head	Kernels /ft^2	Heads /ft^2
100% ET	144	346 ab	69	17089	0.94	2006	3158	1.6
50/100%ET to 10"	148	367 ab	74	17102	0.94	1923	3254	1.7
100%ET to 10"	156	379 a	74	16517	0.97	1954	3317	1.7
50/100%ET to 6"	137	338 b	66	16776	0.96	1976	2959	1.5
50/100%ET to 10"	149	355 ab	72	17457	0.92	2021	3347	1.7
Dryland	135	410 c	71	17993	0.90	1932	3100	1.6
LSD $_{0.05}$	14.2	39.0	10.4	1484	0.08	286	433	0.3
ANOVA (P>F) Trt.	0.047	0.01	0.48	0.40	0.40	0.97	0.44	0.997

[1]WUE = water use efficiency
[2]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Table 8. Sorghum Commission Study. Crop parameters as affected by irrigation timing and amount at Colby, KS, 2015.

Treatment	Grain yield, bu/a	WUE[1], lb/a-in.	Heads, 10^3/a	Seeds /lb	1000 seed, oz	Kernels /head	Kernels /ft^2	Heads /ft^2
100% ET	132	284 a	91.9	18116	0.88	1482	3112	2.1
50/100%ET to 10"	159	363 b	88.2	16846	0.95	1690	3380	2.0
100%ET to 10"	147	312 ab	95.4	16694	0.96	1426	3137	2.2
50/100%ET to 6"	152	360 b	91.3	16116	0.99	1505	3161	2.1
50/100%ET to 10"	129	295 a	84.7	16902	0.95	1434	2725	1.9
Dryland	151	402 ab	91.3	17150	0.93	1603	3366	2.1
LSD $_{0.05}$	29	64.5	15.7	1497	0.07	480	631	0.36
ANOVA (P>F) Trt.	0.221	0.008	0.788	0.127	0.17	0.836	0.398	0.788

[1]WUE = water use efficiency
[2]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Table 9. Sorghum Commission Study. Crop parameters as affected by irrigation timing and amount at Colby, KS, 2016.

Treatment	Grain yield, bu/a	WUE[1], lb/a-in.	Heads, 10^3/a	Seeds /lb	1000 seed, oz	Kernels /head	Kernels /ft^2	Heads /ft^2
100% ET	176 a	447 ab	118	14596 a	1.10 a	1214	3295	2.7
50/100%ET to 10"	178 a	480 ac	121	14899 a	1.08 a	1231	3416	2.8
100%ET to 10"	172 a	426 b	112	14613 a	1.10 a	1261	3233	2.6
50/100%ET to 6"	178 a	496 c	119	15603 b	1.03 b	1311	3573	2.7
50/100%ET to 10"	176a	458 ab	115	14741 a	1.09 a	1264	3332	2.6
Dryland	150 b	490 a	118	16950 c	0.95 c	1209	3266	2.7
LSD $_{0.05}$	13.9	46.6	10.1	690	0.05	113	302	0.23
ANOVA (P>F) Trt.	0.003	0.008	0.56	0.001	0.001	0.836	0.24	0.56

[1]WUE = water use efficiency
[2]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Crop yield response to water

There were significant differences in grain sorghum crop water use in 2015 growing season (Tables 10 to 15). Treatments that received more irrigation water had the higher crop water use (ETc). Crop water use ranged from 25.2 to 21.3, 20.7 to 16.7, and 25.6 to 20.7 inches at Tribune, Garden City and Colby respectively. In 2015, there were significant differences in crop water use between irrigated and the non-irrigated treatments at Garden City and Colby. In 2016, irrigation treatments that limited irrigation to 50% ET prior to booting used less water and consequently had higher WUE compared to other treatments at Colby and Tribune. Crop water use for irrigated treatments averaged 24.1 inches and dryland crop water use was 19.4 in Garden City. In Colby crop water use for irrigated treatments averaged 21.4 in and dryland crop water use was 17.2 in. There is strong year-to-year variations in crop water use as shown in Tables 10 to 15. Water productivity also known as water use efficiency was significantly different between treatments at Colby and Tribune but not at Garden City in 2015 (Tables 4 to 9). Water productivity was comparable between Tribune and Garden City but somewhat lower at Colby (Tables 4 to 9). Averaged across treatments water productivity was 448 lb/ac-in at Tribune and Garden City and 336 lb/ac-in at Colby. In 2016, water productivity was significantly different between treatments. Averaged across treatments water productivity reduced by 21% in Garden City in 2016 compared 2015 while it increased by 39% in Colby in the same period.

Production functions are shown in Figs. 2 & 3, in a wet to normal rainfall years such as 2015, there was low to moderate response to evapotranspiration (crop water use). However, in 2016, Colby received below normal rainfall, and there was strong response to crop water use as shown by an r^2 of 0.9 (Fig. 2). At Garden City, there was a stable moderate response to irrigation with r^2 of about 0.40 to 0.42. These preliminary results indicate no substantial difference in yield for irrigation application amounts between 6 and 10 inches and between growth stage based irrigation treatments. This implies that in a normal year producers might only need to allocate at least 6 inches of irrigation to obtain maximum yield. However, in a drought year this might increase to more than 10 inches under soil conditions and climatic environment of western Kansas.

Table 10. Available water in profile (8 ft), at Tribune, KS, 2015.

	Date		
Treatment	6/10	10/20	Water use (in)
	---Inches/8ft---		
100% ET	16.70	12.27	25.19 a
50-100% ET[1] to 10"	14.90	8.69	22.54 b
100% ET to 10"	15.01	9.46	24.78 a
50-100% ET to 6"	14.50	7.77	21.53 b
100% ET to 6"	15.44	9.17	21.31 b
LSD $_{0.05}$	1.66	3.27	1.98
ANOVA (P>F) Trt.	0.104	0.095	0.02

Planted on June 4 (tubes read 6/10) and harvested on November 12 (tubes read 11/06).
In-season rainfall (6/10 - 11/06) was 9.02".
In-season irrigation (6/10 - 11/06) was 1 = 11.74"; 2 = 7.30"; 3 = 10.21"; 4 = 5.77"; 5 = 6.02".
[1]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Table 11. Available water in profile (8 ft), at Tribune, KS, 2016.

	Date		
Treatment	6/01	10/20	Water use (in)
	---Inches/8ft---		
100% ET	16.31 a	13.31 a	24.87 a
50-100% ET[1] to 10"	14.21	10.29 b	22.64 ab
100% ET to 10"	14.72 b	11.65 b	24.93 a
50-100% ET to 6"	13.78 b	9.87 b	22.63 ab
100% ET to 6"	14.98 b	12.27 b	25.58 a
LSD $_{0.05}$	2.1	0.13	1.4
ANOVA (P>F) Trt.	0.001	0.001	0.001

Planted on June 1, (tubes read 6/01/2016) and harvested on October 20, (tubes read 10/20/2016).
In-season rainfall (6/01/2016 – 10/20/2016) was 12.61".
In-season irrigation (6/01/2016 – 10/20/2016) was 1 = 9.26"; 2 = 6.10"; 3 = 9.26"; 4 = 6.10"; 5 = 9.26".
[1]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Table 12. Available water in profile (8 ft), at Garden City, KS, 2015.

	Date		
Treatment	6/22	10/13	Water use (in)
	---Inches/8ft---		
100% ET	9.9 a	5.6 a	20.7 a
50-100% ET[1] to 10"	10.8 a	6.1 a	20.1 b
100% ET to 10"	12.8 b	7.2 a	20.9 a
50-100% ET to 6"	14.5 b	10.1 b	19.5 ab
100% ET to 6"	8.5 a	5.1 a	18.6 b
Dryland	14.3 b	7.8 a	16.7 c
LSD $_{0.05}$	1.99	2.59	1.26
ANOVA (P>F) Trt.	0.001	0.009	0.001

Planted on June 3 (tubes read 6/22) and harvested on October 18 (tubes read 10/13).
In-season rainfall (6/10 - 10/31) was 13.18".
In-season irrigation (6/01 – 10/31) was 1 = 7.0"; 2 = 6.0"; 3 = 6.0"; 4 = 6.0"; 5 = 6.0", 6 = 1.0".
[1]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Table 13. Available water in profile (8 ft), at Garden City, KS, 2016.

	Date		
Treatment	6/23	10/11	Water use (in)
	---Inches/8ft---		
100% ET	8.7	4.9	24 a
50-100% ET[1] to 10"	7.9	2.6	24 a
100% ET to 10"	8.1	4.5	24 a
50-100% ET to 6"	9.7	3.5	24 a
100% ET to 6"	12.1	5.8	25 a
Dryland	10.0	2.2	19 b
LSD $_{0.05}$	3.1	2.8	2.0
ANOVA (P>F) Trt.	0.29	0.03	0.001

Planted on May 24 (tubes read 6/23) and harvested on October 13 (tubes read 10/11/2016).
In-season rainfall (1/01 - 9/30) was 15.06".
In-season irrigation (7/28 – 9/9) was 1 = 9.0"; 2 = 7.0"; 3 = 9.0"; 4 = 6.0"; 5 = 7.0", 6 = 0.0". Plus 0.75 preplant irrigation
[1]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Table 14. Available water in profile (8 ft), at Colby, KS, 2015.

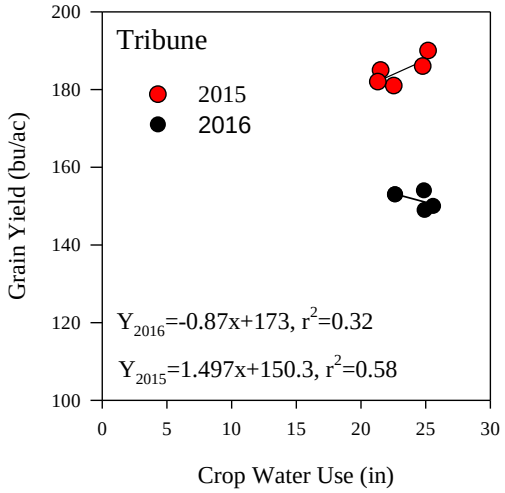
Treatment	Date 6/10	10/20	Water use (in)
	---Inches/8ft---		
100% ET	17.0	10.9 a	25.59 a
50-100% ET[1] to 10"	15.8	8.2 b	24.13 b
100% ET to 10"	16.3	8.9 b	25.91 a
50-100% ET to 6"	16.4	7.8 b	23.28 b
100% ET to 6"	17.5	8.2 b	24.00 b
Dryland	16.1	4.2 c	20.76 c
LSD $_{0.05}$	1.14	1.30	1.01
ANOVA (P>F) Trt.	0.05	0.001	0.001

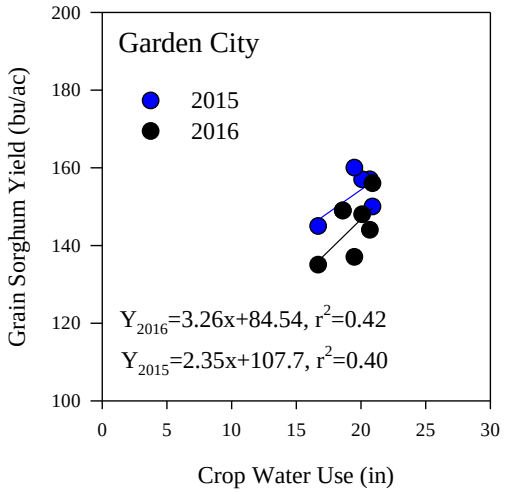
Planted on June 4 (tubes read 6/10) and harvested on October 20 (tubes read 10/20).
In-season rainfall (6/03 - 10/05) was 8.12".
In-season irrigation (6/10 - 9/21) was 1 = 10.56"; 2 = 7.68"; 3 = 9.60"; 4 = 5.76"; 5 = 5.76", 6 = 0.00".
[1]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached

Table 15. Available water in profile (8 ft), at Colby, KS, 2016.

Treatment	Date 6/3	10/5	Water use (in)
	---Inches/8ft---		
100% ET	14.1	10.3 a	22.0 ab
50-100% ET[1] to 10"	14.6	8.5 b	20.9 ab
100% ET to 10"	15.0	9.6 a	22.6 b
50-100% ET to 6"	14.7	7.4 bc	20.2 c
100% ET to 6"	14.4	6.4 c	21.5 ab
Dryland	14.2	4.1 e	17.2 d
LSD $_{0.05}$	2.2	1.7	1.4
ANOVA (P>F) Trt.	0.96	0.001	0.001

Planted on May 25 (tubes read 6/3) and harvested on October 6 (tubes read 10/05).
In-season rainfall (6/03- 10/05) was 7.11".
In-season irrigation (6-23- 9-09) was 1 = 11.12"; 2 = 7.68"; 3 = 10.16"; 4 = 5.76"; 5 = 6.32", 6 = 0.00".
[1]50% ET to boot then 100% ET until seasonal limit of 6 or 10 inches is reached





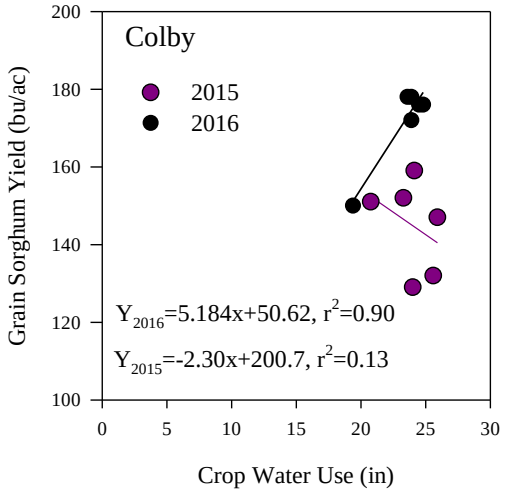
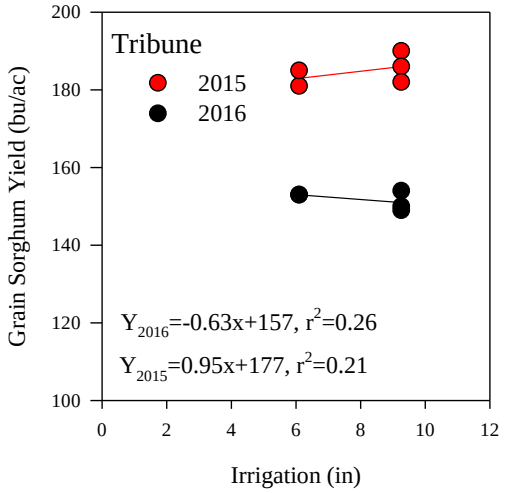
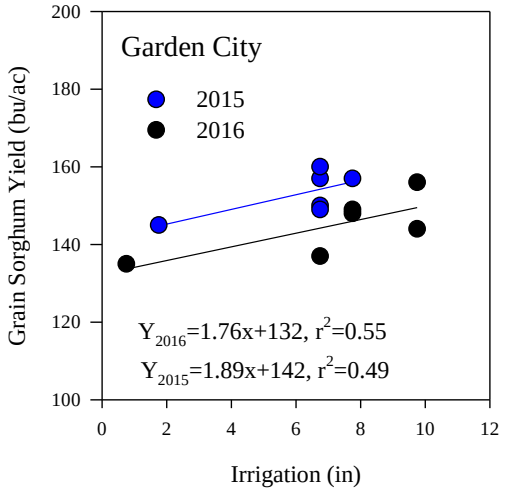


Figure 2. Grain sorghum yield versus crop water use (ETc) at Colby, Garden City and Tribune, Kansas during the 2015 growing season.





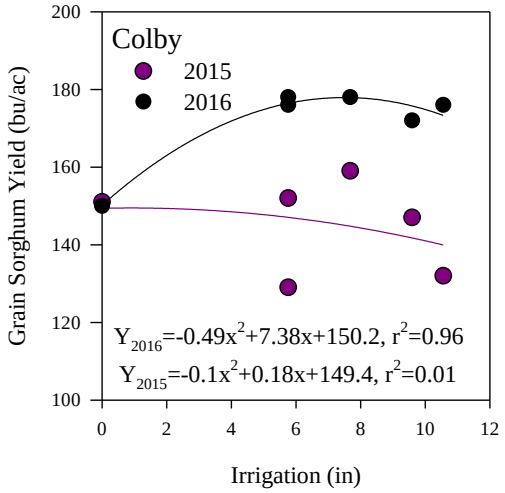


Figure 3. Grain sorghum yield versus irrigation at Colby, Garden City and Tribune, Kansas during the 2015 and 2016 growing season.

CONCLUSIONS

Grain sorghum yield under full and limited irrigated was evaluated at three locations in western Kansas (Colby, Tribune, and Garden City). The top-end yield under full irrigation was 190 bu/ac measured at Tribune in 2015. However, there was no significant differences among irrigation treatments at all the three locations due to the above normal rainfall received during the 2015. In 2016, the fully irrigated treatment (100% ET) was not significantly different from deficit irrigated treatments (treatments 2 to 5) in both years at the three locations. However, dryland yields were lower than irrigated grain sorghum yields at Garden City and Colby. These preliminary results also indicate that there is potential to improve grain sorghum yields and that management that constrains irrigation to replenish only 50% ET prior to boot enhanced water productivity. It is worth noting from this preliminary data that there is no substantial differences in yield between irrigation management limited to 6 and 10 inches of water per season in a normal to wet years, which makes grain sorghum a suitable crop choice for limited irrigation.

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