Kansas Agricultural Experiment Station Research Reports

Volume 2
Issue 7 *Southwest Research-Extension Center Reports*

Article 5

January 2016

Integrated Grain and Forage Rotations

J. D. Holman
Kansas State University, jholman@ksu.edu

T. Roberts
Kansas State University, troberts@ksu.edu

S. Maxwell
Kansas State University, scott8@ksu.edu

Recommended Citation

Holman, J. D.; Roberts, T.; and Maxwell, S. (2016) "Integrated Grain and Forage Rotations," *Kansas Agricultural Experiment Station Research Reports*: Vol. 2: Iss. 7. https://doi.org/10.4148/2378-5977.1250

Integrated Grain and Forage Rotations

Abstract

Producers are interested in growing forages in rotation with grain crops. Many producers are interested in diversifying their operations to include livestock or grow feed for the livestock industry. By integrating forages into the cropping system, producers can take advantage of more markets and reduce market risk. Forages require less water to make a crop than grain crops, so the potential may exist to reduce fallow by including forages in the crop rotation. Reducing fallow through intensified grain/forage rotations may increase the profitability and sustainability compared to existing crop rotations.

This study was started in 2013, with crops grown in-phase beginning in 2014. Grain crops were more sensitive to moisture stress than forage crops. Growing a double-crop forage sorghum after wheat reduced grain sorghum yield the second year, but never reduced second-year forage sorghum yield in the years of this study. As long as double-crop forage sorghum is profitable, it appears the cropping system can be intensified by growing second year forage sorghum. Caution should be used when planting double-crop forage sorghum by evaluating soil moisture condition and precipitation outlook, since other research has found cropping intensity should be reduced in dry years. The "flex-fallow" concept could be used to make a decision on whether or not to plant double-crop forage sorghum to increase the chance of success. Of important note, this research showed forages are more tolerant to moisture stress than grain crops and the potential exists to increase cropping intensity by integrating forages into the rotation.

Keywords

grain and forage rotations, irrigation management, forage crops, profitability and sustainability in crop rotations

Integrated Grain and Forage Rotations

J. Holman, T. Roberts, and S. Maxwell

Summary
Producers are interested in growing forages in rotation with grain crops. Many producers are interested in diversifying their operations to include livestock or grow feed for the livestock industry. By integrating forages into the cropping system, producers can take advantage of more markets and reduce market risk. Forages require less water to make a crop than grain crops, so the potential may exist to reduce fallow by including forages in the crop rotation. Reducing fallow through intensified grain/forage rotations may increase the profitability and sustainability compared to existing crop rotations.

This study was started in 2013, with crops grown in-phase beginning in 2014. Grain crops were more sensitive to moisture stress than forage crops. Growing a double-crop forage sorghum after wheat reduced grain sorghum yield the second year, but never reduced second-year forage sorghum yield in the years of this study. As long as double-crop forage sorghum is profitable, it appears the cropping system can be intensified by growing second year forage sorghum. Caution should be used when planting double-crop forage sorghum by evaluating soil moisture condition and precipitation outlook, since other research has found cropping intensity should be reduced in dry years. The "flex-fallow" concept could be used to make a decision on whether or not to plant double-crop forage sorghum to increase the chance of success. Of important note, this research showed forages are more tolerant to moisture stress than grain crops and the potential exists to increase cropping intensity by integrating forages into the rotation.

Introduction
Interest in growing forages and reducing fallow has necessitated research on soil water and crop yields in intensified grain/forage rotations. Fallow stores moisture, which helps stabilize crop yields and reduces the risk of crop failure; however, only 25 to 30% of the precipitation received during the fallow period of a wheat-sorghum-fallow rotation is stored. The remaining 70 to 85% of precipitation is lost, primarily due to evaporation. Moisture storage in fallow is more efficient earlier in the fallow period, when the soil is dry, and during the winter months, when the evaporation rate is lower. It may be possible to increase cropping intensity without reducing crop yields through the use of forage crops in the rotation. This study evaluated integrated grain/forage rotations compared to traditional, grain-only crop rotations.

Procedures

A study beginning in 2013 evaluated various integrated grain and forage rotations compared to a no-till wheat-grain sorghum-fallow rotation (Table 1). A total of 11 crop rotations were evaluated. The study design was a split-plot randomized complete block design with four replications; crop phase (wheat-sorghum-fallow) was the main plot and alternative crop choices were the split-plot. Each split-plot was 30 ft wide and 120 ft long.

“Flex-fallow” is a spring planting decision based on current soil moisture condition and seasonal outlook. Spring oats were planted when 14 inches or more plant available water (PAW) was determined available by using a Paul Brown moisture probe and seasonal precipitation forecasted outlook was neutral or favorable; otherwise the treatment was left fallow. The flex-fallow treatment was intended to take advantage of growing a crop during the fallow period in wet years and fallowing in dry years. A flex-fallow crop was planted in 2013 and 2016, but not 2014 or 2015.

Winter triticale was planted approximately October 1 in all years. Spring crops were planted as early as soil conditions allowed, ranging from the end of February through the middle of March. Spring forage crops were harvested approximately June 1 in all years. Forage sorghum was either planted around June 1 for full-season or following wheat harvest around July 1 for double-crop. Forage biomass yields were determined from a 3-ft × 120-ft area cut 3 in. high using a small plot Carter forage harvester. Winter wheat and grain sorghum were harvested with a small plot Wintersteiger combine from a 6.5-ft × 120-ft area at grain maturity.

Volumetric soil moisture content was measured at planting and harvest of winter wheat, grain sorghum, forage sorghum, spring oat, or fallow using a Giddings Soil Probe by 1-foot increments to a 6-ft soil depth. In addition, volumetric soil content was measured in the 0–3-in. soil depth at wheat planting to quantify moisture in the seed planting depth. Grain yield was corrected for moisture content, and test weight was measured using a grain analysis computer. Seed weight was determined from a 1,000 seed count using a seed counter computer. Grain samples were analyzed for nitrogen content.

Results and Discussion

Winter Wheat

Winter wheat yield, plant available moisture at planting, water use efficiency, and precipitation storage efficiency prior to planting were not affected by whether forage sorghum or grain were grown in place of one another in the rotation (Table 2). Wheat yields were reduced when oat was grown in place of fallow. Previous research found growing oats in place of fallow reduced wheat yields when wheat yield potential was less than 50 bushels per acre. A flex crop was grown in 2013, but not 2014 or 2015. Dry conditions developed soon after planting a flex crop in 2013, and growing a flex crop in place of fallow reduced 2014 wheat yield 67%.

Grain Sorghum

Grain sorghum yield was highly correlated with plant available moisture at planting, which explained 54% of the variability in grain yield (Figure 1). Approximately 9.5 bushels were grown for every inch of plant available water at planting. Plant available moisture was highest when forage sorghum was not double-cropped between wheat and grain sorghum (Table 3) and tended to be higher when nothing was grown in the fallow phase ahead of winter wheat. Growing double-crop forage sorghum ahead of grain sorghum reduced grain sorghum yield 55% in 2014 and 30% in 2015. Growing a forage sorghum crop after wheat reduced the water use efficiency of the subsequent grain sorghum crop each year, but did not affect precipitation storage efficiency. Growing a forage sorghum crop reduced the test weight and seed weight of grain sorghum in 2015.

Forage Sorghum

Forage sorghum yield was also highly correlated with plant available moisture at planting, but not as high as grain sorghum. Plant available moisture at planting explained approximately 50% of the variability in forage yield (Figure 2). Approximately 640 lb of forage was grown for every inch of plant available water at planting.

Forage sorghum yields were not different across treatments in 2014, except ww/FS-fs-o, which yielded 2,200 lb/a less than ww/fs-FS-o (Table 4). This lower yield was most likely due to less plant available water at planting, 1.3 versus 2.1 inches. In 2014 plant available water averaged 1 inch ahead of double-crop forage sorghum and 4.1 inches ahead of full season forage sorghum. In 2014, most of the annual precipitation occurred later in the year (June-September), which likely helped improve the yield of double-crop forage sorghum relative to full-season forage sorghum. In 2014, double-crop forage sorghum yielded on average 17% less than full-season forage sorghum (3,300 versus 3,900 lb/a). In 2015, most of the precipitation occurred earlier in the year (May-August), which helped increase wheat yields but also resulted in comparatively less moisture at planting double-crop forage sorghum, 1.6 versus 7.2 inches. As a result, in 2015 double-crop forage sorghum yields were reduced 70% compared to full-season forage sorghum (2,400 versus 8,000 lb/a).

Surprisingly, second year forage sorghum yields following double-crop forage sorghum were similar to full-season forage sorghum following wheat with fallow between wheat harvest and sorghum planting (Table 4). Yet forage sorghum following double-crop forage sorghum had an average of 3 inches less soil moisture compared to fallow ahead of forage sorghum. In dry years, this difference in plant available soil water may result in yield differences, but it did not affect yield in this study. These results suggest that as long as the benefits of growing a double-crop forage sorghum crop exceeded costs, an extra crop could be grown in the rotation without adversely affecting full-season forage sorghum yield in a wheat/forage sorghum-forage sorghum rotation under favorable moisture conditions. A partial enterprise analysis of this phase of the rotation only indicated double-crop forage sorghum needs to yield at least 30% of full-season forage sorghum or at least 2,000 lb/a, for a double-crop forage sorghum crop that is grazed to be profitable. The additional variable expenses of growing double-crop forage sorghum would be around $25.00 per acre.

Spring Oat

Spring oat yield was not affected by rotation treatment and yielded 564 lb/a in 2014 and 1,927 lb/a in 2015.

Conclusions

Wheat and spring oat yields were not affected whether grain or forage sorghum were grown in place of each other in the crop rotation. Wheat yields were reduced when oats were grown in place of fallow. Previous research found wheat yields needed to be greater than 50 bushels per acre for wheat yields not to be reduced by growing oats in place of fallow, and wheat yield potential was only 6 bu/a in 2014 and 15 bu/a in 2015.

Grain sorghum yield was more sensitive to moisture stress than forage sorghum. Growing a double-crop forage sorghum after wheat reduced grain yield 30 to 55% the second year, but never reduced forage sorghum yield in the years of this study. However, in low precipitation years, full-season forage sorghum yields might be more negatively impacted than they were in this study. Double-crop forage sorghum yields were affected by moisture conditions more than full-season forage sorghum, and yields were reduced up to 70% compared to full-season yields. As long as double-crop forage sorghum is profitable, which we identified to be around 2,000 lb/a yield when grazed, it appears the cropping system can be intensified without negatively affecting second year forage sorghum yield. Caution should be used when planting double-crop forage sorghum by evaluating soil moisture condition and precipitation outlook, since other research has found cropping intensity should be reduced in dry years. The "flex-fallow" concept could be used to make a decision on whether or not to plant double-crop forage sorghum to increase the chance of success. Of important note, this research showed forages are more tolerant to moisture stress than grain crops and the potential exists to increase cropping intensity by integrating forages into the rotation.

Table 1. Grain and forage crop rotation treatments.

No.	Crop rotation	Abbreviation
1	Wheat-Grain Sorghum-Flex Fallow	ww-gs-fx
2	Wheat-Grain Sorghum-Fallow	ww-gs-fl
3	Wheat/Forage Sorghum-Forage Sorghum-Oat	ww/fs-fs-o
4	Wheat-Forage Sorghum-Oat	ww-fs-sg
5	Wheat/Forage Sorghum-Grain Sorghum-Oat	ww/fs-gs-o
6	Wheat-Grain Sorghum-Oat	ww-gs-o
7	Wheat-Forage Sorghum-Oat (tilled)	ww-fs-o(T)
8	Wheat-Forage Sorghum-Fallow	ww-fs-fl
9	Wheat-Forage Sorghum-Flex Fallow	ww-fs-fx
10	Wheat/Forage Sorghum-Forage Sorghum-Flex Fallow	ww/fs-fs-fx
11	Wheat/Forage Sorghum-Grain Sorghum-Flex Fallow	ww/fs-gs-fx

Table 2. Winter wheat yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City from 2014 to 2015 and average across years.

		Yield		Plant available water		WUE		PSE	
Rotation†	Crop	bu/a	P < 0.05	inches in 6' depth	P < 0.05	bu/a/in	P < 0.05	%	P < 0.05
		2014							
WW-gs-fx	WW	2.0	BC	2.4	AB	0.13	BC	0.27	AB
WW-gs-fl	WW	6.0	A	3.8	AB	0.38	A	0.19	B
WW/fs-fs-o	WW	1.0	C	3.0	AB	0.05	C	0.30	AB
WW-fs-sg	WW	0.1	C	2.9	AB	0.01	C	0.27	AB
WW/fs-gs-o	WW	0.4	C	1.4	B	0.03	C	0.21	B
WW-gs-o	WW	0.2	C	2.5	AB	0.01	C	0.24	B
WW-fs-o(T)	WW	2.3	BC	4.1	A	0.13	BC	0.43	A
WW-fs-fl	WW	5.1	AB	3.7	AB	0.27	AB	0.22	B
WW-fs-fx	WW	*	*	*	*	*	*	*	*
WW/fs-fs-fx	WW	*	*	*	*	*	*	*	*
WW/fs-gs-fx	WW	*	*	*	*	*	*	*	*
LSD		3.1		2.6		0.20		0.18	
		2015							
WW-gs-fx	WW	16.1	A	4.7	AB	1.11	A	*	*
WW-gs-fl	WW	14.6	AB	5.4	A	0.98	AB	0.20	A
WW/fs-fs-o	WW	6.4	DE	1.9	D	0.45	C	0.12	A
WW-fs-sg	WW	6.8	CDE	2.8	BCD	0.58	BC	0.17	A
WW/fs-gs-o	WW	8.1	CDE	1.6	D	0.64	BC	0.16	A
WW-gs-o	WW	8.0	CDE	2.3	CD	0.59	BC	0.10	A
WW-fs-o(T)	WW	7.7	CDE	2.4	CD	0.57	BC	0.12	A
WW-fs-fl	WW	10.3	BCD	4.6	AB	0.67	BC	*	*
WW-fs-fx	WW	11.8	ABC	4.1	ABC	0.93	AB	0.88	A
WW/fs-fs-fx	WW	4.8	E	2.7	BCD	0.34	C	0.12	A
WW/fs-gs-fx	WW	8.1	CDE	1.6	D	0.64	BC	0.16	A
LSD		5.4		2.1		0.44		0.15	

continued

Table 2. Winter wheat yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City from 2014 to 2015 and average across years.

		Yield		Plant available water		WUE		PSE	
Rotation†	Crop	bu/a	P < 0.05	inches in 6' depth	P < 0.05	bu/a/in	P < 0.05	%	P < 0.05
		Average							
WW-gs-fx	WW	9.1		3.6		0.62		0.27	
WW-gs-fl	WW	10.3		4.6		0.68		0.20	
WW/fs-fs-o	WW	3.7		2.5		0.25		0.21	
WW-fs-sg	WW	3.5		2.8		0.29		0.22	
WW/fs-gs-o	WW	4.2		1.5		0.33		0.18	
WW-gs-o	WW	4.1		2.4		0.30		0.17	
WW-fs-o(T)	WW	5.0		3.2		0.35		0.28	
WW-fs-fl	WW	7.7		4.2		0.47		0.22	
WW-fs-fx	WW	11.8		4.1		0.93		0.88	
WW/fs-fs-fx	WW	4.8		2.7		0.34		0.12	
WW/fs-gs-fx	WW	8.1		1.6		0.64		0.16	
LSD									

† WW is winter wheat , FS is forage sorghum, GS is grain sorghum, FL is fallow, FX is flex-fallow, FX(T) is flex-fallow with summer tillage, and O is spring oat.
‡ Data not available.
§ Means in columns followed by different letters are statistically different at P ≤ 0.05.

Table 3. Grain sorghum yield, test weight, 1,000 seed weight, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City from 2014 to 2015 and average across years.

		Yield		Test weight		Seed weight		Plant Available Water		WUE		PSE	
Rotation†	Crop	bu/a	P < 0.05	lb/bu	P < 0.05	g/1,000 seed	P < 0.05	inches in 6' depth	P < 0.05	bu/a/in	P < 0.05	%	P < 0.05
							2014						
ww-GS-fx	GS	47.5	A§	58.0	A	21.3	A	4.5	A	2.96	A	0.22	A
ww-GS-fl	GS	49.5	A	59.1	A	22.6	A	4.4	A	2.99	A	0.18	A
ww/fs-GS-o	GS	17.8	B	57.7	A	21.1	A	4.2	A	1.07	B	0.31	A
ww-GS-o	GS	39.4	AB	57.7	A	22.7	A	6.4	A	2.16	AB	0.36	A
LSD		23.2		2.2		2.0		3.4		1.26		0.28	
							2015						
ww-GS-fx	GS	96.4	AB	60.8	AB	26.3	A	7.3	AB	5.53	A	0.27	A
ww-GS-fl	GS	108.9	A	60.9	A	27.0	A	9.0	A	5.91	A	0.35	A
ww/fs-GS-o	GS	59.4	C	59.8	B	21.6	B	6.0	B	3.68	B	0.25	A
ww-GS-o	GS	84.1	B	60.3	AB	25.8	A	7.9	AB	4.83	AB	0.34	A
LSD		19.2		1.0		3.5		2.4		1.20		0.10	
							Average						
ww-GS-fx	GS	71.9		59.4		23.82		5.9		4.24		0.25	
ww-GS-fl	GS	79.2		60.0		24.82		6.7		4.45		0.27	
ww/fs-GS-o	GS	38.6		58.7		21.32		5.1		2.38		0.28	
ww-GS-o	GS	61.8		59.0		24.24		7.2		3.50		0.35	
LSD													

"† WW is winter wheat , FS is forage sorghum, GS is grain sorghum, and SG is a mixture of spring triticale and spring oat.
§ Means in columns followed by different letters are statistically different at $P \leq 0.05$."

Table 4. Forage sorghum yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City from 2014 to 2015 and average across years.

		Yield		Plant available water		WUE		PSE	
Rotation†	Crop	bu/a	P < 0.05	inches in 6' depth	P < 0.05	bu/a/in	P < 0.05	%	P < 0.05
				2014					
ww/FS-fs-o	FS	2,490	B§	1.3	C	180	B	0.60	AB
ww/fs-FS-o	FS	4,705	A	2.1	BC	566	A	0.20	B
ww-FS-o	FS	3,305	AB	5.7	A	201	B	*‡	*
ww/FS-gs-o	FS	3,964	AB	0.6	C	452	A	0.75	A
ww-FS-fx(T)	FS	3,917	AB	4.3	AB	257	B	*	*
ww-FS-fx	FS	3,531	AB	4.0	AB	225	B	0.45	AB
ww-FS-fl	FS	4,093	AB	4.7	A	268	B	0.30	AB
LSD		2,034		2.3		174		0.54	
				2015					
ww/FS-fs-o	FS	2,320	B	1.7	B	209	B	*	*
ww/fs-FS-o	FS	7,750	A	5.6	A	568	A	0.18	B
ww-FS-o	FS	7,948	A	8.3	A	488	A	0.38	A
ww/FS-gs-o	FS	2,497	B	1.6	B	223	B	*	*
ww-FS-fx(T)	FS	7,103	A	7.8	A	443	A	0.35	AB
ww-FS-fx	FS	8,697	A	7.4	A	533	A	0.20	AB
ww-FS-fl	FS	8,333	A	6.9	A	537	A	0.28	AB
LSD		2,270		3.1		161		0.18	
				Average					
ww/FS-fs-o	FS	2,405		1.5		194		0.60	
ww/fs-FS-o	FS	6,228		3.8		568		0.19	
ww-FS-o	FS	5,627		7.0		344		0.38	
ww/FS-gs-o	FS	3,231		1.1		338		0.75	
ww-FS-fx(T)	FS	5,510		6.0		350		0.35	
ww-FS-fx	FS	6,114		5.7		379		0.33	
ww-FS-fl	FS	6,213		5.8		403		0.29	
LSD									

† WW is winter wheat , FS is forage sorghum, GS is grain sorghum, FL is fallow, FX is flex-fallow, FX(T) is flex-fallow with summer tillage, and O is spring oat.

‡ Data not available.

§ Means in columns followed by different letters are statistically different at P ≤ 0.05.

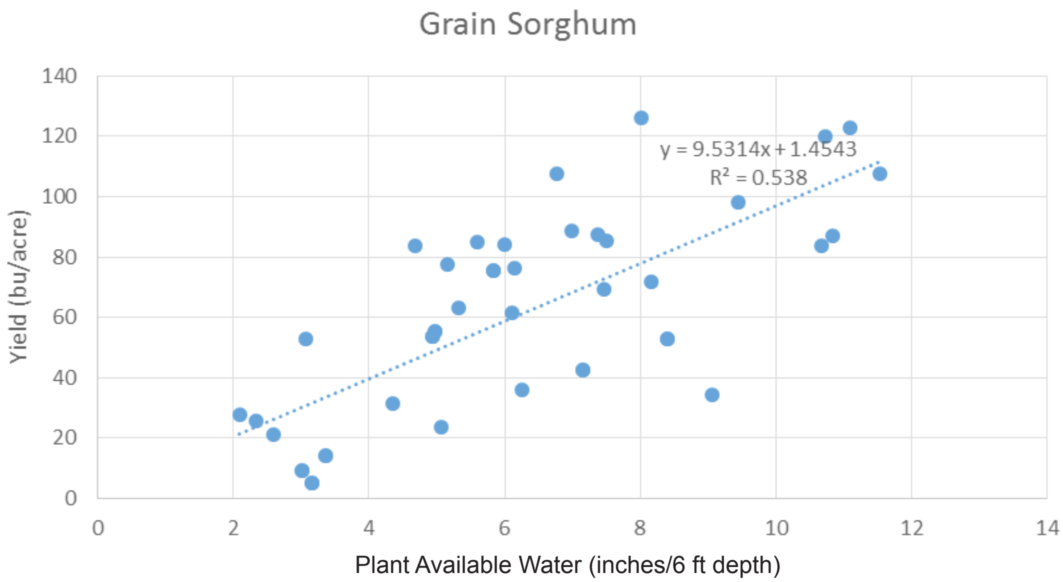

Figure 1. Grain sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2015.

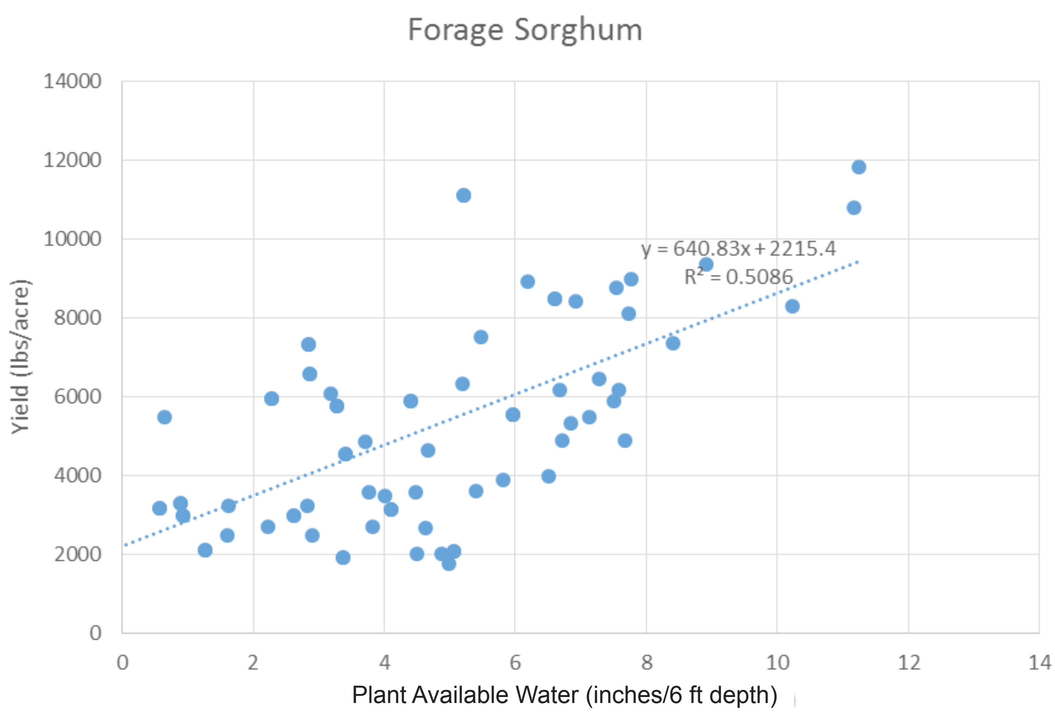

Figure 2. Forage sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2015.