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Sorghum Yield Response to Water Supply and Irrigation Management

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Abstract

Grain sorghum yield, under full and limited irrigation, was evaluated at three locations in western Kansas (Colby, Tribune, and Garden City). The top-end yield under full irrigation was 190 bu/a. However, there were no significant differences among irrigation treatments at all the three locations due to the above normal rainfall received during the 2015 growing season. These preliminary results indicate that there is potential to improve grain sorghum yields under limited irrigation. Additionally, best management practices to maximize kernels per head could have the greatest effect on grain yields.

Keywords

grain sorghum yield, full and limited irrigation, irrigation management, water supply, evapotranspiration, after boot

Cover Page Footnote

This work was funded by the Kansas Grain Sorghum Commission. Sincere appreciation is expressed to all participating researchers and seed suppliers who have supported grain sorghum production in Kansas and the U.S. We would also like to thank the research technicians that helped with implementing the study.

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I. Kisekka, F. Lamm, and A. Schlegel

Summary

Grain sorghum yield, under full and limited irrigation, was evaluated at three locations in western Kansas (Colby, Tribune, and Garden City). The top-end yield under full irrigation was 190 bu/a. However, there were no significant differences among irrigation treatments at all the three locations due to the above normal rainfall received during the 2015 growing season. These preliminary results indicate that there is potential to improve grain sorghum yields under limited irrigation. Additionally, best management practices to maximize kernels per head could have the greatest effect on grain yields.

Introduction

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% evapotranspiration (ET)) at three locations in western Kansas (Colby, Garden City, and Tribune) and the effect of irrigation timing on grain sorghum yields under very limited irrigation (6 or 10 inches total).

Procedures

Experimental Description

The study was conducted at three locations in western Kansas, including 1) the Kansas State University, Southwest Research-Extension Center (SWREC) in Garden City; 2) SWREC, Tribune; and 3) the Northwest Research-Extension Center (NWREC), 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 growing season at each location are shown in Figure 1. The experimental design was a randomized complete block design with four replications.

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 following irrigation treatments were used.

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

As a case study, two limitations on total irrigation were compared to full irrigation. The limitations were 6 and 10 inches (Treatments 2-5). The fully irrigated treatment was managed as a non-water limiting crop with 100% ET replenishment. Soil water in the 8 feet soil profile was measured as a check for adequacy of the ET-based irrigation schedule and also 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 are shown in Tables 1 to 3.

Agronomic Management

The hybrid used was Pioneer 84G62, because it is full season and well adapted under both irrigated and dryland environments. Grain sorghum was planted at a seeding rate of 100,000 seeds per acre on June 4, 2015, and June 2, 2015, 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 fertilizer was applied at a rate of 10 gal/a 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/a and Lumax EZ at a rate of 80 oz/a. Grain sorghum was harvested on November 12, 2015, October 20, 2015, and October 20, 2015 at Tribune, Garden City, and Colby, respectively. The previous crop plantings to this study, in 2014, were fallow, Tribune; corn, Garden City; and sunflower, Colby.

Results and Discussion

Grain Sorghum Yield and Yield Components

There were no significant differences in grain yield between irrigation treatments at Tribune, Garden City, and Colby (Tables 4 to 6). This is probably due to the above normal rainfall received during the 2015 grain sorghum growing season (Figure 1). It was shown that the top-end yield potential can exceed 190 bu/a (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/a. The highest grain sorghum yields were recorded at Tribune, followed by Garden City and Colby, as shown in Tables 4 to 6. Kernels per head, which greatly influences yield, were highest at Tribune. There were more heads per acre at Garden City and Colby compared to Tribune; however, Tribune had higher yields implying the effect of kernel number per head, which was highest at Tribune, exerted a stronger influence on grain yield compared to heads per acre (Tables

4 to 6). Kernel weight was similar between the three locations (Tables 4 to 6). The study will need to be repeated in a normal or dry year to confirm results.

Crop Yield Response to Water

There were significant differences in grain sorghum crop water use (Tables 7 to 9). Treatments that received more irrigation water had 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. Water productivity also known as water use efficiency was significantly different between treatments at Colby and Tribune but not at Garden City (Tables 7 to 9). Water productivity was comparable between Tribune and Garden City but somewhat lower at Colby (Tables 7 to 9). Averaged across treatments water productivity was 8 bu/a/in. at Tribune and Garden City and 6 bu/a/in. at Colby. Production functions are shown in Figure 2, correlation between yield and ETc was higher for Garden City and Tribune. More research under normal or dry years is needed to fully characterize grain sorghum production functions under full and managed deficit/limited irrigation.

Conclusion

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/a measured at Tribune. However, there were no significant differences among irrigation treatments at all of the three locations due to the above normal rainfall received during the 2015 growing season. These preliminary results indicate there is potential to improve grain sorghum yields and that management which maximizes kernels per head could have the greatest effect on grain yields. More research is needed to fully determine grain sorghum top end yield potential and response to managed deficit irrigation under limited water.

Acknowledgments

This work was funded by the Kansas Grain Sorghum Commission. Sincere appreciation is expressed to all participating researchers and seed suppliers who have supported grain sorghum production in Kansas and the U.S. We would also like to thank the research technicians that helped with implementing the study.

Table 1. Sorghum Commission irrigation study at Tribune, KS, 2015.

	Irrigation (inches)				
	Treatment*				
Date	1	2	3	4	5
June 26	1.58	1.58	1.58	1.58	1.58
July 6	1.48		1.48		1.48
July 13	1.48		1.48		1.48
July 23	1.48		1.48		1.48
July 31	1.47	1.47	1.47	1.47	
August 8	1.80	1.80	1.80	1.80	
August 26	0.92	0.92	0.92	0.92	
September 2	1.53	1.53			
TOTAL	***11.74***	***7.30***	***10.21***	***5.77***	***6.02***

**Wheatland (electricity supply company) pulled zone stake (100 block - 4 and 3; 200 block - 4 and 5 watered incorrectly)
9/09/15 - Watered 100 and 200 block treatment 1 and 2 = 1.60 inches.
1 = 100% ET.
2 = 50% ET to boot then 100% ET to 10 inches total.
3 = 100% ET to 10 inches total.
4 = 50% ET to boot then 100% ET to 6 inches total.
5 = 100% ET to 6 inches total.

Table 2. Sorghum Commission irrigation study at Garden City, KS, 2015.

	Irrigation (inches)					
	Treatment*					
Date	1	2	3	4	5	6
*April 7	0.75	0.75	0.75	0.75	0.75	0.75
July 13	1.00					
August 5	1.00	1.00	1.00	1.00	1.00	
August 10	1.00	1.00	1.00	1.00	1.00	
August 24	1.00	1.00	1.00	1.00	1.00	
August 31	1.00	1.00	1.00	1.00	1.00	
September 10	1.00	1.00	1.00	1.00	1.00	1.00
September 18	1.00	1.00	1.00	1.00	1.00	
TOTAL	***7.75***	***6.75***	***6.75***	***6.75***	***6.75***	***1.75***

* Preseason irrigation.
1 = 100% ET.
2 = 50% ET to boot then 100% ET to 10 inches total.
3 = 100% ET to 10 inches total.
4 = 50% ET to boot then 100% ET to 6 inches total.
5 = 100% ET to 6 inches total.

Table 3. Sorghum Commission study irrigation at Colby, KS, 2015.

	Irrigation (inches)					
	Treatment*					
Date	1	2	3	4	5	6
July 7	0.96		0.96		0.96	
July 12	0.96		0.96		0.96	
August 1	0.96		0.96		0.96	
August 4	0.96	0.96	0.96	0.96	0.96	
August 10	0.96	0.96	0.96	0.96	0.96	
August 17	0.96	0.96	0.96	0.96	0.96	
August 20	0.96	0.96	0.96	0.96		
August 24	0.96	0.96	0.96	0.96		
August 29	0.96	0.96	0.96	0.96		
September 2	0.96	0.96	0.96			
September 6	0.96	0.96				
TOTAL	***10.56***	***7.68***	***9.60***	***5.76***	***5.76***	***0.00***

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

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

Treatment*	Grain yield	WUE[1]	Head population	Seeds	1000 seed	Kernels	Kernels	Heads
	bu/a	lb/in	10^3/a	Seed/lb	oz	no/head	--------- no/foot^2 ---------	
1	190	422 b	69.0	16,119	0.99	2,497	3,931	1.6
2	181	447 ab	71.9	16,691	0.96	2,346	3,847	1.7
3	186	419 b	70.6	15,937	1.00	2,352	3,800	1.6
4	185	479 a	67.4	16,198	0.99	2,508	3,832	1.5
5	182	478 a	69.7	16,341	0.98	2,383	3,803	1.6
$LSD_{0.05}$	17	50	10.7	834	0.05	354	379	0.2
ANOVA (P>F)								
Treatment	0.738	0.046	0.918	0.417	0.431	0.766	0.945	0.918

Note: WUE = water use efficiency
1 = 100% ET.
2 = 50% ET to boot then 100% ET to 10 inches total.
3 = 100% ET to 10 inches total.
4 = 50% ET to boot then 100% ET to 6 inches total.
5 = 100% ET to 6 inches total.

Table 5. Sorghum Commission study, crop parameters as affected by irrigation timing and amount at Garden City, KS, 2015.

Treatment	Grain yield	WUE[1]	Head population	Seeds	1000 seed	Kernels	Kernels	Heads
	bu/a	lb/in	10^3/a	Seed/lb	oz	no/head	--------- no/foot^2 ---------	
1	157	426	89.7	17,971	0.89	1,826	3,835	2.1
2	157	436	90.6	16,676	0.96	1,640	3,445	2.1
3	150	403	88.0	16,434	0.97	1,541	3,236	2.1
4	160	461	88.9	16,393	0.98	1,623	3,373	2.1
5	149	444	86.2	16,505	0.97	1,579	3,156	2.0
6	145	490	88.2	18,120	0.88	1,661	3,321	2.0
$LSD_{0.05}$	19	63	13.6	3152	0.13	464	977	0.3
ANOVA (P>F)								
Treatment	0.59	0.095	0.997	0.492	0.409	0.844	0.756	0.997

Note: WUE = water use efficiency
1 = 100% ET.
2 = 50% ET to boot then 100% ET to 10 inches total.
3 = 100% ET to 10 inches total.
4 = 50% ET to boot then 100% ET to 6 inches total.
5 = 100% ET to 6 inches total.

Table 6. Sorghum Commission study, crop parameters as affected by irrigation timing and amount at Colby, KS, 2015.

Treatment	Grain yield	WUE[1]	Head population	Seeds	1000 seed	Kernels	Kernels	Heads
	bu/a	lb/in	10^3/a	Seed/lb	oz	no/head	--------- no/foot^2 ---------	
1	132	284 a	91.9	18,116	0.88	1,482	3,112	2.1
2	159	363 b	88.2	16,846	0.95	1,690	3,380	2.0
3	147	312 ab	95.4	16,694	0.96	1,426	3,137	2.2
4	152	360 b	91.3	16,116	0.99	1,505	3,161	2.1
5	129	295 a	84.7	16,902	0.95	1,434	2,725	1.9
6	151	402 ab	91.3	17,150	0.93	1,603	3,366	2.1
$LSD_{0.05}$	29	64.5	15.7	1,497	0.07	480	631	0.36
ANOVA (P>F)								
Treatment	0.221	0.008	0.788	0.127	0.17	0.836	0.398	0.788

Note: WUE = water use efficiency.
1 = 100% ET.
2 = 50% ET to boot then 100% ET to 10 inches total.
3 = 100% ET to 10 inches total.
4 = 50% ET to boot then 100% ET to 6 inches total.
5 = 100% ET to 6 inches total.

Table 7. Available water in profile (8 ft), at Tribune, KS, 2015.

	Date		
Treatment	6/10	10/20	Water use
	---------- inches/8 ft ----------		
1	16.70	12.27	25.19 a
2	14.90	8.69	22.54 b
3	15.01	9.46	24.78 a
4	14.50	7.77	21.53 b
5	15.44	9.17	21.31 b
$LSD_{0.05}$	1.66	3.27	1.98
ANOVA (P>F)			
Treatment	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 inches.
In-season irrigation (6/10 - 11/06) was 1 = 11.74 inches; 2 = 7.30 inches; 3 = 10.21 inches; 4 = 5.77 inches; 5 = 6.02 inches.
1 = 100% ET.
2 = 50% ET to boot then 100% ET to 10 inches total.
3 = 100% ET to 10 inches total.
4 = 50% ET to boot then 100% ET to 6 inches total.
5 = 100% ET to 6 inches total.

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

	Date		
Treatment	6/22	10/13	Water use
	---------- inches/8 ft ----------		
1	24.3 a	20.0 a	20.7 a
2	25.2 ab	20.6 ab	20.1 b
3	27.2 bd	21.6 a	20.9 a
4	28.9 bc	24.5 b	19.5 ab
5	22.9 a	19.5 a	18.6 b
6	28.9 d	22.2 ab	16.7 c
$LSD_{0.05}$	1.99	2.59	1.26
ANOVA (P>F)			
Treatment	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 - 0/31) was 13.18 inches.
In-season irrigation (6/01-10/31) was 1 = 7.0 inches; 2 = 6.0 inches; 3 = 6.0 inches; 4 = 6.0 inches; 5 = 6.0 inches, 5 = 1.0 inches.
1 = 100% ET.
2 = 50% ET to boot then 100% ET to 10 inches total.
3 = 100% ET to 10 inches total.
4 = 50% ET to boot then 100% ET to 6 inches total.
5 = 100% ET to 6 inches total.

Table 9. Available water in profile (8 ft), at Colby, KS, 2015.

Treatment	Date 6/10	Date 10/20	Water use
	---------- inches/8 ft ----------		
1	17.0	10.9 a	25.59 a
2	15.8	8.2 b	24.13 b
3	16.3	8.9 b	25.91 a
4	16.4	7.8 b	23.28 b
5	17.5	8.2 b	24.00 b
6	16.1	4.2 c	20.76 c
$LSD_{0.05}$	1.14	1.30	1.01
ANOVA (P>F)			
Treatment	0.05	0.001	0.001

In-season rainfall (6/09-9/21) was 8.12 inches.
In-season irrigation (6/10-9/21) was 1 = 10.56 inches; 2 = 7.68 inches; 3 = 9.60 inches; 4 = 5.76 inches; 5 = 5.76 inches, 6 = 0.00 inches.
1 = 100% ET.
2 = 50% ET to boot then 100% ET to 10 inches total.
3 = 100% ET to 10 inches total.
4 = 50% ET to boot then 100% ET to 6 inches total.
5 = 100% ET to 6 inches total.

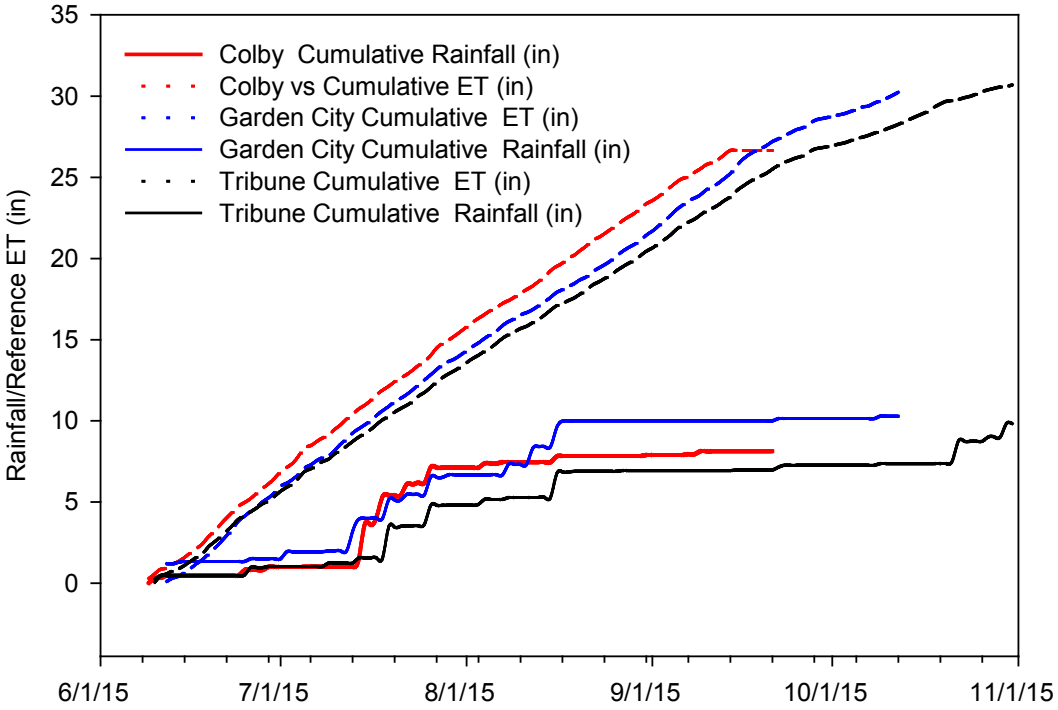
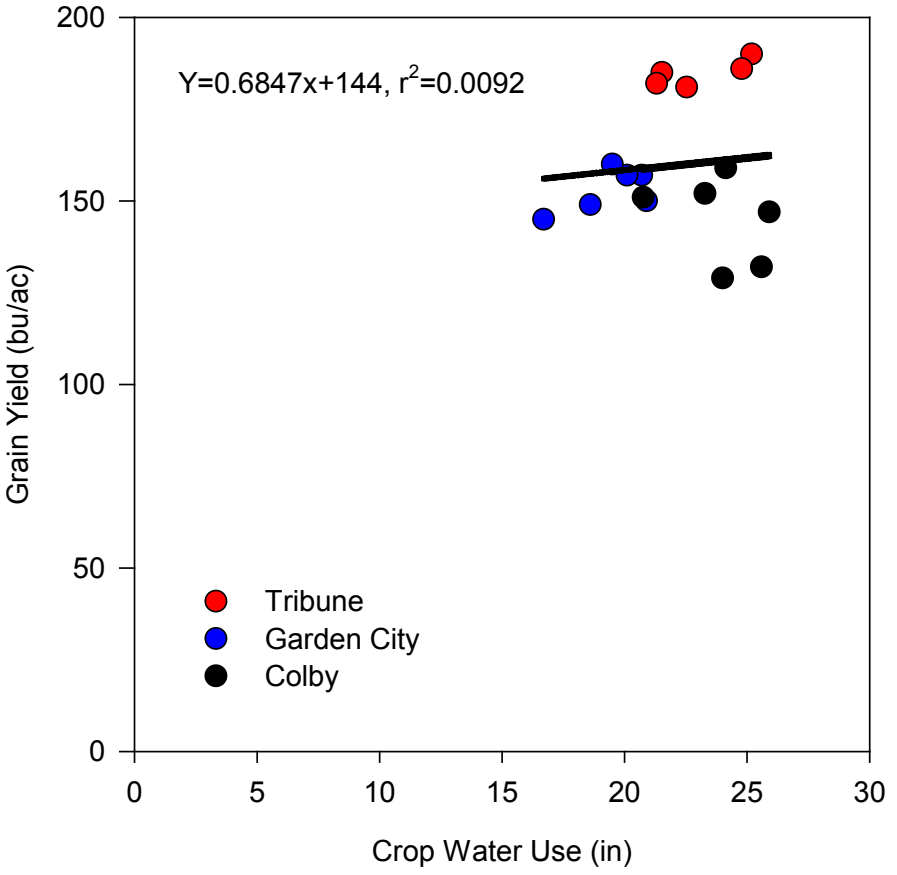


Figure 1. Cumulative rainfall and reference evapotranspiration at Colby, Garden City and Tribune, Kansas, during the 2015 grain sorghum growing season.



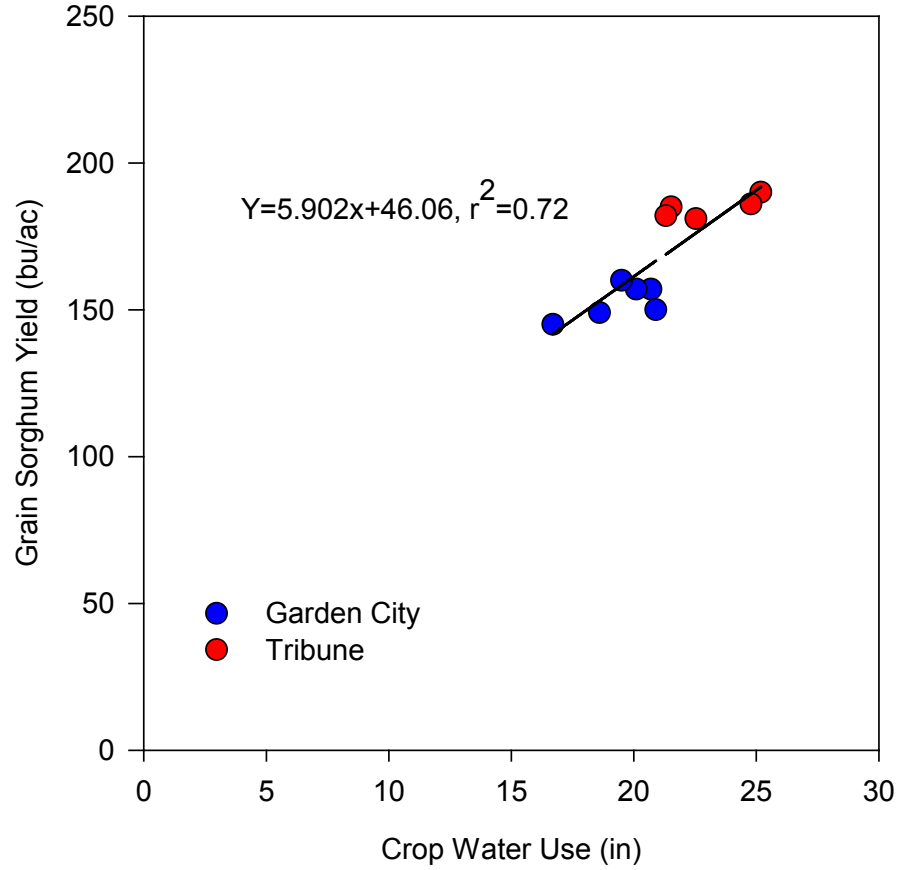


Figure 2. Grain sorghum yield versus crop water use (ETc) at Colby, Garden City, and Tribune, Kansas, during the 2015 growing season.