



SOUTHWEST RESEARCH-EXTENSION CENTER

FIELD DAY 2017

K-STATE
Research and Extension

Kansas State University Agricultural Experiment Station and Cooperative Extension Service



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Weather Information for Tribune

D. Bond and J. Slattery

In 2016, annual precipitation of 19.97 in. was recorded, which is 2.07 in. above normal. Six months had above-normal precipitation. April (5.16 in.) was the wettest month. The largest single amount of precipitation was 1.91 in. on August 7. January, the driest month, only recorded a trace of precipitation.

Snowfall for the year totaled 14.6 in. January, February, March, April, and December had a trace (T), 5.9, 0.8, 0.6, and 7.3 in., respectively, for a total of 17 days of snow cover. The longest consecutive period of snow cover, 7 days, occurred December 17 through December 23.

Record-high temperatures were recorded on 5 days: February 19 (88°F); March 23 (84°F); September 21 (97°F); and November 16 (79°F) and 17 (82°F). Record-high temperatures were tied on 4 days: February 28 (78°F); June 22 (104°F); October 28 (85°F); and November 1 (86°F). A record-low temperature was recorded on December 18 (-22°F). A record-low temperature was tied on November 19 (9°F). July was the warmest month, with a mean temperature of 77.6°F. The hottest day of the year (104°F) occurred on June 22. The coldest day of the year (-22°F) occurred on December 18. December was the coldest month, with a mean temperature of 25.7°F.

Mean air temperature was above normal for 9 months. February had the greatest departure above normal (6.3°F), and December had the greatest departure below normal (-5.2°F). Temperatures were 100°F or higher on 6 days, which is 5 days below normal. Temperatures were 90°F or higher on 67 days, which is 4 days above normal. The latest spring freeze was May 2, which is 4 days earlier than normal; the earliest fall freeze fell on the normal date of October 7. This produced a frost-free period of 158 days, which is 4 days more than the normal of 154 days.

Open-pan evaporation from April through September totaled 61.69 in., which is 9.71 in. below normal. Wind speed for this period averaged 4.6 mph, which is 0.7 mph less than normal.

The 2016 climate information for Tribune is summarized in Table 1.

Table 1. Climatic data, Southwest Research-Extension Center, Tribune, KS

Month	Precipitation (in.)		Monthly average temperatures (°F)						Wind (MPH)		Evaporation (in.)	
			2016		Normal		2016 extreme		2016	Normal	2016	Normal
	2016	Normal	Max	Min	Max	Min	Max	Min				
January	Trace	0.49	48.0	17.1	44.0	16.2	66	3	---	---	---	---
February	0.92	0.52	55.6	24.1	47.5	19.4	88	3	---	---	---	---
March	0.20	1.22	64.7	26.5	56.3	26.8	84	8	---	---	---	---
April	5.16	1.45	66.7	36.4	65.7	34.9	81	24	5.2	6.0	7.46	8.27
May	1.46	2.38	72.4	44.1	75.1	46.4	91	30	5.0	5.6	9.01	11.75
June	1.78	2.94	90.8	58.1	85.7	56.6	104	46	4.4	5.2	13.69	14.04
July	4.07	2.85	92.6	62.5	91.8	61.7	103	56	4.5	5.2	13.35	15.58
August	3.51	2.33	86.8	58.4	89.4	60.4	98	48	3.9	4.7	9.76	12.16
September	2.11	1.18	84.7	51.7	81.5	50.6	97	35	4.3	5.0	8.42	9.60
October	0.04	1.49	78.3	39.2	68.9	37.1	91	25	3.6*	4.5*	7.17*	6.09*
November	0.02	0.55	64.5	28.5	54.9	25.7	86	9	---	---	---	---
December	0.70	0.50	41.2	10.3	44.7	17.0	66	-22	---	---	---	---
Annual	19.97	17.90	70.5	38.1	67.1	37.7	104	-22	4.6	5.3	61.69	71.40

Max = maximum.

Min = minimum.

Normal latest freeze (32°F) in spring: May 6. In 2016: May 2.

Normal earliest freeze (32°F) in fall: October 7. In 2016: October 7.

Normal frost-free (>32°F) period: 154 days. In 2016: 158 days.

Normal for precipitation and temperature is 30-year average (1981–2010) from National Weather Service.

Normal for latest freeze, earliest freeze, wind, and evaporation is 30-year average (1981–2010) from Tribune weather data.

* Normal for October wind and evaporation is 10-year average (2001–2010) from Tribune weather data; October was not included in annual totals.

Weather Information for Garden City, 2016

J. Elliott

Precipitation for 2016 totaled 17.73 in. This was 1.51 in. below the 30-year average of 19.24 in. and followed two years of above normal moisture. April and July 2016 had considerably above average precipitation, causing good summer crop growing conditions. Rainfall diminished after July to 37% of the 30-year-average, resulting in dry conditions for fall wheat planting. Hail was not observed in 2016. Blowing dust was noted on two days in March. The largest daily rainfall events were 1.72 in. on April 16, and 1.68 in. on July 2.

Measurable snowfall occurred in February, March, and December. Annual snowfall totaled 4.0 in. (tied the least record from 1968) compared to an average of 19.7 inches. The largest daily snow amount was 1.5 in. recorded on February 2, and again on December 18. Seasonal snowfall (2015-2016) was only 2.6 in., which set a record for lowest seasonal snowfall amount.

Average daily wind speed was 5.01 mph compared to the 30-year average of 5.10 mph. Open pan evaporation was measured daily from April through October and totaled 79.31 in. This was 9.05 in. above the 30-year mean of 70.26 in.

The mean annual temperature was 56.1°F, which was 2.4°F above the 30-year average of 53.7°F. Triple-digit temperatures were observed on 6 days in 2016, with the highest being 101°F on July 24. Eight record high temperatures were equaled or exceeded in 2015: 90°F on February 19, 91°F on October 16, 98°F on October 17, 100°F on October 18, 90°F on October 29, 91°F on November 1, 82°F on November 16, and 87°F on November 17. On October 18, 100°F was the highest temperature recorded for the month of October.

Sub-zero temperatures occurred four times in 2016. The lowest temperature was -20°F noted on December 18 and was also a record low for the month of December. The all-time record low was -22°F on January 19, 1984. Four record low temperatures were equaled or exceeded: -1 on December 8, -20 on December 18, -11 on December 19, and -10 on December 20.

The last spring freeze was 32°F on May 3, which was four days later than the 30-year average. The first fall freeze was 30°F on October 7, which was five days earlier than normal. This resulted in a 157-day frost-free period, which is eight days shorter than the 30-year average.

The 2016 climate information for Garden City is summarized in Table 1.

WEATHER

Table 1. Climate data, Southwest Research-Extension Center, Garden City

Month	Precipitation		Monthly temperatures					Wind		Evaporation		
			2016 average			2016 extreme						
	2016	avg.	Max	Min	Mean	30-year		2016	30-year	2016	30-year	
	----- in. -----		----- °F -----					----- mph -----		----- in. -----		
January	0.04	0.46	46.6	17.6	32.1	30.4	66	7	4.40	4.50	--	--
February	0.22	0.55	56.6	23.7	40.1	33.9	90	7	5.44	5.24	--	--
March	0.06	1.31	66.6	29.3	48.0	42.9	86	9	6.28	6.31	--	--
April	4.59	1.74	68.9	38.8	53.8	52.3	85	22	6.15	6.42	7.64	8.21
May	0.92	2.98	74.9	45.9	60.4	62.8	93	30	5.28	5.76	10.07	10.04
June	3.61	3.12	91.7	62.1	76.9	72.6	100	46	5.23	5.37	15.41	11.96
July	5.97	2.80	92.2	66.3	79.3	77.9	101	57	4.10	4.59	14.02	13.22
August	1.85	2.51	88.7	62.7	75.7	76.3	100	50	4.07	4.11	11.20	11.28
September	0.17	1.42	86.8	55.2	71.0	67.7	98	37	5.27	4.73	10.62	9.22
October	-	1.21	80.4	42.4	61.4	54.9	100	30	4.99	4.89	10.35	6.33
November	0.08	0.55	65.4	31.0	48.2	41.6	91	11	4.60	4.80	--	--
December	0.22	0.59	42.8	10.5	26.7	31.4	61	-20	4.25	4.45	--	--
Annual	17.73	19.24	71.8	40.5	56.1	53.7	101	-20	5.01	5.10	79.31	70.26

Normal latest spring freeze (32°F): April 29. In 2016: May 3.
 Normal earliest fall freeze (32°F): Oct. 12. In 2016: October 7.
 Normal frost-free period (>32°F): 165 days. In 2016: 157 days.
 30-year averages are for the period 1981-2010. All recordings were taken at 8:00 a.m.

Value of Fungicide Application in Wheat Production in Southwest Kansas

A.J. Foster, R. Lollato, M. Vandever, and E.D. De Wolf

Summary

During the past several years, applying fungicide to wheat has become a more common practice. The availability of cost-effective generic fungicides, as well as the positive yield responses often reported, seem to be the potential drivers for the adoption of such practices by producers. We conducted a wheat fungicide trial in Garden City, KS, to answer the following questions: 1) Do fungicide applications pay? And 2) Can remote sensing technology be used to quantify the efficacy of different fungicide products? The study consisted of two wheat varieties sown on September 29, 2015 (Oakley CL, highly resistant to stripe rust; and TAM 11, highly susceptible to stripe rust), different fungicide products and different times of application. Stripe rust was the major fungal disease impacting wheat yield in southwest Kansas in 2015-16. Fungicide application increased grain yield over the control for all fungicide products. The greatest grain yield resulted from the application of Tebustar. These results suggest that there could be some potential benefits to early season application of fungicide in southwest Kansas, although the majority of the grain yield gain comes from the flag leaf application. Additional years of data are required to make more robust, meaningful interpretations.

Introduction

Wheat yield in southwest Kansas is highly dependent on weather conditions. In years like 2015 and 2016, when adequate moisture was available at the critical stages, such as grain filling, and cool temperatures occurred during heading and flowering, many fields had bumper wheat yields averaging over 100 bu/a. Moisture availability and temperature during the heading to grain filling stages are critical to producing high-yielding wheat. Unfortunately, we cannot order these conditions each year. However, there are some factors we can control, such as selecting varieties, providing adequate nutrition, and applying a foliar fungicide to protect yields in high-disease years. In recent years, with the availability of more affordable generic fungicides, producers are becoming interested in adopting this practice to protect grain yield from major fungal diseases. It is important for producers to be aware that application of fungicides protects yield potential that is present at the time of application. Fungicides serve as yield protectors by enhancing the plant health. Therefore, it is not uncommon for producers to associate delayed harvest with fungicide application. Fungicides allow plants to stay green and keep their leaves longer, using more nutrients during the late development stages.

Previous research has reported variable results regarding the value of fungicide application in the Great Plains. In Kansas, several years of research have indicated that a single fungicide application to a susceptible variety, on average, could provide a 10% yield increase relative to the untreated control. To maximize the benefit of a fungicide application, producers should know the vulnerability of the variety to be treated. Susceptible varieties are more likely to provide a yield benefit compared to a variety with a moderate

to high level of resistance. It is also important to pay attention to weather conditions and scouting reports within a field, a region, and even surrounding states to the south.

Rating the effectiveness of a foliar fungicide application on disease control is often tedious and very subjective. With the onset of remote sensing technology, there are great opportunities to develop more objective approaches for rating varietal resistance to diseases and the efficacy of fungicides. Measurements such as the normalized difference vegetation index (NDVI), which combines wavebands in the red region of the spectrum that is controlled by the leaf pigment content, and wavebands in near-infrared region of the spectrum that is controlled by the leaf internal structures is strongly correlated with plant health. Application of fungicide is reported to enhance plant health that results in the plant staying green longer. Therefore, differences in NDVI before and after fungicide application relative to the control could be used to develop a more objective scale for rating fungicide efficacy.

The objectives of this study were to evaluate the value of variety selection and application of a fungicide as part of an economically optimal foliar disease management plan and to assess the potential for using remote sensing measurements such as NDVI as a tool for rating fungicide efficacy.

Experimental Procedures

An experiment was established at the Southwest Research-Extension Center in Garden City, KS, in fall 2015. The design of the experiment was a randomized complete block design with three replications consisting of eleven fungicide application treatments and two wheat varieties: Oakley CL (highly resistant to stripe rust) and TAM 111 (highly susceptible to stripe rust). The experimental treatments are summarized in Table 1. The plots were seeded on September 29, 2015, at a seeding rate of 240 lb/a. The seeding rate was twice the recommended rate for irrigated wheat. This was a result of a problem with the drill, the plots were planted twice at the recommended 120 lb/a. The plots were 7.5-ft × 30-ft. The plots were fertilized with 100 lb of N at green up in March of 2016 and were sprayed with a mixture of 0.4 pint of Starane, 0.375 quart of MCPA, and 0.1 oz of Ally the first week of April for weed control. Fungicides were applied at 15 GPA with a CO₂ backpack sprayer when the flag leaf was fully emerged and the ligule was visible (Feekes, GS 9). A plot combine 5 ft wide was used to harvest 25 ft from each plot for yield. Subsample was collected from each plot to determine the test weight and moisture content. Yield was adjusted to 13% moisture.

The normalized difference vegetation index (NDVI) was collected before and 30 days after the flag leaf fungicide application. A handheld Greenseeker (Ntech Industries, Inc, Ukiah, CA) sensor was used to measure the NDVI. The difference between the before and after NDVI values were used to assess the efficacy of the fungicide.

Results and Discussion

Timely rainfall events and cool temperature during flowering to grain fill (Table 2) could best describe the climatic condition for the 2015-16 wheat growing season in southwest Kansas. Compared to the 30-year average, the studied season was warmer and wetter in the fall months, drier and warmer in the winter months, wetter and warmer in April, drier but warmer in May, but wetter and cooler in June (Table 2).

These conditions, coupled with good management, were conducive for producing the highest wheat yield for many farms in the southwest region. The wet June and July months were the only problem that led to a delay in harvest and lower test weight.

The result of our study showed that fungicide application was a good investment to maximize yield under these very good growing conditions for the susceptible variety. All fungicide treatments increased grain yield over the control for TAM 111 (Table 3), while fungicide seems to have no impact on yield for Oakley CL (Table 3). The Oakley CL lodged 100% in all plots, which significantly affected the yield and test weight. TAM 111 yield was significantly higher from the early spring application of Priaxor, and the combined application of Aproach and Aproach prima, Prosaro, Twinline, and Tebustar. Fall application of Priaxor at 2 and 4 oz rates and Absolute Maxx also increased yield, but were not significantly different from the control (Table 3). Likewise, the change in the NDVI was not a function of foliar fungicide for the variety Oakley CL, but was for TAM 111. The degree of change in NDVI 30 days after application to TAM 111 offers insight on the effectiveness of the fungicide on the disease control. The NDVI in the untreated plot decreased by 0.07 for TAM 111, compared to 0.01 for the same variety treated with foliar fungicides TebuStar and Twinline, 0.02 for Absolute Maxx, Prosaro, and combined application of Aproach and Aproach Prima and 0.03 for Aproach Prima (Table 3). Table 4 shows a negative return on investment (ROI) when fungicide was added to Oakley CL, but showed positive ROI when fungicide was added to the TAM 111. The negative effect of the fungicide on yield and ROI of Oakley CL should not be interpreted as the fungicide hurting yield, but should be seen more as the fungicide not having a positive yield benefit on the resistant variety. Other variables such as lodging were also contributing factors to yield response observed for the Oakley CL variety. The greatest return on investment was achieved when the generic Tebustar was used. Returns were calculated assuming a wheat price of \$3.00 per bushel.

Conclusion

Cool, wet climatic conditions are conducive for high wheat yield, but to maximize yield in these conditions applying a fungicide to a susceptible wheat variety is a good decision. The generic fungicide was one of the top performers. Fungicide application was not a good decision on the more resistant variety Oakley CL. In general, flag leaf application was the most profitable, even though early spring application of Priaxor did show positive return on investment.

Change in NDVI before and after fungicide application was greater for the untreated TAM 111 compared to the fungicide treated and untreated Oakley CL. The result showed that the use of NDVI measurement could be used as a potential tool for accessing fungicide efficacy. However, more work is needed in this area to develop a protocol for using such measurements.

Oakley CL is a better dryland variety than irrigated, and planting at the extremely high population that we did in this study under irrigation might have contributed to the lower yields observed for the variety due to increased lodging. However, the high population provided a good environment for the disease and disease control. Planting Oakley CL at much lower population (approximately 60 lb/a) could possibly reduce lodging and improve the variety performance under irrigation.

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Table 1. Fungicide rate, time and growth stage of application for each treatment

Treatment	Product	Time of application	Product rate	Stage of application	Date applied	Growth stage (GS)
1	Control	NA	NA	NA	NA	NA
2	Priaxor	Fall	2 fl oz	3 Leaf	October 27	Feekes, GS 2
3	Priaxor	Fall	4 fl oz	3 Leaf	October 27	Feekes, GS 2
4	Priaxor	Spring	2 fl oz	Green up	March 21	Feekes, GS 5
5	Priaxor	Fall	2 fl oz	3 Leaf	October 27	Feekes, GS 2
5	Priaxor	Spring	2 fl oz	Jointing	April 7	Feekes, GS 7
6	Aproach	Spring	3 fl oz	Jointing	April 7	Feekes, GS 7
6	Aproach Prima	Spring	6.8 fl oz	Flag leaf	April 25	Feekes, GS 9
7	Aproach Prima	Spring	6.8 fl oz	Flag leaf	April 25	Feekes, GS 9
8	Tebustar	Spring	4 fl oz	Flag leaf	April 25	Feekes, GS 9
9	Prosaro	Spring	6.5 fl oz	Flag leaf	April 25	Feekes, GS 9
10	Absolute Maxx	Spring	5 fl oz	Flag leaf	April 25	Feekes, GS 9
11	Twinline	Spring	9 fl oz	Flag leaf	April 25	Feekes, GS 9

NA- Not applicable.

Table 2. Precipitation and temperature data for the 2015-2016 wheat growing season at the Southwest Research–Extension Center, Garden City, KS

Month	Average temperature		Rainfall (in.)	
	2015-2016	30-year average*	2015-2016	30-year average
September	60	68	0.03	1.42
October	62	55	2.52	1.21
November	71	42	0.85	0.55
December	69	31	1.14	0.59
January	70	30	0.03	0.46
February	53	34	0.27	0.55
March	48	43	0.04	1.31
April	62	52	4.73	1.74
May	66	63	1.05	2.98
June	61	73	3.96	3.12
July	67	78	5.79	2.8
Annual	63	52	20.41	16.73

* The 30-year averages are for the period 1985-2014.

CROPPING AND TILLAGE SYSTEMS

Table 3. Wheat yield, test weight, and normalized difference vegetation index (NDVI) measured before and after fungicide application, and the difference in NDVI based on the fungicide treatments and wheat variety

Treatments	Yield (bu/a)		Test weight (g)		NDVI_B		NDVI_A		NDVI_diff	
	TAM	OAK	TAM	OAK	TAM	OAK	TAM	OAK	TAM	OAK
Check	82	81	55	55	0.901	0.898	0.832	0.856	-0.07	-0.04
Priaxor (F)	86	84	56	55	0.893	0.899	0.821	0.851	-0.07	-0.05
Priaxor (F)	97	73	56	55	0.882	0.878	0.83	0.857	-0.05	-0.02
Priaxor (S)	109	62	56	55	0.883	0.896	0.844	0.856	-0.04	-0.04
Priaxor (F/S)	106	71	57	55	0.866	0.891	0.825	0.855	-0.04	-0.04
Aproach/ Aproach Prima	103	79	57	55	0.88	0.888	0.86	0.862	-0.02	-0.03
Aproach Prima	96	71	56	55	0.894	0.897	0.86	0.857	-0.03	-0.04
Tebustar	112	68	58	54	0.86	0.898	0.846	0.858	-0.01	-0.04
Prosaro	106	78	57	55	0.883	0.901	0.864	0.853	-0.02	-0.05
Absolute Maxx	97	75	57	55	0.887	0.899	0.868	0.853	-0.02	-0.05
Twinline	108	65	57	54.4	0.86	0.895	0.85	0.857	-0.01	-0.04
LSD _{0.05}	21	20	1.33	1.34	0.029	0.02	0.032	0.02	0.03	0.03
CV	14	16	1.79	1.43	2.04	1.42	2.60	1.85		

NDVI_B: measurement taken before fungicide application, NDVI_A: measurement taken 30 days after fungicide application.

LSD = least significant difference.

CV = coefficient of variation.

TAM = TAM 111.

OAK = Oakley CL.

Table 4. Net return on investment for different fungicide treatments on Oakley CL and TAM 111 wheat varieties for the 2015-2016 growing season

Treatments	Cost of fungicide	Cost of application	Total cost of treatment	Yield (bu/a)		Value of production		Added return to treatment		Net return to treatment		Value of production treatment cost	
				TAM	OAK	TAM	OAK	TAM	OAK	TAM	OAK	TAM	OAK
Control	0.00	0.00	0.00	82	81	246.00	242.01	0.00	0.00	0.00	0.00	246.00	242.01
Priaxor (F)	9.60	6.50	16.10	86	84	258.00	251.01	12.00	9.00	(4.10)	(7.10)	241.90	234.91
Priaxor (F)	19.21	6.50	25.71	97	73	291.00	219.99	45.00	(22.02)	19.29	(47.73)	265.29	194.28
Priaxor (S)	9.60	6.50	16.10	109	62	327.00	185.01	81.00	(57.00)	64.90	(73.10)	310.90	168.91
Priaxor (F/S)	19.21	13.00	32.21	106	71	318.00	213.99	72.00	(28.02)	39.79	(60.23)	285.79	181.78
Aproach/Aproach Prima	23.98	13.00	30.48	103	79	309.00	236.01	63.00	(6.00)	26.02	(36.48)	272.02	205.53
Aproach Prima	17.00	6.50	23.50	96	71	288.00	213.00	42.00	(29.01)	18.50	(52.51)	264.50	189.50
Tebustar	1.34	6.50	7.84	112	68	336.00	203.01	90.00	(39.00)	82.16	(46.84)	328.16	195.17
Prosaro	14.79	6.50	21.29	106	78	318.00	234.00	72.00	(8.01)	50.71	(29.30)	296.71	212.71
Absolute Maxx	10.64	6.50	17.14	97	75	291.00	225.99	45.00	(16.02)	27.86	(33.16)	273.86	208.85
Twinline	16.09	6.50	22.59	108	65	324.00	195.99	78.00	(46.02)	55.41	(68.61)	301.41	173.40

(#), Negative return to treatment.

TAM = TAM 111.

OAK = Oakley CL.

Determining Profitable Annual Forage Rotations

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Summary

Producers are interested in growing annual forages, yet western Kansas lacks proven recommended crop rotations such as those for grain crops. Forage production is important to the region's livestock and dairy industries and is becoming increasingly important as irrigation-well capacity declines. Forages require less water than grain crops and may allow for increased cropping intensity and opportunistic cropping. A study was initiated in 2012 at the Southwest Research-Extension Center in Garden City, KS, comparing several 1-, 3-, and 4-year forage rotations with no-tillage and minimum-tillage (min-tillage). Data presented are from 2013 through 2016. Winter triticale yields were increased by tillage. Double-crop forage sorghum yielded 19% less than full-season forage sorghum across years. Oats failed to make a crop in 2013 and do not appear to be as drought tolerant as forage sorghum. Subsequent years will be used to compare forage rotations and profitability.

Introduction

To stabilize crop yields, dryland rotations in the southwest Kansas region have typically included fallow to accumulate moisture in the soil profile. Fallow is relatively inefficient at storing and utilizing precipitation when compared to storage and utilization of precipitation received during the growing season. Fallow periods increase soil erosion and organic matter loss (Blanco and Holman, 2012), representing a large economic cost to dryland producers.

Forage production may be considered to reduce the frequency of fallow in the region, increase precipitation use efficiency, improve soil quality, and increase profitability. Several annual forage rotations were identified as being potentially acceptable by producers, based on recent forage research and grower feedback. This study tests several forage rotations for water use efficiency, forage quality, and profitability.

Annual forage crops are grown for a shorter time and require less moisture than traditional grain crops. Additionally, annual forages in the cropping system might enable cropping intensity and increase opportunistic cropping. "Opportunistic cropping," or "flex cropping," is the planting of a crop when conditions (soil water and precipitation outlook) are favorable and fallowing when unfavorable. Forage producers in the region commonly grow continuous winter triticale (T), winter triticale or summer crop silage, or forage sorghum or sorghum/sudan hay (S), but they lack a proven rotation concept for forages such as that developed for grain crops (e.g. winter wheat-summer crop-fallow). Producers are interested in forage crop rotations that enable increased pest management control options, spread out equipment and labor resources over the year, reduce weather risk, and increase profitability. Growing forages throughout the year greatly reduces the risk of crop failure.

Double crop yields of winter triticale (WT) and forage sorghum (FS) were 70% of annual cropping at Garden City, KS ($P \leq 0.05$), between 2007 and 2010. Double cropping resulted in about 44% more forage yield than annual cropping. However, crop establishment was more challenging and crop growth was highly dependent on growing season precipitation in the double-crop rotation compared to annual cropping. An intermediate cropping intensity of three crops grown in two years or four crops in three years might be a successful crop rotation in western Kansas. Wheat yields following spring annual forages were similar to wheat yield following fallow in a wheat-fallow rotation in non-drought years, but wheat yields were reduced in drought years (Holman et al., 2012). Forages are valuable feedstuff to the cow/calf, stocker, cattle feeding, and dairy industries throughout the region (Hinkle et al., 2010).

Recently in western Kansas, glyphosate-resistant kochia (*Kochia scoparia*) was identified, and several other grasses (e.g. tumble windmill grass and red three-awn) are already tolerant of glyphosate. Although continuous no-tillage was shown to provide better water conservation and crop yields, this result is contingent upon being able to control all weeds with herbicides during fallow. Limited information is available on the effect of occasional tillage on forage yield. Yield of forage crops following tillage might not be affected as much as in grain crops, since forages require less water.

Study Objectives

1. Improve precipitation use and fallow efficiency of dryland cropping systems by reducing fallow using forage crops.
2. Test a number of forage crop rotations and tillage practices (no-tillage and min-tillage) to identify sustainable forage cropping systems.

Experimental Procedures

An annual forage rotation experiment was initiated in 2012 at the Southwest Research-Extension Center in Garden City, Kansas. All crop phases were in place by 2013, with the exception of T-S-O, which had all crop phases in place by 2015. The study design was a randomized complete block design with four replications. Treatment was crop phase (with all crop phases present every year) and tillage (no-tillage or min-tillage). Plots were 30 ft wide and 30 ft long. Crop rotations were one-, three-, and four-year rotations (see treatment list below). Crops grown were winter triticale (\times *Triticosecale* Wittm.), forage sorghum (*Sorghum bicolor* L.), and spring oat (*Avena sativa* L.). Tillage was implemented after spring oat was harvested in treatments 3 and 5, using a single tillage with a sweep plow with 6-ft blades and trailing rolling pickers.

Treatments Included

1. Continuous forage sorghum (no-tillage): (S-S)
2. Year 1: winter triticale/double-crop forage sorghum
Year 2: forage sorghum
Year 3: spring oat (no-tillage): (T/S-S-O no-tillage)
3. Year 1: winter triticale/double-crop forage sorghum
Year 2: forage sorghum
Year 3: spring oat (single tillage after spring oat, min-tillage):
(T/S-S-O min-tillage)
4. Year 1: winter triticale/double-crop forage sorghum
Year 2: forage sorghum
Year 3: forage sorghum
Year 4: spring oat (no-tillage): (T/S-S-S-O no-tillage)
5. Year 1: winter triticale/double-crop forage sorghum
Year 2: forage sorghum
Year 3: forage sorghum
Year 4: spring oat (single tillage after spring oat, min-tillage):
(T/S-S-S-O min-tillage)
6. Year 1: winter triticale
Year 2: forage sorghum
Year 3: spring oat (no-tillage): (T-S-O)

Winter triticale was planted at the end of September, spring oat was planted the beginning of March, and forage sorghum was planted the beginning of June. Crops were harvested at early heading to optimize forage yield and quality (Feekes 10.1) (Large, 1954). Winter triticale was harvested approximately May 15, spring oat was harvested approximately June 1, and forage sorghum was harvested approximately the end of August. Forage yields were determined from a 3- × 30-ft area cut 3 in. high using a small plot Carter forage harvester from each plot. Forage yield and quality (protein, fiber, and digestibility) were measured at each harvest. Gravimetric soil moisture content was measured at planting and harvest to a depth of 6 ft using 1-ft increments. Precipitation storage efficiency (% of precipitation stored during the fallow period) was quantified for each fallow period, and crop water use efficiency (forage yield divided by soil water used plus precipitation) was determined for each crop harvest. Crop yield response to plant available water (PAW) at planting was being used to estimate yield, and develop a yield prediction model based on historical or expected weather conditions. Most producers use a soil probe rather than gravimetric sampling to determine soil moisture status, so soil penetration with a Paul Brown soil probe was used four times per plot at planting to estimate soil water availability. Previous studies found a soil moisture probe provided a practical, easy way to determine soil moisture level and crop yield potential.

Data produced by this study will be used to evaluate the economics of forage rotations and tillage. Production costs and returns will be calculated using typical values for the region. The implications of using forages on crop insurance dynamics and risk exposure is a critical component of a producer's decision-making process and will be evaluated at the conclusion of this study.

Results and Discussion

Rotation Yield

Annual rotation yield was determined by measuring total yield for the rotation and dividing by the number of years in the rotation. This method allows for comparing rotations of different years to each other for annual forage production (Table 1). A very dry year in 2013 resulted in low crop yields and no spring oat yield. In 2013, S-S produced the highest annual yield. In 2014, annual yield was comparable across treatments except for T/S-S-O (no-tillage), which had lower yield than T/S-S-S-O (min-tillage) and was comparable to all other treatments. The crop rotation of T-S-O was not in phase until 2015, so no comparison was made to that rotation until 2015. In 2015, T/S-S-O (no-tillage) yielded less than S-S, but more than T-S-O and comparable to all other treatments. The T-S-O annual yield was less than all other treatments in 2015. In 2016, precipitation primarily occurred June–August, which favored forage sorghum yield. The highest yielding rotation in 2016 was S-S, followed by T/S-S-S-O (no-tillage), and T-S-O yielded the least. Tillage increased the yield of triticale and thus the yield of T/S-S-O was improved with tillage, but yield improvement in the 4-yr rotation was not as evident due to triticale occurring less frequently in the rotation.

Forage yield per crop harvest was determined for each rotation, since planting and harvesting expenses are the major expenses to growing a crop; yield and value per ton are the major income components. Crop rotations with greater yield per harvest are likely to be more profitable compared to rotations with low yield per harvest, since some of the variable and fixed expenses are less. Although oat and triticale yield less than forage sorghum, they are also higher in crude protein and digestibility and are worth more per unit than forage sorghum. A full economic analysis of rotations will be completed at the conclusion of this study. In 2013, S-S had the greatest yield per harvest, and all other rotations had similar yields per harvest (Table 1). In 2014, T/S-S-O (no-tillage) had lower average harvest yields than S-S or T/S-S-S-O (min-tillage) but was similar to T/S-S-O (min-tillage) and T/S-S-S-O (no-tillage). In 2015, S-S had the greatest yield per harvest, and T-S-O had the lowest yield per harvest, which was lower than S-S or T/S-S-S-O (no-tillage), but comparable to the other treatments. In 2016, S-S had the greatest yield per harvest and T-S-O had the least. Sorghum has the greatest yield potential of the three crops investigated, but S-S does not allow for crop diversification, improved weed management, higher forage quality (oats and triticale), or the ability to reduce weather risk by growing a crop during different times of the year.

Crop Yield

Full-season sorghum yields either grown after T/S or S yielded similarly across rotations (Table 2 and Figure 1). Double-crop forage sorghum yielded less than full-season forage sorghum, but varied greatly from year to year based on precipitation during the growing season. Double crop forage sorghum yielded 70% less than full-season in 2013, 7% less in 2014, 12% less in 2015, and 10% less in 2016. Across all years, double-crop (5,970 lb/a) averaged 20% less than full-season forage sorghum (7,410 lb/a). The lower yield of double-crop forage sorghum was due to less available soil moisture at planting. Sorghum yield was not affected by tillage or length of rotation.

Triticale yield was not affected by length of rotation but was affected by tillage. Averaged across years, triticale in min-tillage (3,770 lb/a) yielded 178% more than no-tillage

(2,110 lb/a). The only tillage in this study occurred in the fallow period before triticale and, in this study, benefitted the triticale crop. Other studies and producers have found tillage ahead of a winter wheat crop has minimal impact on yield and can improve weed control, but tillage ahead of grain sorghum often reduced grain yield. For these reasons, tillage was only used ahead of triticale and, similarly to winter wheat, did not reduce yields, but actually increased yields in the first 4 years of this study.

Oats failed to make a crop in 2013 due to drought conditions, and yields were similar among rotations in 2014 (400 lb/a), 2015 (4,900 lb/a), and 2016 (2,300 lb/a). Yields in 2015 were higher than 2013 and 2014 due to favorable spring precipitation. Oat yield was not affected by tillage or rotation.

Soil Water

Plant available water at planting was measured to a 6-foot soil depth, and soil water content varied by year and planting period. On average, soil water was greatest at full-season forage sorghum planting (5.26 inches) and was not different among the other planting periods, ranging from 3.32 to 3.52 inches (Table 2 and Figure 2). Double-crop forage sorghum averaged 3.46 inches of PAW at planting.

Water use efficiency (WUE) was greatest in forage sorghum, with full-season producing 650 lb/a/in. and double-crop producing 601 lb/a/in. Water use efficiency for winter triticale averaged 428 lb/a/in., and oats was 350 lb/a/in. The yield potential and thus water use efficiency was greater with forage sorghum than triticale or oat. However, when precipitation was favorable during a particular growing season, such as oat in 2015, the WUE of oat was comparable to forage sorghum. In years with moisture stress, WUE of double-crop forage sorghum was less than full-season, but in favorable moisture years WUE of double-crop was greater than full-season (Table 2 and Figure 3).

Precipitation storage efficiency (PSE) varied by fallow period and ranged from 8% ahead of winter triticale to 56% for double-cropped forage sorghum. Precipitation storage ahead of full-season forage sorghum was 38% and ahead of oat planting was 42% (Table 2 and Figure 4).

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CROPPING AND TILLAGE SYSTEMS

Table 1. Rotation treatment yields across years between 2013 and 2016

Crop rotation	Total treatment yield (dry matter lb/a)				
	2013	2014	2015	2016	Average [†]
S-S	4,262	7,426	10,244	8,025	7,489
T/S-S-O (no-tillage)	3,451	13,322	25,732	16,067	14,643
T/S-S-O (min-tillage)	4,020	20,130	28,742	18,404	17,824
T/S-S-S-O (no-tillage)	7,702	27,260	38,091	27,320	25,093
T/S-S-S-O (min-tillage)	8,896	30,266	36,394	23,831	24,847
T-S-O [‡]	*	*	18,404	10,060	14,232

	Annualized treatment yield (dry matter lb/a)				
	2013	2014	2015	2016	Average [†]
S-S	4,262	7,426	10,244	8,025	7,489
T/S-S-O (no-tillage)	1,150	4,441	8,577	5,356	4,881
T/S-S-O (min-tillage)	1,340	6,710	9,581	6,135	5941
T/S-S-S-O (no-tillage)	1,926	6,815	9,523	6,830	6,273
T/S-S-S-O (min-tillage)	2,224	7,566	9,099	5,958	6,212
T-S-O	*	*	6,135	3,353	4,744
LSD _{0.05} [§]	1,508	3,038	1,488	801	938

	Yield per harvest (dry matter lb/a)				
	2013	2014	2015	2016	Average [†]
S-S	4,262	7,426	10,244	8,025	7,489
T/S-S-O (no-tillage)	863	3,331	6,433	4,017	3,661
T/S-S-O (min-tillage)	1,005	5,032	7,185	4,601	4,456
T/S-S-S-O (no-tillage)	1,540	5,452	7,618	5,464	5,019
T/S-S-S-O (min-tillage)	1,779	6,053	12,131	4,766	6,183
T-S-O	*	*	3,681	3,353	3,517
LSD _{0.05} [§]	1,323	2,566	1,331	693	791

[†] Average of years 2013-2016.

[‡] T-S-O treatment started in 2015.

[§] Forage sorghum (S), Continuous forage sorghum (S-S), Winter triticale/double crop forage sorghum (T/S), and spring oat (O).

Table 2. Forage dry matter yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) for all crop rotations and phases between 2013 and 2017 at the Southwest Research-Experiment Station near Garden City, KS

Rotation	Treatment	Crop	2013							
			Dry matter yield		Plant available water		WUE		PSE	
			lb/a	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	lb/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
s-S [†]	1	Sorghum	4,262.00	a [‡]	3.55	ab	591.60	a	0.38	ac
t/S-s-o (no-tillage)	2	Sorghum	1,385.40	cd	1.14	dg	319.00	bd	-0.19	bc
t/s-S-o (no-tillage)	2	Sorghum	2,612.70	bc	1.70	cg	356.30	bd	0.09	ac
t/S-s-o (min-tillage)	3	Sorghum	972.00	de	0.93	fg	188.80	ef	0.71	a
t/s-S-o (min-tillage)	3	Sorghum	3,875.90	ab	3.08	ac	523.50	ab	0.17	ac
t/S-s-s-o (no-tillage)	4	Sorghum	1,199.30	de	0.39	g	273.20	cd	0.48	ac
t/s-S-s-o (no-tillage)	4	Sorghum	3,086.50	ab	2.86	ad	401.40	ac	0.26	ac
t/s-s-S-o (no-tillage)	4	Sorghum	3,955.00	a	2.55	bf	484.50	ab	0.14	ac
t/S-s-s-o (min-tillage)	5	Sorghum	9,613.30	de	1.11	eg	209.10	ce	-0.35	c
t/s-S-s-o (min-tillage)	5	Sorghum	4,220.60	a	3.25	ac	602.20	a	0.16	ac
t/s-s-S-o (min-tillage)	5	Sorghum	3,989.50	a	2.89	ac	410.50	ac	0.25	ac
t-S-o	6	Sorghum	* [§]	*	*	*	*	*		
T/s-s-o (no-tillage)	2	Triticale	142.10	de	1.56	cg	31.50	ef	-0.21	bc
T/s-s-o (min-tillage)	3	Triticale	188.40	de	1.10	eg	40.70	ef	0.02	ac
T/s-s-s-o (no-tillage)	4	Triticale	310.70	de	0.81	g	61.80	ef	-0.03	ac
T/s-s-s-o (min-tillage)	5	Triticale	722.20	de	1.55	cg	163.20	ef	0.00	ac
T-s-o	6	Triticale	*	*	*	*	*	*		
t/s-s-O (no-tillage)	2	Oat	0.00	e	2.68	be	0.00	f	-0.06	ac
t/s-s-O (min-tillage)	3	Oat	0.00	e	3.16	ac	0.00	f	0.11	ac
t/s-s-s-O (no-tillage)	4	Oat	0.00	e	3.46	ab	0.00	f	0.48	ac
t/s-s-s-O (min-tillage)	5	Oat	0.00	e	4.49	a	0.00	f	0.61	ab
t-s-O	6	Oat	*	*	*	*	*	*	*	*
LSD _{0.05} [§]			1,321.70		1.73		206.83		0.83	

continued

Table 2. Forage dry matter yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) for all crop rotations and phases between 2013 and 2017 at the Southwest Research-Experiment Station near Garden City, KS

Rotation	Treatment	Crop	2014							
			Dry matter yield		Plant available water		WUE		PSE	
			lb/a	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	lb/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
s-S [†]	1	Sorghum	7,426.00	ac	4.19	cf	679.20	ac	0.11	eg
t/S-s-o (no-tillage)	2	Sorghum	5,341.00	cd	2.22	f	536.20	bd	0.58	ac
t/s-S-o (no-tillage)	2	Sorghum	6,629.00	ac	3.67	df	600.70	ac	0.08	fg
t/S-s-o (min-tillage)	3	Sorghum	7,016.00	ac	3.58	df	666.60	ac	0.60	ac
t/s-S-o (min-tillage)	3	Sorghum	7,577.00	ac	3.75	df	794.50	ab	0.24	cg
t/S-s-s-o (no-tillage)	4	Sorghum	6,505.00	ac	3.60	df	624.40	ac	0.82	a
t/s-S-s-o (no-tillage)	4	Sorghum	8,415.00	ab	2.91	ef	855.00	a	-0.02	g
t/s-s-S-o (no-tillage)	4	Sorghum	9,107.00	a	4.41	ce	802.00	ab	0.37	bg
t/S-s-s-o (min-tillage)	5	Sorghum	9,122.00	a	3.93	cf	862.80	a	0.72	ab
t/s-S-s-o (min-tillage)	5	Sorghum	7,458.00	ac	4.32	ce	669.10	ac	0.17	eg
t/s-s-S-o (min-tillage)	5	Sorghum	5,894.00	bc	5.52	bd	494.50	cd	0.34	bg
t-S-o	6	Sorghum	*	*	*	*	*	*	*	*
T/s-s-o (no-tillage)	2	Triticale	695.00	e	3.21	ef	121.00	de	0.20	cg
T/s-s-o (min-tillage)	3	Triticale	4,650.00	cd	6.60	b	609.60	ac	0.58	ac
T/s-s-s-o (no-tillage)	4	Triticale	2,449.00	de	5.87	bc	301.30	de	0.53	ad
T/s-s-s-o (min-tillage)	5	Triticale	7,013.00	ac	8.92	a	724.10	ac	0.82	a
T-s-o	6	Triticale	*	*	*	*	*	*	*	*
t/s-s-O (no-tillage)	2	Oat	657.00	e	2.96	ef	80.20	e	0.51	ae
t/s-s-O (min-tillage)	3	Oat	887.00	e	3.79	df	126.40	e	0.43	af
t/s-s-s-O (no-tillage)	4	Oat	784.00	e	3.13	ef	101.50	e	0.57	ad
t/s-s-s-O (min-tillage)	5	Oat	779.00	e	4.07	cf	91.20	e	0.58	ac
t-s-O	6	Oat	*	*	*	*	*	*	*	*
LSD _{0.05} [§]			3,067.40		1.98		292.24		0.40	

continued

Table 2. Forage dry matter yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) for all crop rotations and phases between 2013 and 2017 at the Southwest Research-Experiment Station near Garden City, KS

Rotation	Treatment	Crop	2015							
			Dry matter yield		Plant available water		WUE		PSE	
			lb/a	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	lb/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
s-S [†]	1	Sorghum	10,244.00	ab	5.84	be	1,009.00	a	0.42	bf
t/S-s-o (no-tillage)	2	Sorghum	8,665.00	bc	4.61	dh	886.90	ab	0.60	ad
t/s-S-o (no-tillage)	2	Sorghum	9,125.00	bc	4.66	dg	894.60	ab	0.38	cg
t/S-s-o (min-tillage)	3	Sorghum	9,910.00	ac	6.29	bd	876.80	ac	0.91	a
t/s-S-o (min-tillage)	3	Sorghum	10,380.00	ab	7.08	ab	876.20	ac	0.55	be
t/S-s-s-o (no-tillage)	4	Sorghum	8,988.00	bc	5.27	bf	929.90	ab	0.72	ab
t/s-S-s-o (no-tillage)	4	Sorghum	11,216.00	a	6.53	ac	1,004.70	a	0.48	bf
t/s-s-S-o (no-tillage)	4	Sorghum	9,976.00	ac	5.79	be	908.70	ab	0.45	bf
t/S-s-s-o (min-tillage)	5	Sorghum	8,091.00	c	5.21	cf	767.50	ae	0.70	ac
t/s-S-s-o (min-tillage)	5	Sorghum	11,229.00	a	8.22	a	866.40	ac	0.66	ad
t/s-s-S-o (min-tillage)	5	Sorghum	9,300.00	ac	6.19	be	821.10	ad	0.48	bf
t-S-o	6	Sorghum	9,105.00	bc	6.26	bd	780.90	ae	0.23	eh
T/s-s-o (no-tillage)	2	Triticale	2,870.00	e	2.28	j	584.40	de	-0.02	i
T/s-s-o (min-tillage)	3	Triticale	4,072.00	de	4.37	ei	605.30	ce	0.00	hi
T/s-s-s-o (no-tillage)	4	Triticale	2,738.00	e	2.76	hj	516.50	e	-0.20	i
T/s-s-s-o (min-tillage)	5	Triticale	3,356.00	de	3.35	gj	564.40	de	-0.05	hi
T-s-o	6	Triticale	4,008.00	de	3.09	gj	734.40	ae	-0.20	i
t/s-s-O (no-tillage)	2	Oat	5,072.00	d	2.22	j	939.00	ab	0.23	eh
t/s-s-O (min-tillage)	3	Oat	4,380.00	de	2.67	ij	785.80	ae	0.09	gi
t/s-s-s-O (no-tillage)	4	Oat	5,174.00	d	2.49	j	942.00	ab	0.21	fh
t/s-s-s-O (min-tillage)	5	Oat	4,418.00	de	3.54	fj	666.90	be	0.36	dg
t-s-O	6	Oat	5,291.00	d	3.05	gj	825.50	ad	0.20	fh
LSD _{0.05} [§]			2,050.30		1.85		281.50		0.33	

continued

Table 2. Forage dry matter yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) for all crop rotations and phases between 2013 and 2017 at the Southwest Research-Experiment Station near Garden City, KS

Rotation	Treatment	Crop	2016							
			Dry matter yield		Plant available water		WUE		PSE	
			lb/a	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	lb/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
s-S [†]	1	Sorghum	8,024.90	a	6.88	ad	568.40	bc	0.43	cf
t/S-s-o (no-tillage)	2	Sorghum	7,065.40	ab	3.27	fh	861.80	a	0.74	ab
t/s-S-o (no-tillage)	2	Sorghum	7,145.40	ab	6.58	ad	463.10	bf	0.48	be
t/S-s-o (min-tillage)	3	Sorghum	7,674.10	a	5.22	bf	613.70	b	0.87	a
t/s-S-o (min-tillage)	3	Sorghum	7,766.70	a	7.03	ac	497.50	be	0.48	be
t/S-s-s-o (no-tillage)	4	Sorghum	6,633.60	ab	3.87	eg	561.60	bc	0.60	ac
t/s-S-s-o (no-tillage)	4	Sorghum	7,678.70	a	6.28	ae	549.10	bc	0.36	cf
t/s-s-S-o (no-tillage)	4	Sorghum	7,644.80	a	7.56	ab	565.10	bc	0.47	be
t/S-s-s-o (min-tillage)	5	Sorghum	6,053.40	bc	4.71	cg	446.40	bf	0.51	bd
t/s-S-s-o (min-tillage)	5	Sorghum	7,701.30	a	7.20	ab	454.60	bf	0.50	bd
t/s-s-S-o (min-tillage)	5	Sorghum	7,599.70	a	8.55	a	518.00	bd	0.57	bc
t-S-o	6	Sorghum	7,695.90	a	6.47	ad	498.60	be	0.18	fg
T/s-s-o (no-tillage)	2	Triticale	3,301.50	gef	1.32	h	370.90	cg	-0.19	h
T/s-s-o (min-tillage)	3	Triticale	5,131.10	cd	4.03	eg	509.70	bd	0.19	eg
T/s-s-s-o (no-tillage)	4	Triticale	4,411.20	de	3.04	fh	456.60	bf	0.04	gh
T/s-s-s-o (min-tillage)	5	Triticale	5,043.80	cd	4.58	dg	515.90	bd	0.27	dg
T-s-o	6	Triticale	4,226.70	def	2.52	gh	457.60	bf	0.03	gh
t/s-s-O (no-tillage)	2	Oat	1,856.40	h	3.60	fh	199.00	g	0.75	ab
t/s-s-O (min-tillage)	3	Oat	2,963.50	fgh	4.00	eg	337.30	cg	0.59	ac
t/s-s-s-O (no-tillage)	4	Oat	2,061.00	gh	3.31	fh	247.00	fg	0.54	bd
t/s-s-s-O (min-tillage)	5	Oat	2,477.10	gh	3.76	fg	291.40	dg	0.64	ac
t-s-O	6	Oat	2,364.10	gh	3.53	fh	262.90	eg	0.72	a
LSD _{0.05} [§]			1,392.30		2.43		242.28		0.29	

continued

Table 2. Forage dry matter yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) for all crop rotations and phases between 2013 and 2017 at the Southwest Research-Experiment Station near Garden City, KS

Rotation	Treatment	Crop	Average							
			Dry matter yield		Plant available water		WUE		PSE	
			lb/a	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	lb/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
s-S [†]	1	Sorghum	7,489.23	ab	5.11	ae	712.05	a	0.33	cf
t/S-s-o (no-tillage)	2	Sorghum	5,614.20	d	2.81	ji	650.98	ab	0.43	bd
t/s-S-o (no-tillage)	2	Sorghum	6,378.03	bd	4.15	dh	578.68	ad	0.26	df
t/S-s-o (min-tillage)	3	Sorghum	6,393.03	cd	4.00	ei	586.48	ad	0.77	a
t/s-S-o (min-tillage)	3	Sorghum	7,399.90	ac	5.23	ad	672.93	ab	0.36	ce
t/S-s-s-o (no-tillage)	4	Sorghum	5,831.48	d	3.28	gj	597.28	ad	0.66	ab
t/s-S-s-o (no-tillage)	4	Sorghum	7,599.05	ab	4.64	be	702.55	a	0.27	df
t/s-s-S-o (no-tillage)	4	Sorghum	7,670.70	ac	5.08	ae	690.08	ab	0.36	ce
t/S-s-s-o (min-tillage)	5	Sorghum	6,056.93	d	3.74	fi	571.45	ad	0.40	be
t/s-S-s-o (min-tillage)	5	Sorghum	7,652.23	ac	5.75	ac	648.08	ac	0.37	ce
t/s-s-S-o (min-tillage)	5	Sorghum	6,695.80	bd	5.79	ab	561.03	ad	0.41	be
t-S-o	6	Sorghum	8,400.45	a	6.36	a	639.75	ac	0.70	ef
T/s-s-o (no-tillage)	2	Triticale	1,752.15	g	2.09	j	276.95	g	-0.05	g
T/s-s-o (min-tillage)	3	Triticale	3,510.38	ef	4.03	dh	441.33	df	0.20	ef
T/s-s-s-o (no-tillage)	4	Triticale	2,477.23	fg	3.12	gj	334.05	eg	0.08	fg
T/s-s-s-o (min-tillage)	5	Triticale	4,033.75	e	4.60	cg	491.90	ce	0.26	df
T-s-o	6	Triticale	3,200.00	e	2.80	ji	596.00	ad	-0.09	g
t/s-s-O (no-tillage)	2	Oat	1,896.35	g	2.86	ji	304.55	fg	0.36	ce
t/s-s-O (min-tillage)	3	Oat	2,057.63	g	3.40	gj	312.38	fg	0.30	cf
t/s-s-s-O (no-tillage)	4	Oat	2,004.75	g	3.09	hj	322.63	fg	0.45	be
t/s-s-s-O (min-tillage)	5	Oat	1,918.53	g	3.96	ei	262.38	g	0.55	ac
t-s-O	6	Oat	2,250.00	ef	3.29	gj	544.20	bd	0.46	be
LSD _{0.05} [§]			1,293.90		1.33		158.54		0.26	

[†] Crop within rotation is identified by capitalization.

[‡] S is forage sorghum, T is triticale, and O is oat.

[§] T-S-O treatment started in 2015.

¶ Means in columns followed by different letters are statistically different at $P \leq 0.05$.

CROPPING AND TILLAGE SYSTEMS

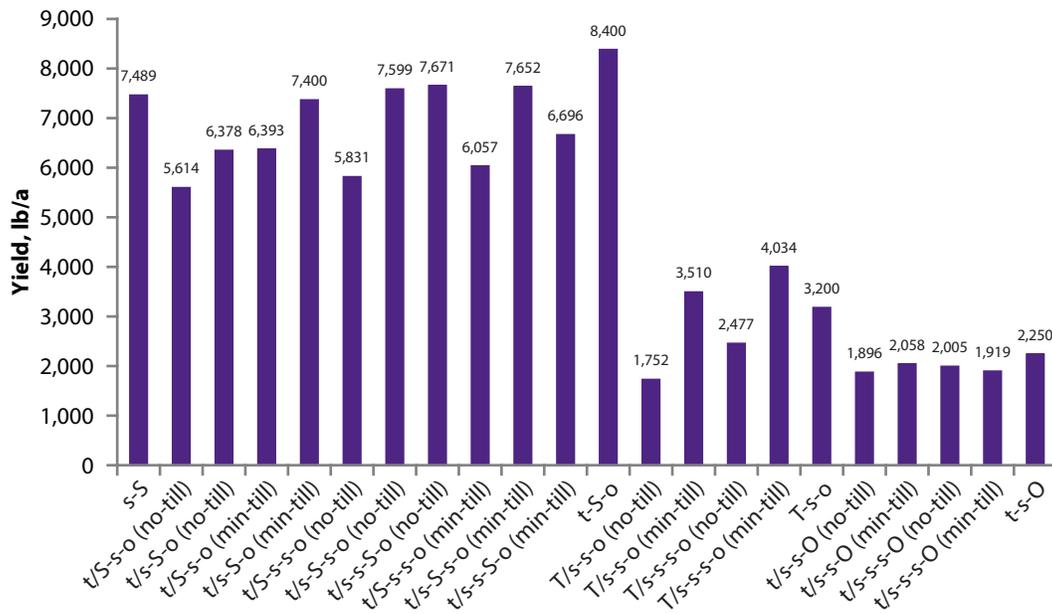


Figure 1. Forage dry-matter yield for all crop rotations and phases averaged across years from 2013 to 2016. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

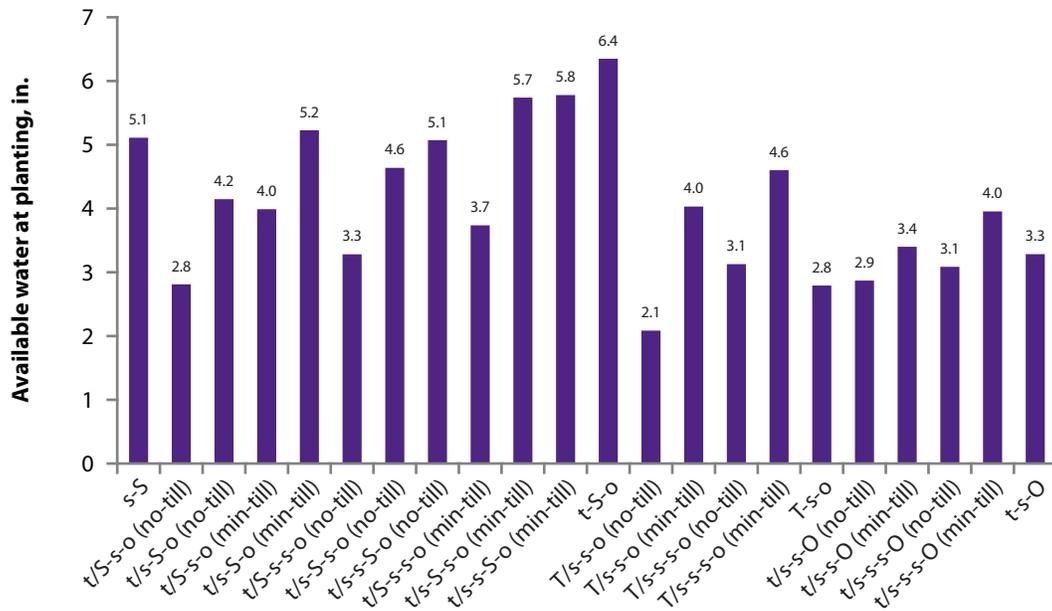


Figure 2. Plant available water in a six-foot soil profile at planting for all crop rotations and phases averaged across years from 2013 to 2016. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

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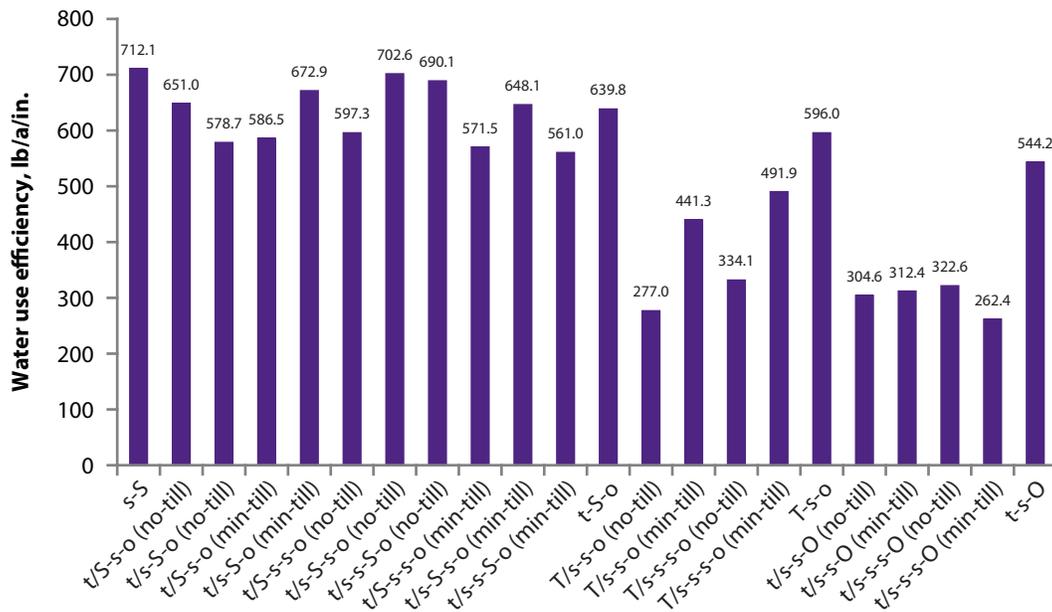


Figure 3. Water use efficiency (WUE) [forage dry matter yield/((ending-beginning soil water content) + growing season precipitation)] for all crop rotations and phases averaged across years from 2013 to 2016. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

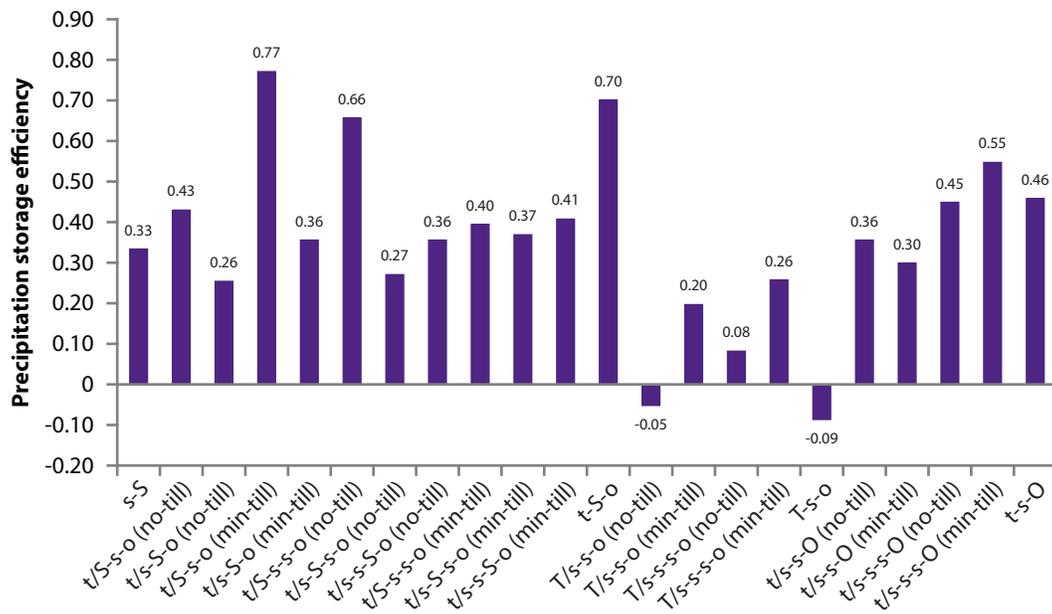


Figure 4. Precipitation storage efficiency (PSE) [precipitation/(ending-beginning soil water content)] for the fallow period preceding the crop for all crop rotations and phases averaged across years from 2013 to 2016. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

Integrated Grain and Forage Rotations

J. Holman, A. Obour, 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. If 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 to plant double-crop forage sorghum to increase the chance of success. Importantly, 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 no-tillage wheat-sorghum-fallow rotation is stored. The remaining 75 to 70% 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 by using forage crops in the rotation. This study evaluated integrated grain/forage rotations compared to traditional grain-only crop rotations.

Experimental Procedures

A study beginning in 2013 evaluated various integrated grain and forage rotations compared to a no-tillage wheat-grain sorghum-fallow rotation. All phases of the rotation were present every year and in-phase by 2014. A total of 11 crop rotations were evaluated. Beginning in 2013, the wheat/forage sorghum-grain sorghum-oat rotation was replaced with a wheat/forage sorghum-grain sorghum-fallow rotation since the no-fallow rotation tended to be too intensively cropped during dry years. 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 in 2014 or 2015.

Each year, winter triticale was planted approximately October 1. 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. 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- × 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- × 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-ft 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 (GAC 2100, Dickey-John). Seed weight was determined from a 1,000-seed count using a seed counter computer (801, Seedbuco). 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 bu/a. 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%. Dry fall conditions and rabbit feeding killed the wheat crop in 2016 and there was no yield that year.

Grain Sorghum

Grain sorghum yield was highly correlated with plant available moisture at planting, which explained 44% of the variability in grain yield (Figure 1). Approximately 7.8 bushels were grown for every acre-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 61% in 2014, 38% in 2015, and 20% in 2016. 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 only.

Forage Sorghum

Forage sorghum yield was also correlated with plant available moisture at planting, but not as much as grain sorghum. Plant available moisture at planting explained approximately 36.5% of the variability in forage yield (Figure 2). Approximately 530 lb of forage was grown for every inch of plant available water (PAW) at planting.

Forage sorghum yields were not different across treatments in 2014, except double crop FS in winter wheat/forage sorghum-forage sorghum-spring oat (ww/FS-fs-o) yielded 2,200 lb/a less than full-season forage sorghum in the same rotation of winter wheat/forage sorghum-forage sorghum-spring oat (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 1.0 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) than 2014, which helped increase wheat yields but also resulted in comparatively less moisture at planting time of 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). In 2016 moisture conditions were favorable during the growing season (June–August), resulting in good forage yields across all treatments. There were 0.8 inches more PAW at planting of the full-season compared to double-crop forage sorghum. Double crop yields were reduced on average 43% compared to full-season forage sorghum (3,900 vs. 6,900 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 planted after double-crop forage sorghum had an average of 3 inches less soil moisture compared to forage sorghum planted after wheat with a fallow period between crops. In dry years this difference in plant available soil water may result in yield differences, but it did not affect yield in this study. The yield plateau of a forage crop is lower than a grain crop, which might explain why there was no yield penalty for second-year forage sorghum grown after either fallow or double-crop forage sorghum. These results suggest that as long as the benefits of growing a double-crop forage sorghum crop exceeded costs, an extra forage sorghum crop could be grown in the rotation. A partial enterprise analysis of this phase of the rotation only indicated double-crop forage sorghum yield needs to be 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/a.

Spring Oat

Spring oat yield was not affected by rotation treatment and yielded 564 lb/a in 2014, 1,927 lb/a in 2015, and 1,877 lb/a in 2016.

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. Oats were grown in place of fallow those years that indicated favorable moisture conditions. Wheat yields were reduced when oats were grown in place of fallow. Previous research found wheat yields needed to be greater than 50 bushels for wheat yields not to be reduced by growing oats in place of fallow. Wheat yield potential was only 6 bu/a in 2014, 15 bu/a in 2015, and failed to make grain in 2016.

Grain sorghum yield was more sensitive to moisture stress than forage sorghum. Growing a double-crop forage sorghum after wheat reduced grain yield 20 to 60% 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. Moisture conditions affected double-crop forage sorghum yields 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.

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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-o
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
12 [†]	Wheat/forage sorghum-grain sorghum-fallow	ww/fs-gs-fl

[†] Beginning in 2013, treatment 12 replaced treatment 5.

Table 2. Winter wheat yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City, KS, from 2014 to 2016 and average across years. There was no grain yield in 2016.

		2014							
		Yield		Plant available water		WUE		PSE	
Rotation [†]	Crop	bu/a	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	bu/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
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-o	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	

continued

CROPPING AND TILLAGE SYSTEMS

Table 2. Winter wheat yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City, KS, from 2014 to 2016 and average across years. There was no grain yield in 2016.

		2015							
Rotation [†]	Crop	Yield		Plant available water		WUE		PSE	
		bu/a	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	bu/a	<i>P</i> < 0.05	%	<i>P</i> < 0.05
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	
		Average							
	Crop	Yield		Plant available water		WUE		PSE	
		bu/a		Inches in 6 ft depth		bu/a		%	
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 are for the abbreviated crop phase in large caps.

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

[¶] Flex-fallow was planted in 2012, 2013, and 2016.

Table 3. Grain sorghum yield, plant available water at planting (PAW), water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City, KS, from 2014 to 2016 and average across years. There was no grain yield in 2016.

		2014											
Rotation [†]	Crop	Yield		Test weight		Seed weight		PAW		WUE		PSE	
		bu/a	<i>P</i> < 0.05	lb/bu	<i>P</i> < 0.05	g/1,000 seed	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	bu/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
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
ww/fs-GS-fx	GS	17.8	b	57.7	a	21.1	a	4.2	a	1.07	b	0.31	a
ww/fs-GS-fl	GS	---	---	---	---	---	---	---	---	---	---	---	---
LSD		23.2		2.2		2.0		3.4		1.26		0.28	

		2015											
Rotation [†]	Crop	Yield		Test weight		Seed weight		PAW		WUE		PSE	
		lb/a	<i>P</i> < 0.05	lb/bu	<i>P</i> < 0.05	g/1,000 seed	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	lb/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
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
ww/fs-GS-fx	GS	59.4	c	59.8	b	21.6	b	6.0	b	3.68	b	0.25	a
ww/fs-GS-fl	GS	---	---	---	---	---	---	---	---	---	---	---	---
LSD		19.2		1.0		3.5		2.4		1.20		0.10	

continued

Table 3. Grain sorghum yield, plant available water at planting (PAW), water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City, KS, from 2014 to 2016 and average across years. There was no grain yield in 2016.

		2016											
		Yield		Test weight		Seed weight		PAW		WUE		PSE	
Rotation [†] *	Crop	lb/a	<i>P</i> < 0.05	lb/bu	<i>P</i> < 0.05	g/1,000 seed	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	lb/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
ww-GS-fx [‡]	GS	58.4	ab [§]	58.8	a	58.8	a	7.2	a	3.19	a	0.22	a
ww-GS-fl	GS	64.6	a	59.2	a	59.2	a	7.4	a	3.47	a	0.21	a
ww/fs-GS-o [†]	GS	---	---	---	---	---	---	---	---	---	---	---	---
ww-GS-o	GS	55.7	ab	59.6	a	59.6	a	6.2	a	3.11	a	0.18	a
ww/fs-GS-fx	GS	51.0	ab	59.1	a	59.1	a	3.9	b	3.08	a	0.22	a
ww/fs-GS-fl	GS	43.7	b	58.6	a	58.6	a	3.2	b	2.64	a	0.19	a
LSD		17.7		2.4		2.4		1.5		1.05		0.13	
		Average											
		Yield		Test weight		Seed weight		PAW				PSE	
		lb/a		lb/bu		g/1,000 seed		Inches in 6 ft depth	lb/a inch ⁻¹			%	
ww-GS-fx [‡]	GS	67.4		59.2		35.48		6.3	3.89			0.24	
ww-GS-fl	GS	74.4		59.8		36.29		7.0	4.12			0.25	
ww/fs-GS-o [†]	GS	38.6		58.7		21.32		5.1	2.38			0.28	
ww-GS-o	GS	59.7		59.2		36.02		6.9	3.37			0.29	
ww/fs-GS-fx	GS	42.7		58.8		33.89		4.7	2.61			0.26	
ww/fs-GS-fl	GS	43.7		58.6		58.55		3.2	2.64			0.19	
LSD													

[†] WW is winter wheat, fs is forage sorghum, GS is grain sorghum, and o is spring oat.

[‡] Beginning in 2013, treatment 12 replaced treatment 5.

* Data are for the abbreviated crop phase in large caps.

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

[¶] Flex-fallow was planted in 2012, 2013, and 2016.

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

Rotation [†]	Crop	2014							
		Yield		PAW		WUE		PSE	
		lb/a	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	lb/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
ww/FS-fs-o	FS	4705	a ^s	1.3	c	565.85	a	0.60	ab
ww/fs-FS-o	FS	2490	b	2.1	bc	179.85	b	0.20	b
ww-FS-sg	FS	3305	ab	5.7	a	201.15	b	*	*
ww/FS-gs-o	FS	3964	ab	0.6	c	452.25	a	0.75	a
ww-FS-fx(t)	FS	3917	ab	4.3	ab	257.23	b	*	*
ww-FS-fx [‡]	FS	3531	ab	4.0	ab	225.11	b	0.45	ab
ww-FS-fl	FS	4093	ab	4.7	a	268.19	b	0.30	ab
ww/FS-fs-fx	FS	4705	a	1.3	c	565.85	a	0.60	ab
ww/fs-FS-fx	FS	2490	b	2.1	bc	179.85	b	0.20	b
ww/FS-gs-fx	FS	3964	ab	0.6	c	452.25	a	0.75	a
ww/FS-fs-fl	FS	4705	a	1.3	c	565.85	a	0.60	ab
ww/fs-FS-fl	FS	2490	b	2.1	bc	179.85	b	0.20	b
ww/FS-gs-fl	FS	3964	ab	0.6	c	452.25	a	0.75	a
LSD		2033		2.3		174.45		0.54	

continued

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

Rotation [†]	Crop	2015							
		Yield		PAW		WUE		PSE	
		lb/a	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	lb/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
ww/FS-fs-o	FS	2320	b	1.7	b	208.93	b	*	*
ww/fs-FS-o	FS	7750	a	5.6	a	567.53	a	0.18	b
ww-FS-sg	FS	7948	a	8.3	a	487.55	a	0.38	a
ww/FS-gs-o	FS	2497	b	1.6	b	223.25	b	*	*
ww-FS-fx(t)	FS	7103	a	7.8	a	443.35	a	0.35	ab
ww-FS-fx	FS	8697	a	7.4	a	533.00	a	0.20	ab
ww-FS-fl	FS	8333	a	6.9	a	537.00	a	0.28	ab
ww/FS-fs-fx	FS	2320	b	1.7	b	208.93	b	*	*
ww/fs-FS-fx	FS	7750	a	5.6	a	567.53	a	0.18	b
ww/FS-gs-fx	FS	2497	b	1.6	b	223.25	b	*	*
ww/FS-fs-fl	FS	---	---	---	---	---	---	---	---
ww/fs-FS-fl	FS	---	---	---	---	---	---	---	---
ww/FS-gs-fl	FS	---	---	---	---	---	---	---	---
LSD		2270		3.1		161.09		0.18	

continued

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

Rotation [†]	Crop	2016							
		Yield		PAW		WUE		PSE	
		lb/a	<i>P</i> < 0.05	Inches in 6 ft depth	<i>P</i> < 0.05	lb/a inch ⁻¹	<i>P</i> < 0.05	%	<i>P</i> < 0.05
ww/FS-fs-o	FS	---	---	---	---	---	---	---	---
ww/fs-FS-o	FS	---	---	---	---	---	---	---	---
ww-FS-sg	FS	6450	a	5.4	bc	422.34	ac	0.12	b
ww/FS-gs-o	FS	---	---	---	---	---	---	---	---
ww-FS-fx(t)	FS	6793	a	5.1	bc	431.63	ac	0.16	b
ww-FS-fx	FS	7223	a	8.2	a	469.17	a	0.21	ab
ww-FS-fl	FS	7018	a	6.8	ab	437.54	ab	0.23	ab
ww/FS-fs-fx	FS	3233	c	6.0	ac	207.93	e	*	*
ww/fs-FS-fx	FS	6726	a	4.4	bc	433.92	ac	0.35	a
ww/FS-gs-fx	FS	4090	bc	3.5	c	318.31	ce	*	*
ww/FS-fs-fl	FS	3563	bc	5.2	bc	255.72	de	*	*
ww/fs-FS-fl	FS	6905	a	3.4	c	492.03	a	0.25	ab
ww/FS-gs-fl	FS	4816	b	4.4	bc	349.45	bd	*	*
LSD		1512		2.9		119.22			

continued

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

Rotation [†]	Crop	Average			
		Yield lb/a	PAW Inches in 6 ft depth	WUE lb/a inch ⁻¹	PSE %
ww/FS-fs-o	FS	3513	1.5	387.39	0.60
ww/fs-FS-o	FS	5120	3.8	373.69	0.19
ww-FS-sg	FS	5901	6.4	370.35	0.25
ww/FS-gs-o	FS	3230	1.1	337.75	0.75
ww-FS-fx(‡)	FS	5938	5.7	377.40	0.25
ww-FS-fx	FS	6484	6.5	409.09	0.29
ww-FS-fl	FS	6481	6.1	414.24	0.27
ww/FS-fs-fx	FS	3420	3.0	327.57	0.60
ww/fs-FS-fx	FS	5655	4.0	393.77	0.24
ww/FS-gs-fx	FS	3517	1.9	331.27	0.75
ww/FS-fs-fl	FS	4134	3.2	410.79	0.60
ww/fs-FS-fl	FS	4698	2.7	335.94	0.22
ww/FS-gs-fl	FS	4390	2.5	400.85	0.75
LSD					

[†] ww is winter wheat , FS is forage sorghum, gs is grain sorghum, and o is spring oat.

[‡] Beginning in 2013, treatment 12 replaced treatment 5.

[§] Means in columns followed by different letters are statistically different at $P \leq 0.05$.

[¶] Flex-fallow was planted in 2012, 2013, and 2016.

CROPPING AND TILLAGE SYSTEMS

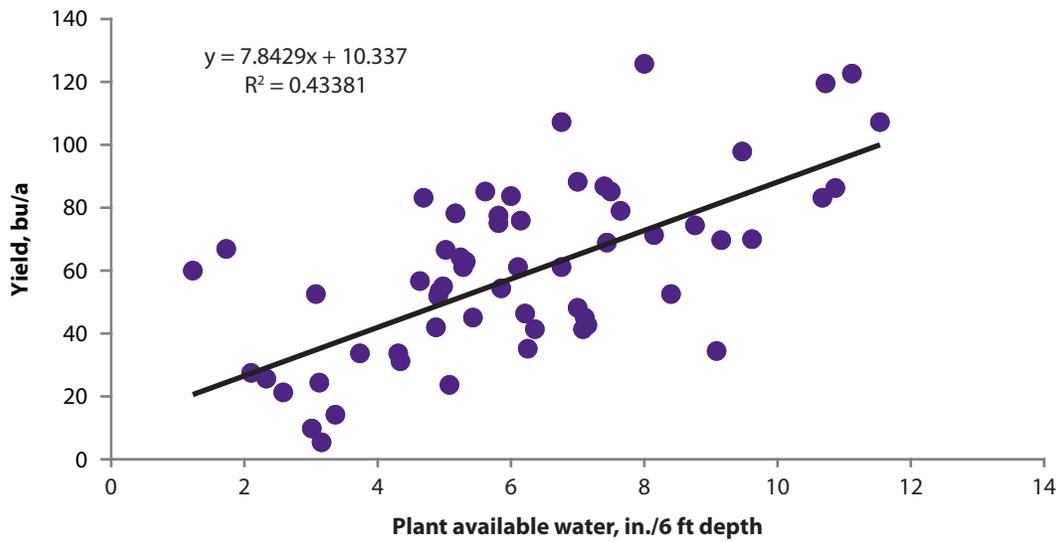


Figure 1. Grain sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2016.

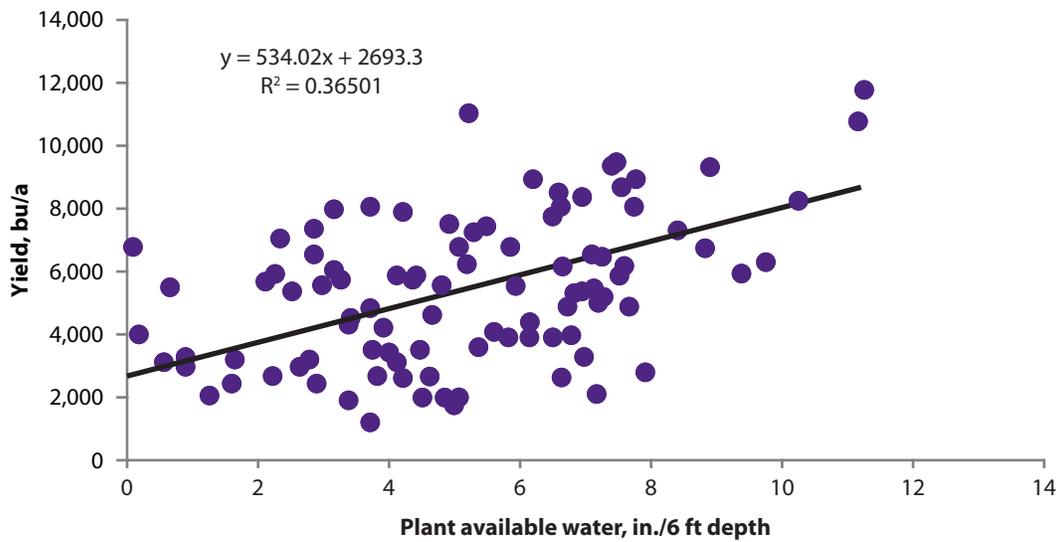


Figure 2. Forage sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2016.

Estimating Annual Forage Yields with Plant Available Water and Growing Season Precipitation

J. Holman, A. Obour, I. Kisekka, A. Schlegel, T. Roberts, and S. Maxwell

Summary

Forage production is important for western Kansas region's livestock and dairy industries and has become increasingly important as irrigation-well capacity declines. Forages require less water than grain crops and may allow for increased cropping intensity and opportunistic cropping. Being able to estimate forage production is important for determining forage availability versus forage needs. Data from several studies were used to quantify annual forage yield response to plant available water (PAW) at planting and growing season precipitation (GSP). In addition, water use efficiency was quantified. Forages evaluated included winter triticale, spring triticale, and forage sorghum.

Introduction

Annual forage crops are grown for a shorter time and require less moisture than traditional grain crops. Including annual forages in the cropping system might enable increased cropping intensity and opportunistic cropping. "Opportunistic cropping," or "flex cropping," is the planting of a crop when conditions (soil water and precipitation outlook) are favorable and fallowing when unfavorable. Forage producers in the region commonly grow winter triticale, forage sorghum, or spring triticale/oat. Producers are interested in forage crop rotations that enable increased pest management control options, spread out equipment and labor resources over the year, reduce weather risk, and increase profitability. Growing forages throughout the year greatly reduces the risk of crop failure. Understanding the yield relationship to PAW and GSP would help producers better meet their forage needs. Therefore, the objectives of this study were to quantify yield relationship of winter, spring, and summer forages with PAW and GSP. The study will quantify water use efficiency of winter, spring, and summer forages.

Experimental Procedures

Annual forages were grown as part of several different rotation experiments near Garden City, Kansas. Plant available water, growing season precipitation, and forage yield were measured annually. Data for winter triticale were available from 2008 through 2016; forage sorghum, from 2008 through 2016; and spring triticale from 2012 through 2016.

Annually, winter triticale was planted at the end of September, spring triticale was planted at the beginning of March, and forage sorghum was planted at the beginning of June. Crops were harvested at early heading to optimize forage yield and quality (Feekes 10.1) (Large, 1954). Annually, winter triticale was harvested approximately May 15, spring oat was harvested approximately June 1, and forage sorghum was harvested approximately the end of August. Forage yields were determined from a 3- × 30-ft area cut

3-in. high using a small plot Carter forage harvester for each plot. Forage yield was measured at each harvest. Gravimetric soil moisture content was measured at planting and harvest to a depth of 6 ft using 1-ft increments. Precipitation storage efficiency (percent of precipitation stored during the fallow period) was quantified for each fallow period, and crop water use efficiency (forage yield divided by soil water used plus precipitation) was determined for each crop harvest. Crop yield response to plant available water at planting was regressed to estimate yield. These yield data will eventually be used to develop a yield prediction model based on historical or expected weather conditions when sufficient years of data are obtained.

Data produced by this study will be used to evaluate the economics of forage rotations and tillage. Production costs and returns will be calculated using typical values for the region. The implication of using forages on crop insurance dynamics and risk exposure is a critical component of a producer's decision-making process and will be evaluated at the conclusion of this study.

Results and Discussion

Winter Triticale

Winter triticale forage yield was correlated to PAW and GSP, although yield response was highly variable. Plant available water explained approximately 20% and GSP explained 11% of the variability in forage yield (Figures 1 and 2). Together, PAW and GSP explained 48% of the variability in forage yield (Figure 3). For every inch of water used (soil water plus GSP), yield was increased 640 lb/a. Averaged across the study period, yield was 3,700 lb/a.

Spring Triticale

Spring triticale forage yield was not significantly correlated to PAW and GSP, and yield response was highly variable. Plant available water explained approximately 6% and GSP explained 10% of the variability in forage yield (Figures 4 and 5). Together, PAW and GSP only explained 11% of the variability in forage yield (Figure 6). For every inch of water used (soil water plus GSP), yield was increased 195 lb/a. Averaged across the study period, yield was 1,500 lb/a.

Forage Sorghum

Forage sorghum forage yield was correlated to PAW but not GSP, and yield response was variable. Plant available water explained approximately 32% and GSP explained 5% of the variability in forage yield (Figures 7 and 8). Together, PAW and GSP explained 21% of the variability in forage yield (Figure 9). For every inch of water used (soil water plus GSP), yield was increased 392 lb/a. Averaged across the study period, yield was 5,500 lb/a.

References

Large, E.C. 1954. Growth stages in cereals illustration of the Feekes scale. *Plant Pathology*. 3 (4): 128–129. doi:10.1111/j.1365-3059.1954.tb00716.x

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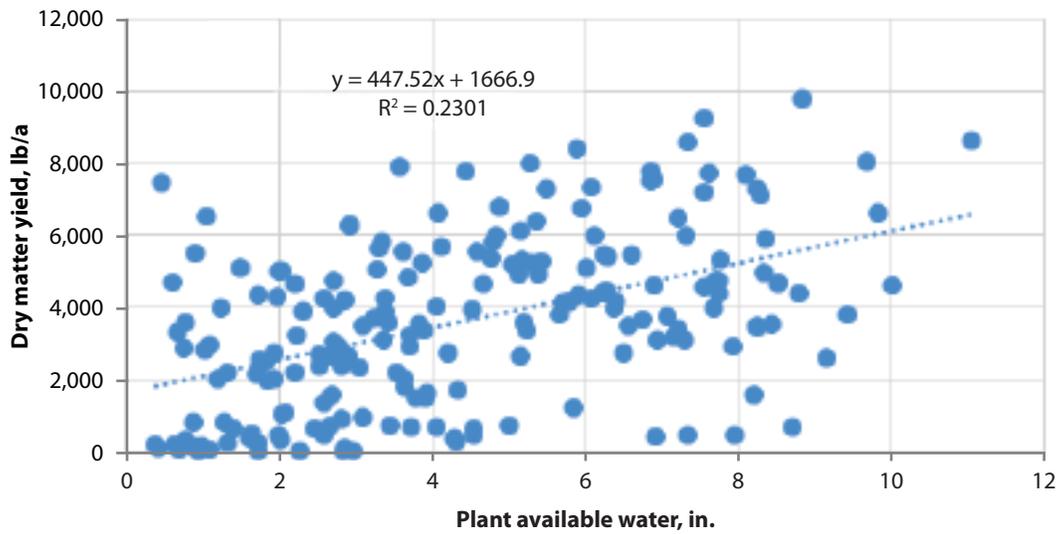


Figure 1. Winter triticale yield response to plant available water at planting.

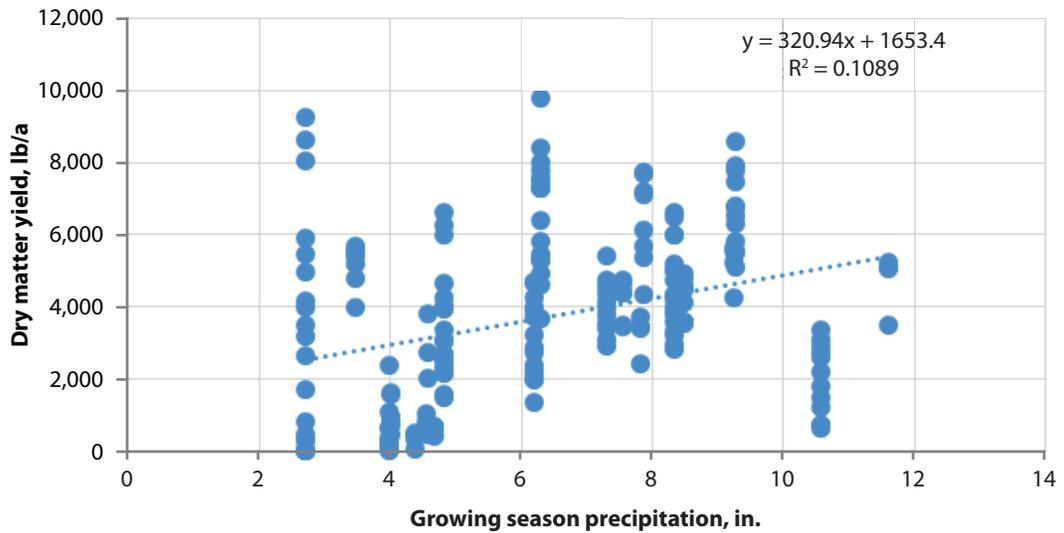


Figure 2. Winter triticale yield response to growing season precipitation.

CROPPING AND TILLAGE SYSTEMS

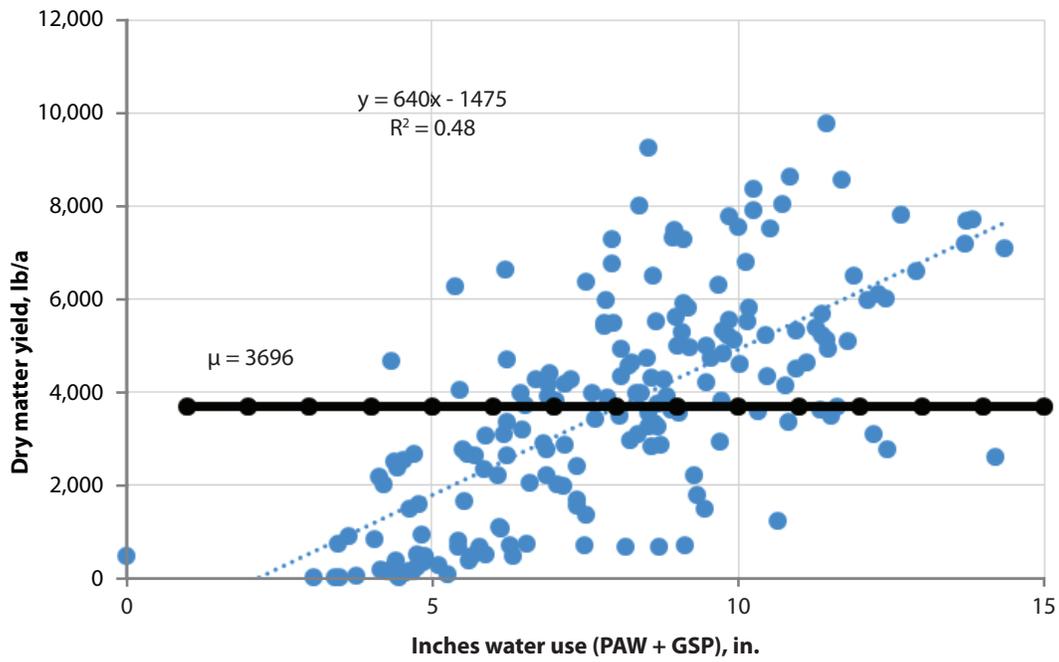


Figure 3. Winter triticale yield response to water use (soil water plus growing season precipitation) and average yield (bold line) across the study period. PAW = plant available water at planting. GSP = growing season precipitation.

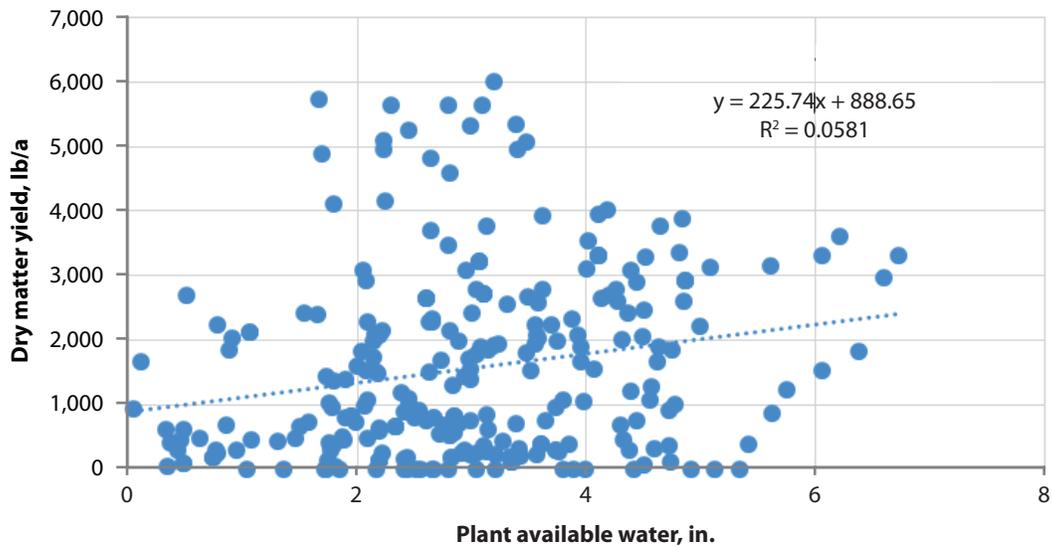


Figure 4. Spring triticale yield response to plant available water at planting.

CROPPING AND TILLAGE SYSTEMS

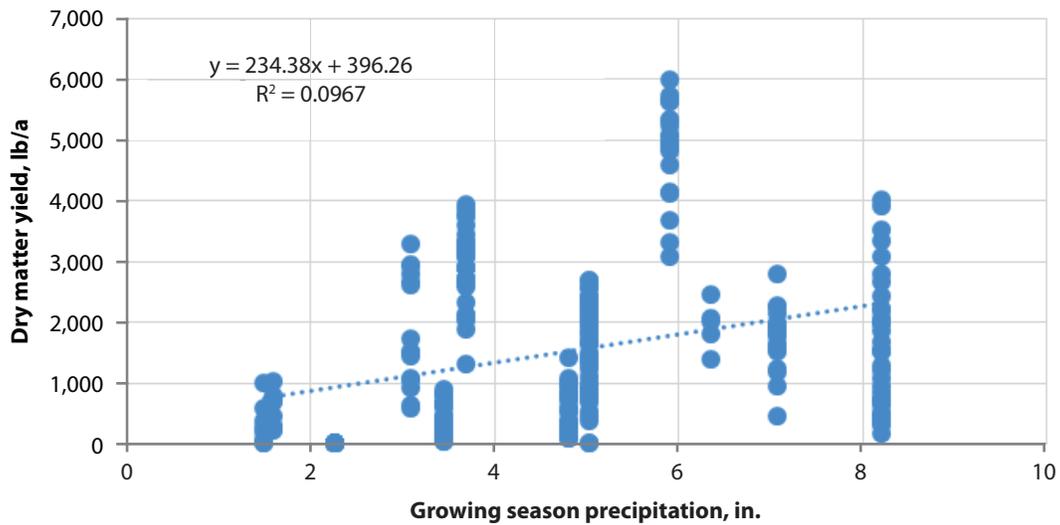


Figure 5. Spring triticale yield response to growing season precipitation.

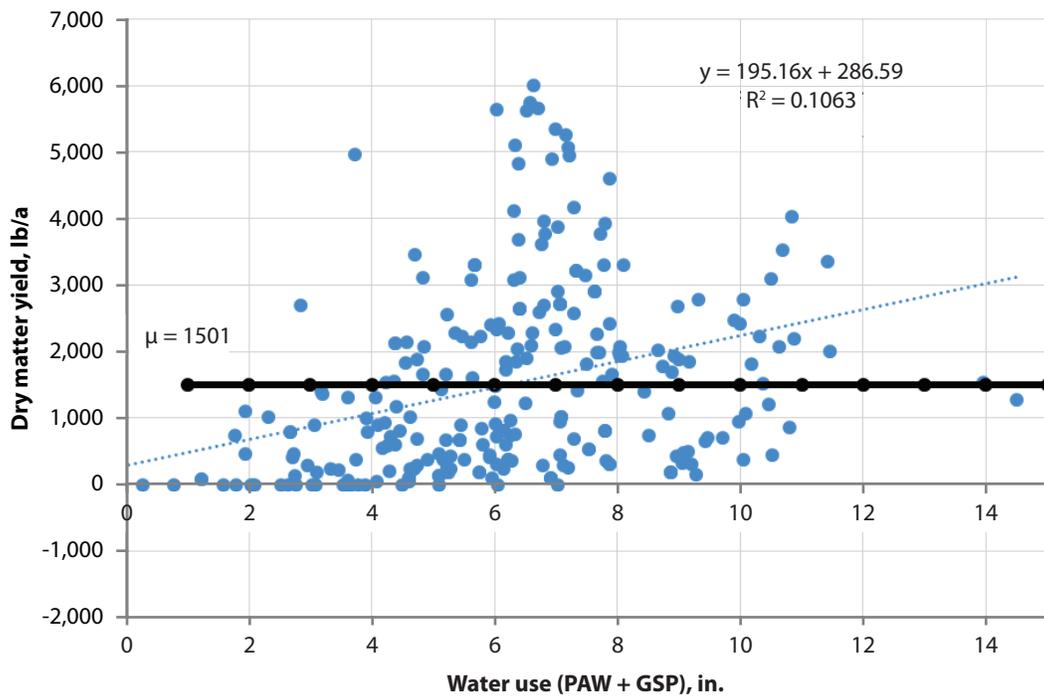


Figure 6. Spring triticale yield response to water use (soil water plus growing season precipitation) and average yield (bold line) across the study period. PAW = plant available water at planting. GSP = growing season precipitation.

CROPPING AND TILLAGE SYSTEMS

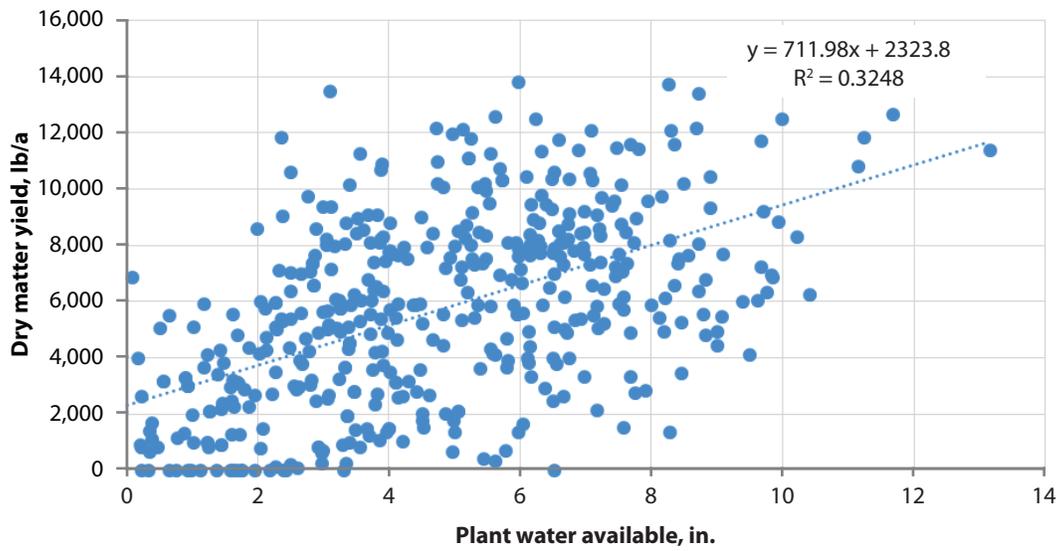


Figure 7. Forage sorghum yield response to plant available water at planting.

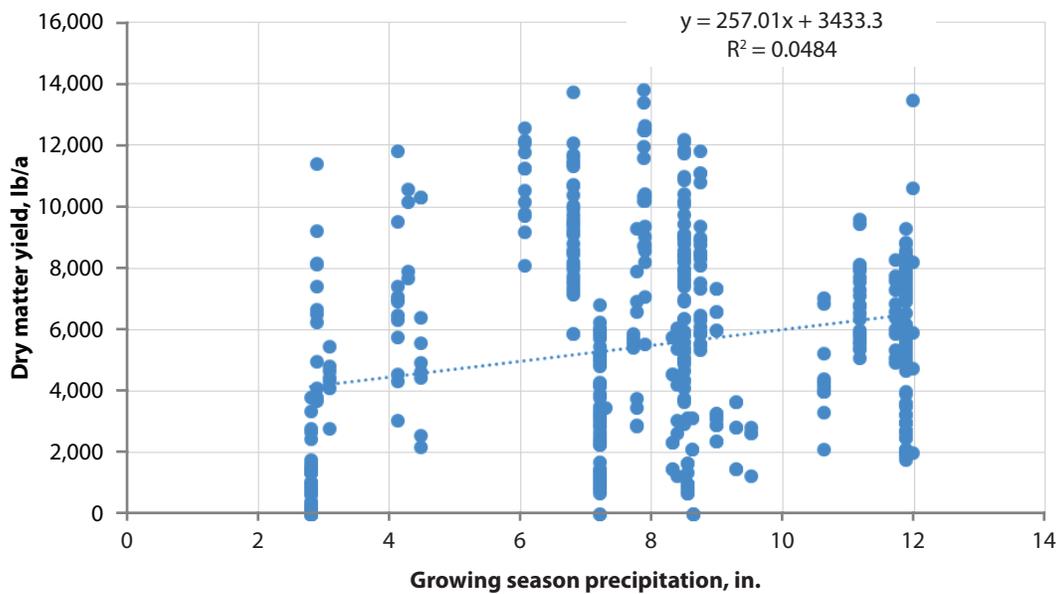


Figure 8. Forage sorghum yield response to growing season precipitation.

CROPPING AND TILLAGE SYSTEMS

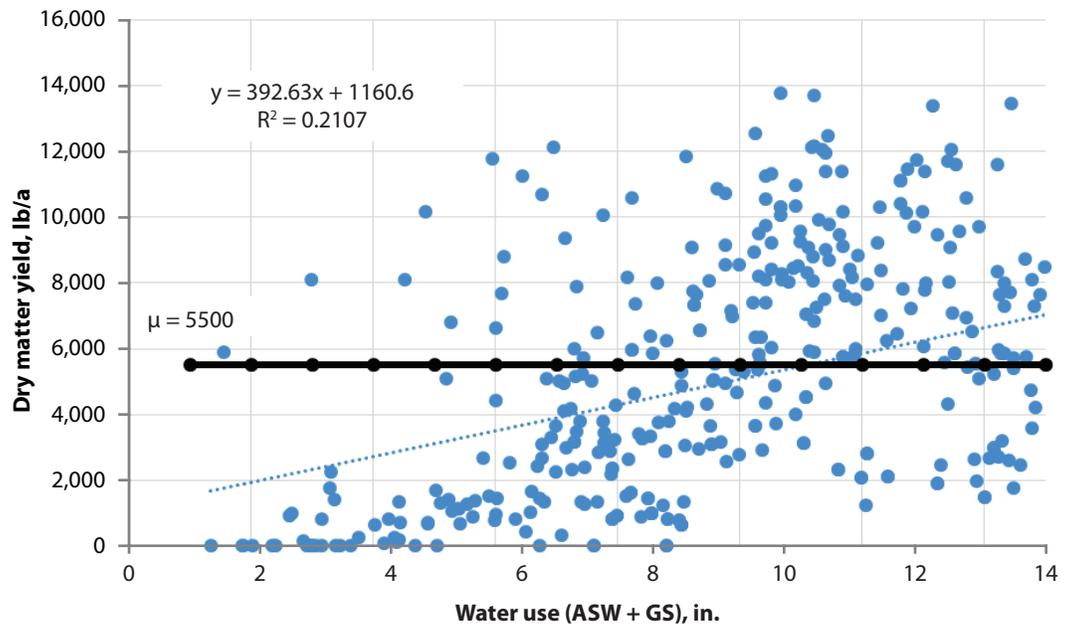


Figure 9. Forage sorghum yield response to water use (soil water plus growing season precipitation) and average yield (bold line) across the study period.

Fallow Replacement Crop (Cover Crops, Annual Forages, and Short-Season Grain Crops) Effects on Wheat and Grain Sorghum Yields

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

Summary

Producers are interested in growing cover crops and reducing fallow. Growing a crop during the fallow period would increase profitability if crop benefits exceeded expenses. Benefits of growing a cover crop were shown in high rainfall areas, but limited information is available on growing cover crops in place of fallow in the semiarid Great Plains. A study was conducted from 2007–2017 that evaluated cover crops, annual forages, and short season grain crops grown in place of fallow. In the first experiment (2007-2012), the rotation was no-tillage wheat-fallow. The second experiment (2012-2017) rotation was no-tillage wheat-grain sorghum-fallow. This report presents results from the second experiment. Wheat yield was affected by the previous crop, but growing a previous crop, such as hay or cover, did not affect wheat yield. Wheat yield following the previous crop was dependent on precipitation during fallow and the growing season. In dry years (2011-2014), growing a crop during the fallow period reduced wheat yields, while growing a crop during the fallow period had little impact on wheat yield in wet years (2008-2010). The length of the fallow period also affected yields of the following wheat crop. Growing a cover or hay crop until June 1 affected wheat less than if a winter or spring crop were grown for grain, which utilized the land until approximately the first week of July. Cover crops did not improve wheat or grain sorghum yields compared to fallow. To be successful, the benefits of growing a cover crop during the fallow period must be greater than the expense of growing it and must compensate for any negative yield impacts on the subsequent crop. Cover crops always resulted in less profit than fallow, while annual forages often increased profit compared to fallow. The negative effects on wheat yields might be minimized with flex-fallow, which is the concept of only growing a crop in place of fallow in years when soil moisture at planting and precipitation outlook are favorable at the time of making the decision to plant.

Introduction

Interest in replacing fallow with a cash crop or cover crop has necessitated research on soil, water, and wheat yields following a shortened fallow period. 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 no-tillage wheat-fallow rotation is stored. The remaining 75 to 70% 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 winter wheat yield. This study evaluated replacing part of the fallow period with a cover, annual forage, or short-season grain crop, measuring plant available water at wheat planting and winter wheat yield.

Experimental Procedures

A study from 2007–2014 evaluated cover crops, annual forages, and spring grain crops (peas, oat, or triticale) grown in place of fallow in a no-tillage wheat-fallow rotation. This first experiment was modified beginning in 2012 to a wheat-grain sorghum-fallow rotation. Treatments that stayed the same between experiments 1 and 2 were maintained in the same plots so that long-term treatment impacts could be determined. Fallow replacement crops (cover crop, annual forage, or short-season grain crop) were either grown as standing cover, harvested for forage (annual forage crop), or harvested for grain.

In experiment 1 (2007-2012) both winter and spring crop species were evaluated. Winter species included yellow sweet clover (*Melilotus officinalis* (L.) Lam.) hairy vetch (*Vicia villosa* Roth ssp.), lentil (*Lens culinaris* Medik.), Austrian winter forage pea (*Pisum sativum* L. ssp.), Austrian winter grain pea (*Pisum sativum* L. ssp.), and triticale (\times *Triticosecale* Wittm.). Spring species included lentil (*Lens culinaris* Medik.), forage pea (*Pisum sativum* L. ssp.), grain pea (*Pisum sativum* L. ssp.), and triticale (\times *Triticosecale* Wittm.). Crops were grown in monoculture and in two-species mixtures of each legume plus triticale. Crops grown for grain were grown in monoculture only. Winter lentil was grown in place of yellow sweet clover beginning in 2008. Crops grown in place of fallow were compared with a wheat-fallow and continuous wheat rotation for a total of 16 treatments. The study design was a split-split-plot randomized complete block design with four replications; crop phase (wheat-fallow) was the main plot, fallow replacement was the split-plot, and fallow replacement method (forage, grain, or cover) was the split-split-plot. The main plot was 480-ft wide and 120-ft long, the split-plot was 30-ft wide and 120-ft long, and the split-split plot was 15-ft wide and 120-ft long.

In experiment 2 (2012-2014) spring crops were grown the year following grain sorghum. Grain sorghum is harvested late in the year and most years does not allow growing a winter crop during the fallow period. Spring planted treatments included spring grain pea, spring pea plus spring oat (*Avena sativa* L.), spring pea plus spring triticale, spring oat, spring triticale, and a six species “cocktail” mixture of spring oat, spring triticale, spring pea, buckwheat var. Mancan (*Fagopyrum esculentum* Moench), purple top turnip (*Brassica campestris* L.), and forage radish (*Raphanus sativus* L.). In addition, spring grain pea, spring oat, and safflower (*Carthamus tinctorius* L.) were grown for grain. Safflower was only grown in 2012, and that treatment was replaced with spring oat grown for grain beginning in 2013. Additional treatments initiated in 2013 were yellow sweetclover planted with grain sorghum and allowed to grow into the fallow year, daikon radish (*Brassica rapa* L.) planted with winter wheat in a wheat-grain sorghum-fallow rotation, shogoin turnip (*Raphanus sativus* L.) planted with winter wheat in a wheat-grain sorghum-fallow rotation, and spring oats or a cocktail planted in a “flex-fallow” system (Table 1). The flex-fallow treatment was planted when a minimum of 4 inches of PAW (12 inches in 2013) was determined using a Paul Brown moisture probe at spring planting; 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. Crops grown for grain were grain peas, spring oat, and triticale. Crops grown in place of fallow were compared with a wheat-grain sorghum-fallow rotation for a total of 16 treatments (Table 1). The study design was a split-split-plot randomized complete block design with four replications; crop phase (wheat-grain

sorghum-fallow) was the main plot, fallow replacement was the split-plot, and fallow replacement method (forage, grain, or cover) was the split-split-plot. The main plot was 330-ft wide and 120-ft long, the split-plot was 30-ft wide and 120-ft long, and the split-split plot was 15-ft wide and 120-ft long.

Annually, winter wheat was planted on approximately October 1. Spring crops were planted as early as soil conditions allowed, ranging from the end of February through the middle of March. Spring cover and forage crops were chemically terminated or forage-harvested approximately June 1 at early heading (Feekes 10.1) (Large, 1954). Biomass yields for both cover crops and forage crops were determined from a 3- × 120-ft area cut 3-in. high using a small plot Carter forage harvester from within the split-split-plot managed for forage. Winter and spring grain peas and winter wheat were harvested with a small plot Wintersteiger combine from a 6.5- × 120-ft area at grain maturity, which occurred approximately the first week of July.

Volumetric soil moisture content was measured at planting and harvest of winter wheat, grain sorghum, and fallow using a Giddings Soil Probe by 1-ft 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 adjusted to 13.5% moisture content, and test weight was measured using a grain analysis computer. Grain samples were analyzed for nitrogen content.

Results and Discussion

Year

Fallow and growing-season precipitation varied greatly during the course of this study (Table 2). Historical 30-yr (1984-2014) average precipitation during the fallow period between grain sorghum harvest and wheat planting (November-December plus January-September) was 18.03 in., and precipitation during the fallow period between wheat harvest and grain sorghum planting (July-December plus January-May) was 16.12 in. Long-term average growing-season precipitation for wheat (October-June) averaged 12.51 in., and growing-season precipitation for grain sorghum (June-October) averaged 11.06 in. Precipitation during the fallow period ahead of wheat planting was below normal in 2012 and 2013. Growing-season precipitation for wheat was below normal in 2013 and above normal in 2016. Precipitation was above normal during the fallow period preceding sorghum and during the sorghum growing season for those years of this study. These differences in precipitation amount and timing affected plant-available soil water at wheat and grain sorghum planting and subsequently affected crop yields.

Precipitation storage efficiency averaged 28% with cover and 22% with hay, and stored soil water in the 0-6-ft profile averaged 3.5 inches with cover and 2.8 inches with hay at wheat planting. Plant-available soil water in the 0-3-in. soil depth was not different between cover and hay treatments. Although more soil water tended to be available in the profile following cover crops compared to hay crops, this effect was not large enough to affect wheat yields. The greater average plant-available soil water and precipitation storage with cover crop is likely due to more surface residue in the cover crop treatments compared with hay treatments, which likely helps reduce water runoff and evaporation near the soil surface.

Winter Wheat Yield in Wheat-Grain Sorghum-Fallow

In 2013, 6.25 inches of precipitation occurred during the winter wheat growing season between planting and harvest. This was 50% of normal (12.5 inches) for this time period, and was the third consecutive year of drought. The 30-year average precipitation during the fallow period (November-October) of a wheat-grain sorghum-fallow rotation averaged 18.03 inches, and 12.88 inches of precipitation occurred during fallow between November 1, 2011, and October 1, 2012. Below-normal precipitation during fallow and the winter wheat growing season resulted in any treatment other than fallow significantly reducing wheat yield 50% or more. The cover crop cocktail treatment yielded 79% less than fallow. Wheat following fallow yielded 19 bu/a and all other treatments yielded between 3 to 9 bu/a (Figure 1).

In 2014, 14.57 inches of precipitation occurred during the winter wheat growing season between planting and harvest. This was above average, but most of the rain came in June (10.5 inches), which was too late to benefit the wheat crop. Therefore, wheat yields were significantly reduced by 40-80% by any treatment other than fallow, and fallow only yielded 6 bu/a (Figure 2).

In 2015, 12.18 inches of precipitation occurred during the winter wheat growing season between planting and harvest, with most of this occurring in May (6.38 inches). Were it not for the rainfall received in May, yields likely would have been less than 10 bu/a in fallow. Precipitation received in the previous fallow period (between grain sorghum harvest and wheat planting) from November 2013 to October 2015 was 18.87 inches and 30-yr average for this period was 18.03 inches. The early season moisture stress and late season precipitation minimized yield differences between treatments and fallow (Figure 3). Only oats for grain, oat, and pea/triticale yielded less than fallow (15 bu/a).

In 2016, a large infestation of rabbits and feeding damage resulted in a failed crop and no grain production.

Grain Sorghum Yield in Wheat-Grain Sorghum-Fallow

The first year that grain sorghum was in-phase with a cover crop grown in 2013 ahead of wheat prior to planting grain sorghum was in 2015. There were 12 inches of precipitation during the growing season between planting and harvest during 2015. The 30-year average precipitation during this time period (June-November) averaged 11.06 inches. The above normal rainfall in 2015, particularly early in the growing season (5.36 inches in July and 3.24 inches in August), resulted in above normal sorghum yields, ranging from 84 to 109 bu/a (Figure 4). Despite the above-normal rainfall and yields, there was still a correlation with 2015 grain sorghum and 2014 winter wheat yields; thus, the impact of growing a cover crop was evident two years later.

In 2016, sorghum yielded similarly among treatments. The difference in sorghum yield response to treatment between years was likely due to greater wheat yields and more residue following the 2015 wheat crop compared to the 2014 wheat crop. The poor wheat crop in 2014 resulted in low soil residue cover, and the effect of this was shown by differences in sorghum water use efficiency (WUE) among treatments in 2015. In

2016, there were no differences in sorghum yield or WUE across treatments. Additionally, sufficient precipitation during the preceding fallow period and growing season resulted in an average sorghum yield of 63 bu/a, which helped negate any antecedent differences in soil water.

Cover vs. Annual Forage

Similar to the first experiment, there was no difference in wheat or grain sorghum yields whether the previous crop was left as cover or harvested for forage, despite slightly more plant-available water following cover than forage harvest. This indicates the previous crop can be harvested for forage rather than left standing as a cover crop without negatively affecting wheat or grain sorghum yields.

Conclusions

Fallow helps stabilize crop yields in dry years. Annual precipitation in this study ranged from 12.1 to 23.3 inches. The 30-year average precipitation was 19.24 inches. In dry years (2011-2015), growing a crop during the fallow period reduced wheat yields, but in wet years (2008-2010), growing a crop during the fallow period had little impact on wheat yield. The length of the fallow period also affected yields of the following wheat crop. Growing a cover or hay crop until June 1 affected wheat less than if winter wheat or spring crops were grown for grain production, which utilized the land until approximately the first week of July.

Forages can be profitable to grow in place of fallow in favorable moisture years. However, cover crops were always an expense to grow. The cropping system can be intensified by replacing part of the fallow period with annual forages or spring grain crops to increase profit and improve soil quality; however, in semiarid environments, wheat yields will be reduced in years with below-normal precipitation. Across years there was a tendency for wheat yields to not be affected by growing a crop in place of fallow when wheat yield potential was 50 bu/a or greater. The negative effect on yield was greater when wheat yield potential was least and the drought period lasted for more than a year. Some of the reduction in grain yield can be offset by growing a cover crop for forage or grain. Negative impacts on grain yields might also be minimized over time with “flex-fallow.” Flex-fallow is the concept of only planting a crop in place of fallow when soil moisture levels and precipitation outlook are favorable. Under drought conditions such as 2011-2014, using flex-fallow, a crop would not have been grown in place of fallow. Therefore, flex-fallow may help reduce the negative effects of reduced fallow. Conversely, flex-fallow will not prevent reduced yield in years when growing-season precipitation levels are below normal. Additional years of data are required to determine the feasibility of flex-fallow and the effects of replacing fallow in a wheat-summer crop-fallow rotation.

References

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CROPPING AND TILLAGE SYSTEMS

Table 1. Fallow treatments 2007-2016

Crop	Cover	Hay	Grain	Year produced										
				2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Fallow	-	-	-	x	x	x	x	x	x	x	x	x	x	x
Cocktail mix [†]	x	x	-	-	-	-	-	-	-	x	x	x	x	x
Cocktail mix (flex) ^{††}	-	x	-	-	-	-	-	-	-	-	-	N	N	Y
Spring oat (flex)	-	x	-	-	-	-	-	-	-	-	Y	N	N	Y
Spring oat	-	x	-	-	-	-	-	-	-	x	x	x	x	x
Spring oat (grain)	-	-	x	-	-	-	-	-	-	-	x	x	x	x
Spring pea	x	x	-	x	x	x	x	x	x	x	-	-	-	-
Spring pea (grain)	-	-	x	-	-	-	x	x	x	x	x	x	x	x
Spring pea/spring oat	x	x	-	-	-	-	-	-	-	x	x	x	-	-
Spring pea/spring triticale	x	x	-	-	-	-	-	-	-	x	x	x	-	-
Spring triticale	x	x	-	-	-	-	-	-	-	x	x	x	-	-
Spring triticale	-	x	-	-	x	x	x	x	-	-	-	-	x	x
Spring triticale (grain)	-	-	x	-	-	-	-	-	-	-	-	-	x	x
Spring oat/triticale/pea	x	x	-	-	-	-	-	-	-	-	x	x	x	x
Spring triticale/oat	x	x	-	-	-	-	-	-	-	-	-	-	x	x
Spring triticale/pea	-	x	-	-	x	x	x	x	x	x	-	-	-	-
Spring triticale/lentil	-	-	-	-	x	x	x	x	x	-	-	-	-	-
Spring lentil	-	-	-	x	x	x	x	x	x	-	-	-	-	-

[†] Oat, triticale, pea, buckwheat, forage brassica and forage radish.

^{††} Flex: Plant when soil moisture is 14 inches (12 inches in 2013) or > and precipitation outlook is neutral or favorable. Flex-fallow was planted in 2013 and 2016, but was not planted in 2014 and 2015.

x = treatment present. - = treatment not present.

CROPPING AND TILLAGE SYSTEMS

Table 2. Annual and 30-year monthly, growing season, and fallow precipitation at the Southwest Research-Extension Center near Garden City, KS, 2012–2016

Year	Month	Precipitation	Precipitation
		in. -----	
2012	January	0.00	0.46
	February	0.59	0.55
	March	1.92	1.31
	April	1.77	1.74
	May	0.30	2.98
	June	1.03	3.12
	July	2.41	2.80
	August	1.22	2.51
	September	1.19	1.42
	October	0.98	1.21
	November	0.00	0.55
	December	0.73	0.59
	Total	12.14	19.24
	Wheat growing season (October-June)	8.50	12.51
	Grain sorghum growing season (June-October)	6.83	11.06
	Fallow preceding wheat (November-September)	16.17	18.03
Fallow preceding grain sorghum (July-May)	10.81	16.12	
2013	January	0.48	0.46
	February	1.54	0.55
	March	0.13	1.31
	April	0.28	1.74
	May	1.25	2.98
	June	1.84	3.12
	July	2.23	2.80
	August	6.09	2.51
	September	1.83	1.42
	October	0.88	1.21
	November	0.74	0.55
	December	0.00	0.59
	Total	17.29	19.24
	Wheat growing season (October-June)	7.23	12.51
	Grain sorghum growing season (June-October)	12.87	11.06
	Fallow preceding wheat (November-September)	16.40	18.03
Fallow preceding grain sorghum (July-May)	10.21	16.12	

continued

CROPPING AND TILLAGE SYSTEMS

Table 2. Annual and 30-year monthly, growing season, and fallow precipitation at the Southwest Research-Extension Center near Garden City, KS, 2012–2016

Year	Month	Precipitation	Precipitation average [†] (30 yr)
		----- in. -----	
2014	January	0.12	0.46
	February	0.38	0.55
	March	0.25	1.31
	April	0.69	1.74
	May	0.63	2.98
	June	10.50	3.12
	July	3.81	2.80
	August	1.99	2.51
	September	2.71	1.42
	October	1.78	1.21
	November	0.03	0.55
	December	0.40	0.59
	Total	23.29	19.24
	Wheat growing season (October-June)	14.19	12.51
	Grain sorghum growing season (June-October)	20.79	11.06
	Fallow preceding wheat (November-September)	21.82	18.03
Fallow preceding grain sorghum (July-May)	13.84	16.12	
2015	January	0.30	0.46
	February	1.21	0.55
	March	0.32	1.31
	April	0.37	1.74
	May	6.38	2.98
	June	1.39	3.12
	July	5.36	2.80
	August	3.24	2.51
	September	0.04	1.42
	October	2.87	1.21
	November	0.98	0.55
	December	0.81	0.59
	Total	23.27	19.24
	Wheat growing season (October-June)	12.18	12.51
	Grain sorghum growing season (June-October)	12.90	11.06
	Fallow preceding wheat (November-September)	19.04	18.03
Fallow preceding grain sorghum (July-May)	19.30	16.12	

continued

CROPPING AND TILLAGE SYSTEMS

Table 2. Annual and 30-year monthly, growing season, and fallow precipitation at the Southwest Research-Extension Center near Garden City, KS, 2012–2016

Year	Month	Precipitation	Precipitation average [†] (30 yr)	
		-----	in. -----	
2016	January	0.04	0.46	
	February	0.22	0.55	
	March	0.06	1.31	
	April	4.59	1.74	
	May	0.92	2.98	
	June	3.61	3.12	
	July	5.97	2.80	
	August	1.85	2.51	
	September	0.17	1.42	
	October	0.00	1.21	
	November	0.08	0.55	
	December	0.22	0.59	
	Total		17.73	19.24
		Wheat growing season (October-June)	14.10	12.51
		Grain sorghum growing season (June-October)	11.60	11.06
		Fallow preceding wheat (November-September)	19.22	18.03
		Fallow preceding grain sorghum (July-May)	19.13	16.12

[†]30-year average (1984-2014).

Growing season amounts are those amounts accumulated between crop planting and termination.

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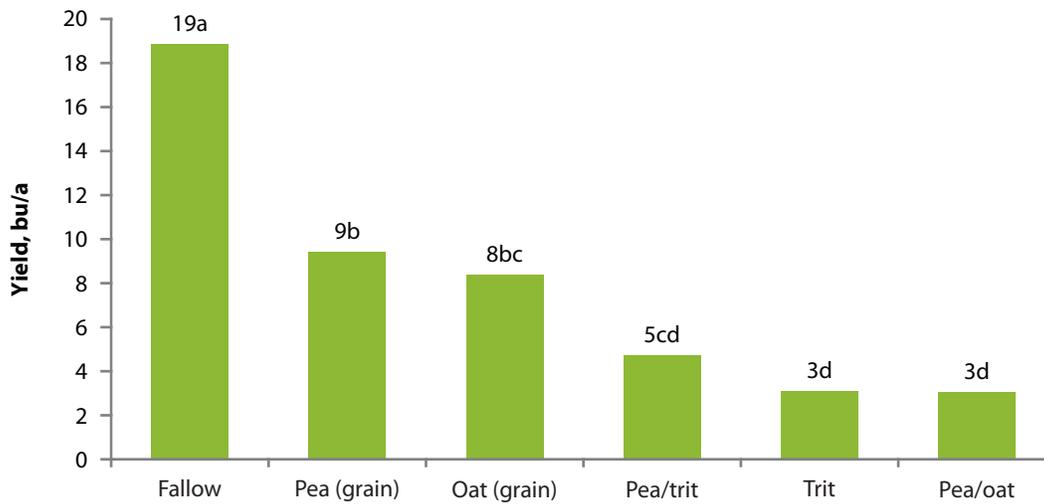


Figure 1. Winter wheat yield (bu/a) in 2013 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$. Trit = triticale.

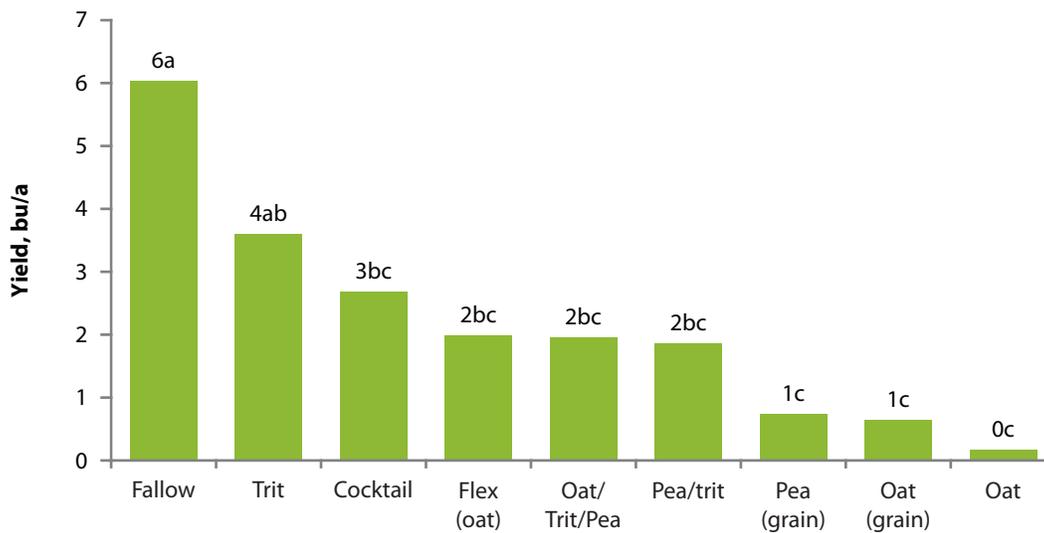


Figure 2. Winter wheat yield (bu/a) in 2014 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$. Trit = triticale.

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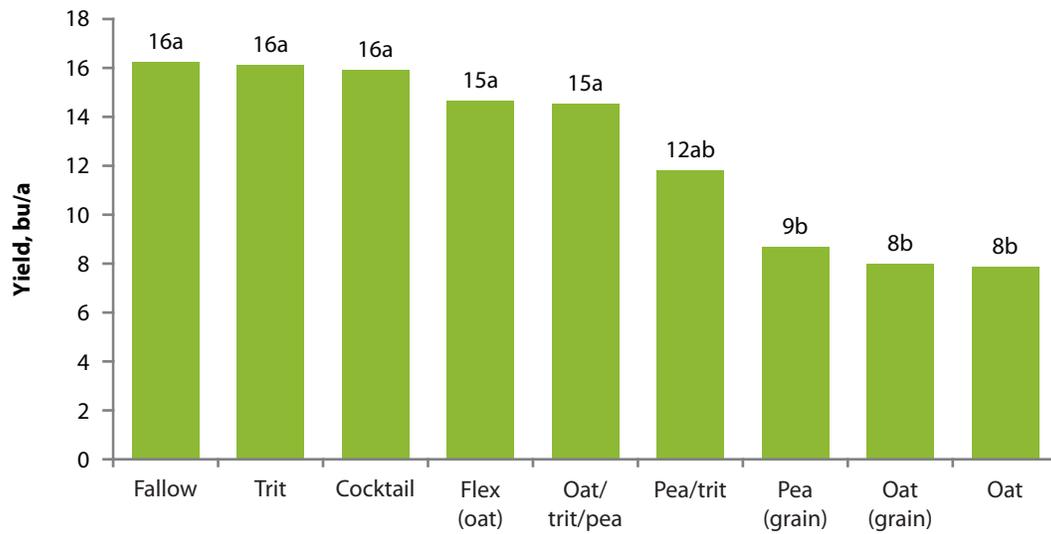


Figure 3. Winter wheat yield (bu/a) in 2015 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$. Trit = triticale.

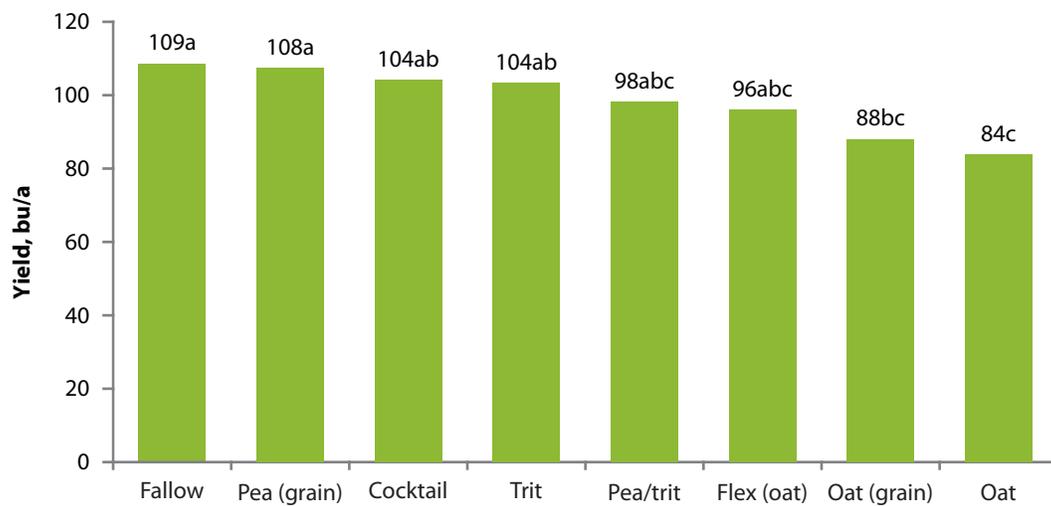


Figure 4. Grain sorghum yield in 2015 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$. Trit = triticale.

Large-Scale Dryland Cropping Systems

A. Schlegel and L. Haag

Summary

This study was conducted from 2008 to 2016 at the Kansas State University Southwest Research-Extension Center near Tribune, KS. The purpose of the study was to identify whether more intensive cropping systems can enhance and stabilize production in rainfed cropping systems to optimize economic crop production, more efficiently capture and utilize scarce precipitation, and maintain or enhance soil resources and environmental quality. The crop rotations evaluated were continuous grain sorghum (SS), wheat-fallow (WF), wheat-corn-fallow (WCF), wheat-sorghum-fallow (WSF), wheat-corn-sorghum-fallow (WCSF), and wheat-sorghum-corn-fallow (WSCF). All rotations were grown using no-tillage practices except for WF, which was grown using reduced-tillage. The efficiency of precipitation capture was not greater with more intensive rotations. Length of rotation did not affect wheat yields. Corn yields were about 55% and grain sorghum yields about 70% greater when following wheat than when following corn or grain sorghum. Grain sorghum yields were about 60% greater than corn in similar rotations.

Introduction

The change from conventional tillage to no-tillage cropping systems has allowed for greater intensification of cropping in semi-arid regions. In the central High Plains, wheat-fallow (1 crop in 2 years) has been a popular cropping system for many decades. This system is being replaced by more intensive wheat-summer crop-fallow rotations (2 crops in 3 years). There has also been increased interest in further intensifying the cropping systems by growing 3 crops in 4 years or continuous cropping. This project evaluates several multi-crop rotations that are feasible for the region, along with alternative systems that are more intensive than 2- or 3-year rotations. The objectives are to 1) enhance and stabilize production of rainfed cropping systems using multiple crops and rotations, using best management practices to optimize capture and utilization of precipitation for economic crop production, and 2) enhance adoption of alternative rainfed cropping systems that provide optimal profitability.

Experimental Procedures

The crop rotations are 2-year (wheat-fallow [WF]); 3-year (wheat-grain sorghum-fallow [WSF] and wheat-corn-fallow [WCF]); 4-year rotations (wheat-corn-sorghum-fallow [WCSF] and wheat-sorghum-corn-fallow [WSCF]); and continuous sorghum [SS]). All rotations are grown using no-tillage (NT) practices except for WF, which is grown using reduced-tillage (RT). All phases of each rotation are present each year. Plot size is a minimum of 100 × 450 ft. In most instances, grain yields were determined by harvesting the center 60 ft (by entire length) of each plot with a commercial combine and determining grain weight with a weigh-wagon or combine yield monitor. Soil water was measured in 12-inch increments to 96 inches near planting and after harvest either gravimetrically (RT WF) or by neutron attenuation (NT plots).

Results and Discussion

Precipitation averaged 98% of normal (17.90 in.) across the 9-yr study period and was near normal (+/- 15%) in 6 out of 9 years with two wet years (>20% above normal) and one exceptionally dry year (42% of normal) (Figure 1). Fallow accumulation, fallow efficiency, and profile available water at wheat planting was greater with WF than all other wheat rotations (Table 1). The fallow efficiencies of the 3- and 4-yr NT rotations were only 54-68% of WF under RT. With more water available, crop water use was also greater with WF than with wheat in other rotations. There were no differences in available water at wheat planting or crop water use among the 3- and 4-yr rotations.

Fallow accumulation prior to corn planting and profile available soil water at planting was greater following wheat (WCF or WCSF) than following grain sorghum (WSCF) (Table 1). However, the fallow period following wheat was longer, resulting in low fallow efficiencies (~17%) following wheat and only 24% following sorghum. Similar to wheat, corn water use was greater with greater available soil water at planting. Grain sorghum responded similarly to corn, with greater fallow accumulation and soil water at planting (and greater crop water use) when following wheat than following corn or sorghum. Again, fallow efficiencies prior to grain sorghum were low (20% or less).

Wheat yields were much greater than normal in 2016 and were greater than 50 bu/a for all treatments (Figure 2). The effect of cropping systems was not consistent across years, with WF sometimes in the highest yielding group and sometimes in the lowest yielding group. Averaged across the 9 years, cropping system had little effect on wheat yields.

Similar to wheat, grain sorghum yields were very good in 2016, with all treatments producing yields of 100 bu/a or greater (Figure 3). Consistent with earlier years, sorghum yields were higher following wheat than either corn or sorghum. Average grain sorghum yields following wheat were about 70% greater than following corn or sorghum.

Corn yields were also very good in 2016 (Figure 4). Corn yields following wheat in either the 3- or 4-yr rotations were always greater than corn yields following grain sorghum, except in 2015, where corn yields following sorghum (wsCf) were greater than wCf. On average, corn yields following wheat were about 55% greater than following grain sorghum.

When examining grain yields across crops, the greatest yields were produced by grain sorghum following wheat (either wSf or wScf) of about 70 bu/a (Figure 5). These yields were about 60% greater than corn following wheat (wCf or wCsf). Sorghum yields following wheat were about 70% greater than sorghum following corn or sorghum (wcSf or SS) while corn yields following wheat (wCf or wCsf) were more than 55% greater than following sorghum.

Acknowledgments

This research project received support from the U.S. Department of Agriculture, Agricultural Research Service Ogallala Aquifer Program.

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Table 1. Fallow accumulation, fallow efficiency, profile (8 ft) available soil water at planting, and crop water use by wheat, corn, and grain sorghum in several crop rotations, Tribune, KS, 2008-2016

Crop	Rotation	Fallow accumulation	Fallow efficiency	Profile ASW at planting ²	Crop water use
		inch	%	----- inch -----	
Wheat	W ^f	6.41a	28a	9.32a	17.31a
	W ^{sf}	2.79bc	19b	6.07b	13.44b
	W ^{cf}	2.33c	15c	5.79b	13.36b
	W ^{scf}	3.09b	19b	6.03b	13.59b
	W ^{csf}	2.79bc	17b	6.15b	13.46b
LSD _{0.05}		0.50	3	0.61	0.52
Corn	wC ^f	2.36a	17b	5.46a	13.64a
	wC ^{sf}	2.14a	16b	5.36a	13.54a
	wsC ^f	1.38b	24a	4.38b	12.87b
LSD _{0.05}		0.38	3	0.62	0.40
Grain sorghum	wS ^f	2.27b	15b	5.54a	12.86a
	wS ^{cf}	2.76a	18ab	5.91a	13.19a
	wcS ^f	1.26c	16b	4.66b	12.18b
	SS	1.62c	20a	4.75b	12.16b
LSD _{0.05}		0.38	3	0.61	0.39

¹ Wheat-fallow rotation is reduced-tillage; all other rotations are no-tillage. Means within a column with the same letter for the same crop are not statistically different at $P = 0.05$. The capital letter in the rotation denotes the crop phase of the rotation.

² Available soil water (ASW) in an 8 ft profile at planting.

CROPPING AND TILLAGE SYSTEMS

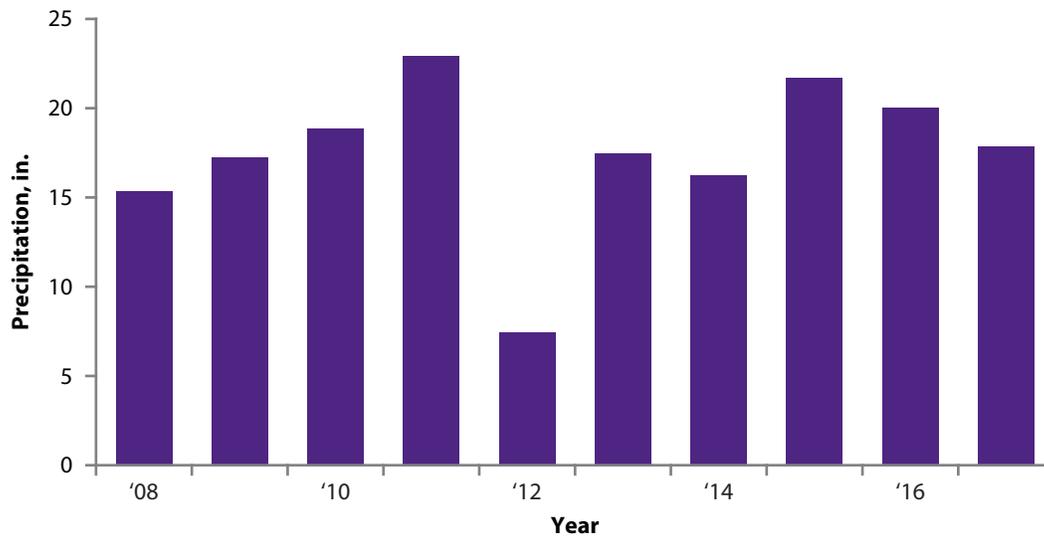


Figure 1. Annual (2008-2016) and normal precipitation (1981-2010, last bar), Tribune, KS.

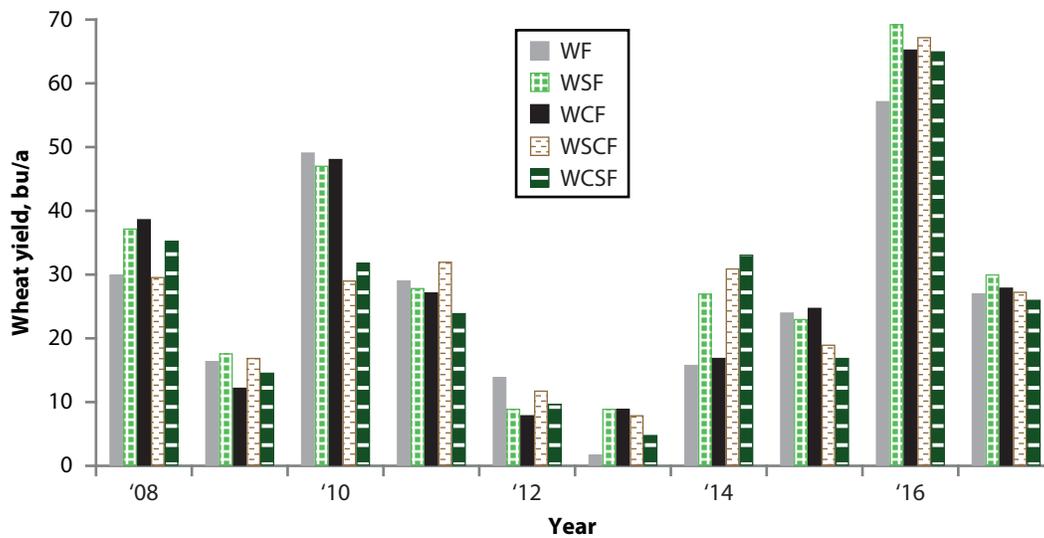


Figure 2. Wheat yields by cropping system, 2008-2016. Last set of columns are treatment means. Wheat-fallow (WF), wheat-sorghum-fallow (WSF), wheat-corn-fallow (WCF), wheat-corn-sorghum-fallow (WSCF), and wheat-sorghum-corn-fallow (WCSF).

CROPPING AND TILLAGE SYSTEMS

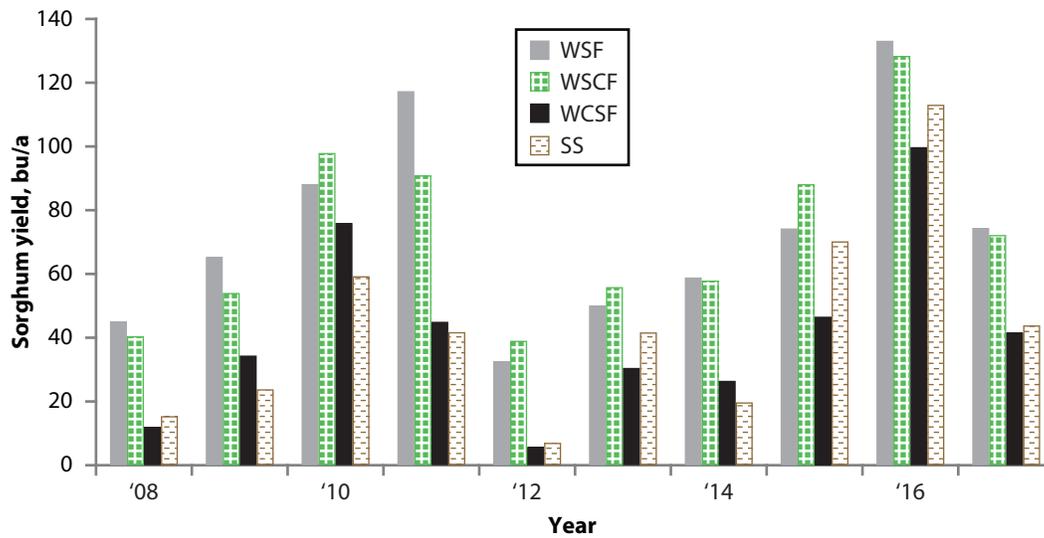


Figure 3. Grain sorghum yields by cropping system, 2008-2016. Last set of columns are treatment means. tWheat-sorghum-fallow (WSF), wheat-sorghum-corn-fallow (WSCF), wheat-corn-sorghum-fallow (WCSF), and continuous grain sorghum (SS).

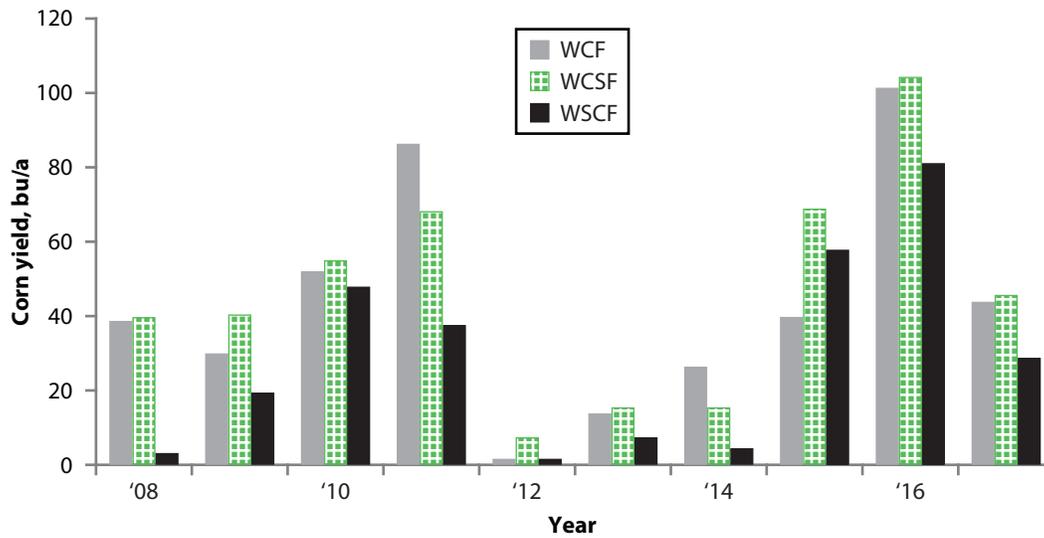


Figure 4. Corn yields by cropping system, 2008-2016. Last set of columns are treatment means. Wheat-corn-fallow (WCF), wheat-corn-sorghum-fallow (WCSF), and wheat-sorghum-corn-fallow (WCSF).

CROPPING AND TILLAGE SYSTEMS

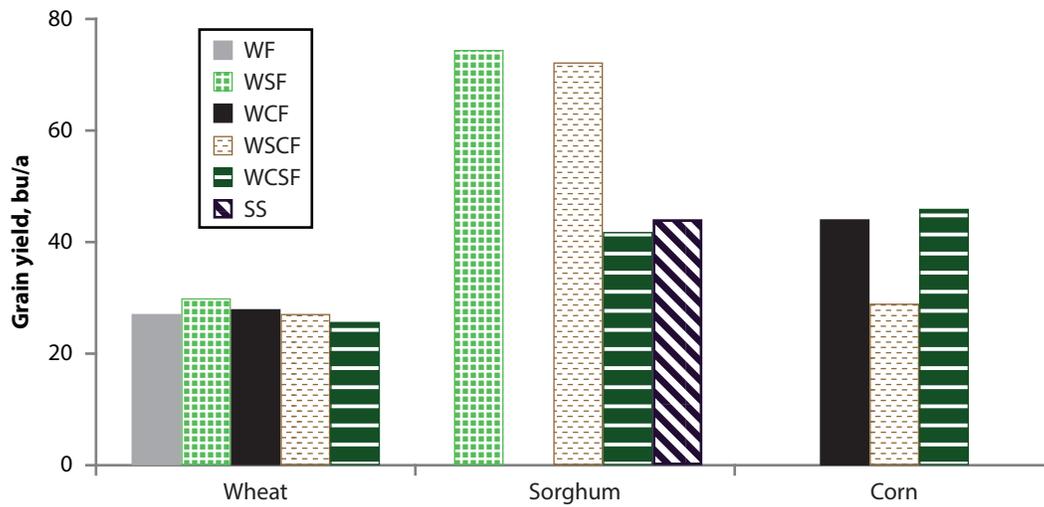


Figure 5. Average grain yields by cropping system, 2008-2016. Wheat-fallow (WF), wheat-sorghum-fallow (WSF), wheat-corn-fallow (WCF), wheat-sorghum-corn-fallow (WSCF), wheat-corn-sorghum-fallow (WCSF), and continuous grain sorghum (SS).

Tillage Intensity in a Long-Term Wheat-Sorghum-Fallow Rotation

A. Schlegel

Summary

This study was initiated in 1991 at the Kansas State University Southwest Research-Extension Center near Tribune, KS. The purpose of the study was to identify the effects of tillage intensity on precipitation capture, soil water storage, and grain yield in a wheat-sorghum-fallow rotation. Grain yields of wheat and grain sorghum increased with decreased tillage intensity in a wheat-sorghum-fallow (WSF) rotation. In 2016, available soil water at wheat and sorghum planting was greater for reduced tillage (RT) than no-tillage (NT) and least for conventional tillage (CT). Averaged across the 16-yr study, available soil water at wheat and sorghum planting was similar for RT and NT and about 1 inch greater than CT. Averaged across the past 16 years, NT wheat yields were 4 bu/a greater than RT and 7 bu/a greater than CT. Grain sorghum yields in 2016 were 15 bu/a greater with long-term NT than short-term NT. Averaged across the past 16 years, sorghum yields with long-term NT have been 70% greater than with short-term NT (68 vs. 40 bu/a).

Experimental Procedures

Research on different tillage intensities in a WSF rotation at the Tribune unit of the Southwest Research-Extension Center was initiated in 1991. The three tillage intensities in this study are conventional (CT), reduced (RT), and no-tillage (NT). The CT system was tilled as needed to control weed growth during the fallow period. On average, this resulted in four to five tillage operations per year, usually with a blade plow or field cultivator. The RT system originally used a combination of herbicides (one to two spray operations) and tillage (two to three tillage operations) to control weed growth during the fallow period; however, in 2001, the RT system was changed to using NT from wheat harvest through sorghum planting (short-term NT) and CT from sorghum harvest through wheat planting. The NT system exclusively used herbicides to control weed growth during the fallow period. All tillage systems used herbicides for in-crop weed control.

Results and Discussion

Soil Water

The amount of available water in the soil profile (0 to 8 ft) at wheat planting varied greatly from year to year (Figure 1). In 2016, available soil water at wheat planting was greater with RT than NT and least with CT. Averaged across the 16-yr study, available soil water at wheat planting was similar for RT and NT (about 7 inches) and about 1 inch greater than CT.

Similar to wheat, the amount of available water in the soil profile at sorghum planting varied greatly from year to year (Figure 2). In 2016, available soil water at sorghum planting was greater with RT than NT and least with CT. On average, available soil water at sorghum planting was similar for RT and NT and about 1 inch more than CT.

Grain Yields

Wheat yields in 2016 were 55 to 65 bu/a greater than the long-term average (Table 1). Since 2001, wheat yields have been depressed in 10 of 16 years, primarily because of lack of precipitation, while winterkill reduced yields in 2015. Reduced tillage and NT increased wheat yields. On average, wheat yields were 7 bu/a higher for NT (24 bu/a) than CT (17 bu/a). Wheat yields for RT were 3 bu/a greater than CT even though both systems had tillage prior to wheat. Yields of NT were significantly less than CT or RT in only 1 of the 16 years.

The yield benefit from RT was greater for grain sorghum than wheat. Grain sorghum yields for RT averaged 16 bu/a more than CT, whereas NT averaged 28 bu/a more than RT (Table 2). For sorghum, both RT and NT used herbicides for weed control during fallow, so the difference in yield could be attributed to short-term compared with long-term NT. In 2016, sorghum yields were 15 bu/a greater with long-term NT than short-term NT. This consistent yield benefit with long-term vs. short-term NT has been observed since the RT system was changed in 2001. Averaged across the past 16 years, sorghum yields with long-term NT have been 70% greater than with short-term NT (68 vs. 40 bu/a).

Acknowledgment

The U.S. Department of Agriculture, Agricultural Research Service Ogallala Aquifer Program partially supported this research project.

CROPPING AND TILLAGE SYSTEMS

Table 1. Wheat response to tillage in a wheat-sorghum-fallow rotation, Tribune, KS, 2001–2016

Year	Tillage			LSD (0.05)	ANOVA ($P > F$)		
	Conventional	Reduced	No-tillage		Tillage	Year	Tillage × year
	----- bu/a -----						
2001	17	40	31	8	0.002		
2002	0	0	0	---	---		
2003	22	15	30	7	0.007		
2004	1	2	4	2	0.001		
2005	32	32	39	12	0.360		
2006	0	2	16	6	0.001		
2007	26	36	51	15	0.017		
2008	21	19	9	14	0.142		
2009	8	10	22	9	0.018		
2010	29	35	50	8	0.002		
2011	22	20	20	7	0.649		
2012	0	1	5	1	0.001		
2013	0	0	0	---	---		
2014	10	11	18	12	0.336		
2015	10	9	9	9	0.966		
2016	72	85	82	18	0.239		
Mean	17c	20b	24a	2	0.001	0.001	0.001

ANOVA = analysis of variance.

LSD = least significant difference.

CROPPING AND TILLAGE SYSTEMS

Table 2. Grain sorghum response to tillage in a wheat-sorghum-fallow rotation, Tribune, KS, 2001–2016

Year	Tillage			LSD (0.05)	ANOVA ($P > F$)		
	Conventional	Reduced	No-tillage		Tillage	Year	Tillage × year
	----- bu/a -----						
2001	6	43	64	7	0.001		
2002	0	0	0	---	---		
2003	7	7	37	8	0.001		
2004	44	67	118	14	0.001		
2005	28	38	61	35	0.130		
2006	4	3	29	10	0.001		
2007	26	43	62	42	0.196		
2008	16	25	40	20	0.071		
2009	19	5	72	31	0.004		
2010	10	26	84	9	0.001		
2011	37	78	113	10	0.001		
2012	0	0	0	---	---		
2013	37	51	78	32	0.053		
2014	38	72	94	28	0.008		
2015	56	60	102	55	0.153		
2016	55	124	139	47	0.010		
Mean	24c	40b	68a	6	0.001	0.001	0.001

ANOVA = analysis of variance.
LSD = least significant difference.

CROPPING AND TILLAGE SYSTEMS

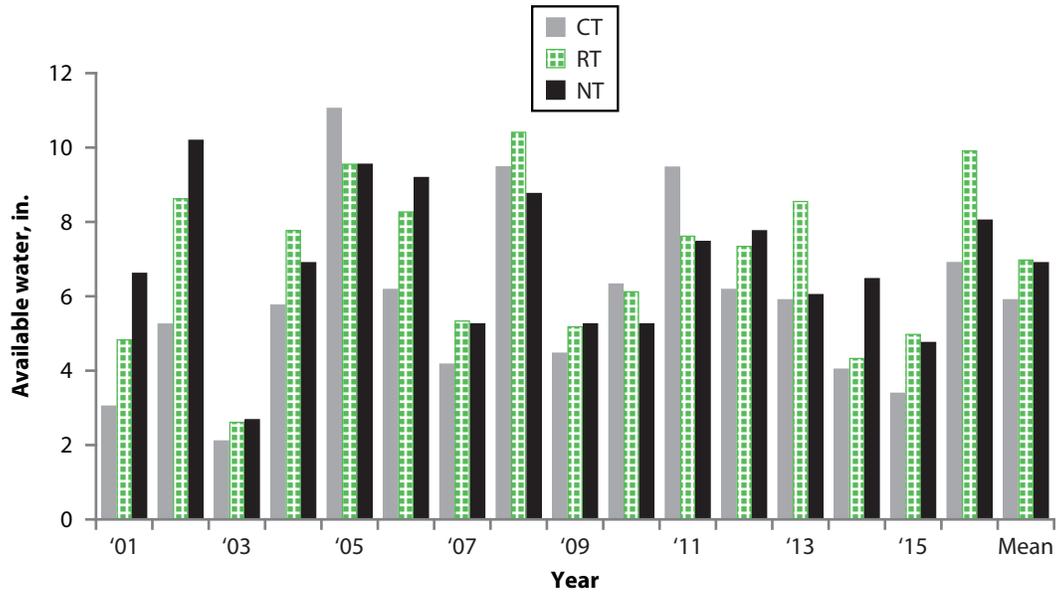


Figure 1. Available soil water in 8-ft profile at planting of wheat in a wheat-sorghum-fallow rotation as affected by tillage intensity, Tribune, KS, 2001–2016. The last set of bars (Mean) is the average across years. CT = conventional tillage, RT = reduced tillage, NT = no-tillage.

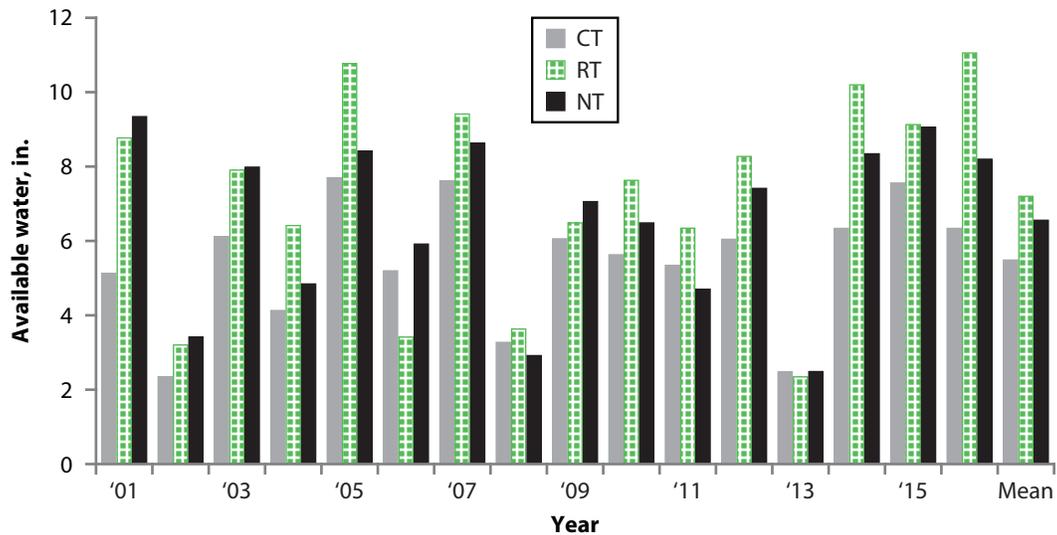


Figure 2. Available soil water in 8-ft profile at planting of grain sorghum in a wheat-sorghum-fallow rotation as affected by tillage intensity, Tribune, KS, 2001–2016. The last set of bars (Mean) is the average across years. CT = conventional tillage, RT = reduced tillage, NT = no-tillage.

Wheat Stubble Height on Subsequent Corn and Grain Sorghum Crops

A. Schlegel and L. Haag

Summary

A field study initiated in 2006 at the Southwest Research-Extension Center near Tribune, KS, was designed to evaluate the effects of three wheat stubble heights on subsequent grain yields of corn and grain sorghum. Corn and sorghum yields in 2016 were greater than the long-term average. When averaged from 2007 through 2016, corn grain yields were 10 bu/a greater when planted into either high or strip-cut stubble than into low-cut stubble. Average grain sorghum yields were 6 bu/a (but not significantly) greater in high-cut stubble than low-cut stubble. Similarly, water use efficiency was greater for high or strip-cut stubble for corn and high-cut stubble for grain sorghum than for low-cut stubble. Harvesting wheat shorter than necessary causes a yield penalty for the subsequent row crops, especially dryland corn.

Introduction

Seeding of summer row crops throughout the west-central Great Plains often occurs following wheat in a 3-year rotation (wheat-summer crop-fallow). Wheat residue provides numerous benefits including evaporation suppression, delayed weed growth, improved capture of winter snowfall, and soil erosion reductions. Stubble height affects wind velocity profile, surface radiation interception, and surface temperatures, all of which affect evaporation suppression and winter snow catch. Taller wheat stubble is also beneficial to pheasants in postharvest and overwinter fallow periods. Using stripper headers increases harvest capacity and provides taller wheat stubble than previously attainable with conventional small-grains platforms. Increasing wheat cutting heights or using a stripper header should further improve the effectiveness of standing wheat stubble. The purpose of this study is to evaluate the effect of wheat stubble height on subsequent summer row crop yields.

Experimental Procedures

This study was conducted at the Southwest Research-Extension Center dryland station near Tribune, KS. From 2007 through 2016, corn and grain sorghum were planted into standing wheat stubble of three heights. Optimal (high) cutter-bar height is the height necessary to maximize both grain harvested and standing stubble remaining (typically around two-thirds of total plant height). The short cut treatment was half of optimal cutter-bar height, and the third treatment was stubble remaining after stripper header harvest. For 2016, these heights were 25, 17, and 8 in. (cut after 2015 wheat harvest). In 2016, corn and grain sorghum were seeded at rates of 15,000 seeds/a and 45,000 seeds/a, respectively. Nitrogen was applied to all plots at a rate of 80 lb/a. Starter fertilizer (10-34-0 nitrogen phosphorus potassium (N-P-K)) was surface-dribbled off-row at a rate of 7 gal/a. Plots were 40 × 60 ft, with treatments arranged in a randomized complete block design with six replications. Two rows from the center of each plot were harvested with a plot combine for yield and yield component analysis. Soil water mea-

surements were obtained with neutron attenuation to a depth of 6 ft in 1-ft increments at seeding and harvest to determine water use and water use efficiency.

Results and Discussion

The 2016 growing season was above normal for precipitation, with April having more than 5 inches and July more than 4 inches. This produced above-average yields for both corn and sorghum (Tables 1-4). Corn yields were 10 bu/a greater in high- or strip-cut than low-cut wheat stubble, which is consistent with the long-term average. Biomass production and water use efficiency were also greater with the taller stubble.

Grain sorghum yields in 2016 were not affected by stubble height (Table 3). When averaged across years from 2007 through 2016, the highest yields were obtained in the high-cut stubble but were not significantly greater than the other stubble heights. None of the other measured parameters for grain sorghum were affected by wheat stubble height except for greater water use efficiency in high-cut vs. low-cut stubble.

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Table 1. Corn yield, biomass, and yield components as affected by stubble height, Tribune, KS, 2016

Stubble height	Yield bu/a	Plant	Ear	Biomass	Residue	1,000-seed	Kernels	WUE ¹
		population	population			weight		
		-----	10 ³ /a -----	-----	lb/a -----	oz	no/ear	lb/in.
Low	112	14.0	14.1	12868	7547	13.67	523	353b
High	122	14.1	14.0	11906	6116	13.73	569	397a
Strip	123	14.0	13.9	11715	5911	13.89	568	393a
LSD _{0.05}	12	0.7	0.6	1389	1521	0.38	48	35
ANOVA (P > F)								
Stubble height	0.138	0.952	0.814	0.191	0.074	0.470	0.094	0.035

¹Water use efficiency (lb of grain/inch of water use).

LSD = least significant difference.

ANOVA = analysis of variance.

Table 2. Corn yield, biomass, and yield components as affected by stubble height, Tribune, KS, 2007 - 2016

Stubble height	Yield bu/a	Plant	Ear	Biomass	Residue	1,000-seed	Kernels	WUE ¹
		population	population			weight		
		-----	10 ³ /a -----	-----	lb/a -----	oz	no/ear	lb/in.
Low	76b	13.9	13.5	9151b	5550	10.56	520	285b
High	86a	13.9	13.9	10210a	6144	10.84	509	324a
Strip	86a	14.0	13.9	10208a	6139	10.74	544	324a
LSD _{0.05}	5	0.5	0.6	634	549	0.29	85	21
ANOVA (P > F)								
Year	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Stubble height	0.001	0.970	0.319	0.001	0.052	0.154	0.720	0.001
Year × stubble height	0.979	0.994	0.975	0.351	0.077	0.793	0.932	0.963

¹Water use efficiency (lb of grain/inch of water use).

LSD = least significant difference.

ANOVA = analysis of variance.

CROPPING AND TILLAGE SYSTEMS

Table 3. Sorghum yield and yield components as affected by stubble height, Tribune, KS, 2016

Stubble height	Yield bu/a	Head	Biomass ----- lb/a -----	Residue	1,000-seed	Kernels no/head	WUE ¹ lb/in.
		population 10 ³ /a			weight oz		
Low	125	66.8	13213	7102	0.93	1792	424
High	131	69.6	13614	7173	0.95	1778	445
Strip	128	66.2	13660	7411	0.93	1855	433
LSD _{0.05}	5	0.4	847	777	0.03	80	34
ANOVA (P > F)							
Stubble height	0.059	0.193	0.462	0.661	0.177	0.121	0.439

¹ Water use efficiency (lb of grain/inch of water use).

LSD = least significant difference.

ANOVA = analysis of variance.

Table 4. Sorghum yield, biomass, and yield components as affected by stubble height, Tribune, KS, 2007 - 2016

Stubble height	Yield bu/a	Head	Biomass ² ----- lb/a -----	Residue ²	1,000 seed	Kernels no/head	WUE ¹ lb/in.
		population 10 ³ /a			weight oz		
Low	96	52.8	10647	5994	0.88	1920	380b
High	102	54.5	11235	6319	0.89	1988	408a
Strip	98	53.8	10837	6060	0.87	1906	393ab
LSD _{0.05}	5	2.4	595	531	0.02	121	21
ANOVA (P > F)							
Year	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Stubble height	0.061	0.384	0.140	0.442	0.104	0.353	0.032
Year × stubble height	0.996	0.846	0.997	0.989	0.673	0.024	0.932

¹ Water use efficiency (lb of grain/inch of water use).

² 2015 values not included in average - no samples collected.

LSD = least significant difference.

ANOVA = analysis of variance.

Wheat and Grain Sorghum in Four-Year Rotations

A. Schlegel, J. Holman, and C. Thompson

Summary

In 1996, an effort began to quantify soil water storage, crop water use, and crop productivity on dryland systems in western Kansas. Research on 4-year crop rotations with wheat and grain sorghum was initiated at the Southwest Research-Extension Center near Tribune, KS. Rotations were wheat-wheat-sorghum-fallow (WWSF), wheat-sorghum-sorghum-fallow (WSSF), and continuous wheat (WW). Soil water at wheat planting averaged about 9 in. following sorghum, which is about 3 in. more than the average for the second wheat crop in a WWSF rotation. Soil water at sorghum planting was only about 1 in. less for the second sorghum crop compared with sorghum following wheat. Grain yield of recrop wheat averaged about 80% of the yield of wheat following sorghum. Grain yield of continuous wheat averaged about 65% of the yield of wheat grown in a 4-year rotation following sorghum. Generally, wheat yields were similar following one or two sorghum crops. Similarly, average sorghum yields were the same following one or two wheat crops. Yield of the second sorghum crop in a WSSF rotation averaged ~65% of the yield of the first sorghum crop.

Introduction

In recent years, cropping intensity has increased in dryland systems in western Kansas. The traditional wheat-fallow system is being replaced by wheat-summer crop-fallow rotations. Research was conducted to better understand if more intensive cropping is feasible with concurrent increases in no-tillage. Objectives of this research were to quantify soil water storage, crop water use, and crop productivity of 4-year and continuous cropping systems.

Experimental Procedures

Research on 4-year crop rotations with wheat and grain sorghum was initiated in 1996 at the Tribune unit of the Southwest Research-Extension Center. Rotations were WWSF, WSSF, and WW. No-tillage was used for all rotations except during the first two years when reduced tillage was used for wheat following sorghum. Available water was measured in the soil profile (0 to 6 ft) at planting and harvest of each crop. The center of each plot was machine harvested after physiological maturity, and yields were adjusted to 12.5% moisture.

Results and Discussion

Soil Water

The amount of available water in the soil profile (0 to 6 ft) at wheat planting varied greatly from year to year (Figure 1). In 2016, available soil water was slightly greater for wheat following sorghum and slightly less for wheat following wheat compared to the long-term average. Soil water was similar following fallow after either one or two sorghum crops and averaged about 9 in. across the 20-year study period. Water at planting of the second wheat crop in a WWSF rotation was generally less than at planting

of the first wheat crop, except in 1997 and 2003. Soil water for the second wheat crop averaged more than 3 in. (or about 40%) less than that for the first wheat crop in the rotation. Continuous wheat averaged about 0.8 in. less water at planting than the second wheat crop in a WWSF rotation.

Similar to wheat, the amount of available water in the soil profile at sorghum planting varied greatly from year to year (Figure 2). Soil water was similar following fallow after either one or two wheat crops and averaged about 8 in. over 21 years. Water at planting of the second sorghum crop in a WSSF rotation was generally less than that at planting of the first sorghum crop. Averaged across the entire study period, the first sorghum crop had about 1.3 in. more available water at planting than the second crop.

Grain Yields

In 2016, wheat yields were greater than the long-term average for all rotations (Table 1). Averaged across 20 years, recrop wheat (the second wheat crop in a WWSF rotation) yielded about 80% of first-year wheat crop in WWSF. Before 2003, recrop wheat yielded about 70% of first-year wheat. Wheat yields following two sorghum crops are 2 bu/a greater than following one sorghum crop. In most years, continuous wheat yields have been similar to recrop wheat yields, but in several years (2003, 2007, 2009, and 2014), recrop wheat yields were considerably greater than continuous wheat yields.

Sorghum yields in 2016 for all rotations were 46 to 58 bu/a greater than the long-term average (Table 2). Sorghum yields were similar following one or two wheat crops, which is consistent with the long-term average. The second sorghum crop yields were 73% of the first sorghum crop in 2016, which is slightly greater than the long-term average of about 65%.

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Table 1. Wheat response to dryland crop rotation, Tribune, KS, 1997–2016

Year	Rotation				LSD 0.05	ANOVA (P > F)		
	Wssf ¹	Wwsf	wWsf	WW		Rotation	Year	Year × rotation
	----- bu/a -----							
1997	57	55	48	43	8	0.017		
1998	70	64	63	60	12	0.391		
1999	74	80	41	43	14	0.001		
2000	46	35	18	18	10	0.001		
2001	22	29	27	34	14	0.335		
2002	0	0	0	0	---	---		
2003	29	27	66	30	14	0.001		
2004	5.7	6.1	0.4	0.5	1.6	0.001		
2005	45	40	41	44	10	0.690		
2006	28	26	7	2	8	0.001		
2007	75	61	63	41	14	0.004		
2008	40	40	5	6	5	0.001		
2009	37	39	50	24	15	0.029		
2010	63	60	29	23	9	0.001		
2011	25	22	25	17	8	0.152		
2012	14	20	10	9	15	0.380		
2013	0	0	0	0	---	---		
2014	51	45	31	12	18	0.004		
2015	49	36	24	24	12	0.001		
2016	78	77	58	52	12	0.001		
Mean	40a	38b	30c	24d	2	0.001	0.001	0.001

¹ W, wheat; S, sorghum; capital letters denote current year's crop.

Wheat-sorghum-sorghum-fallow (WSSF), wheat-wheat-sorghum-fallow (WWSF), and continuous wheat (WW).

ANOVA = analysis of variance.

LSD = least significant difference.

CROPPING AND TILLAGE SYSTEMS

Table 2. Grain sorghum response to crop rotation, Tribune, KS, 1996–2016

Year	Rotation				ANOVA (P>F)		
	wSsf ¹	wsSf	wwSf	LSD 0.05	Rotation	Year	Year × rotation
	----- bu/a -----						
1996	58	35	54	24	0.117		
1997	88	45	80	13	0.001		
1998	117	100	109	12	0.026		
1999	99	74	90	11	0.004		
2000	63	23	67	16	0.001		
2001	68	66	73	18	0.673		
2002	0	0	0	---	---		
2003	60	41	76	18	0.009		
2004	91	79	82	17	0.295		
2005	81	69	85	20	0.188		
2006	55	13	71	15	0.001		
2007	101	86	101	9	0.008		
2008	50	30	57	12	0.005		
2009	89	44	103	53	0.080		
2010	98	52	105	24	0.004		
2011	119	47	105	34	0.005		
2012	0	0	0	---	---		
2013	105	98	100	23	0.742		
2014	91	5	84	29	0.001		
2015	125	82	124	22	0.005		
2016	134	98	139	10	0.001		
Mean	81a	52b	81a	4	0.001	0.001	0.001

¹ W, wheat; S, sorghum; capital letters denote current year's crop.

Wheat-sorghum-sorghum-fallow (WSSF) and wheat-wheat-sorghum-fallow (WWSF).

ANOVA = analysis of variance.

LSD = least significant difference.

CROPPING AND TILLAGE SYSTEMS

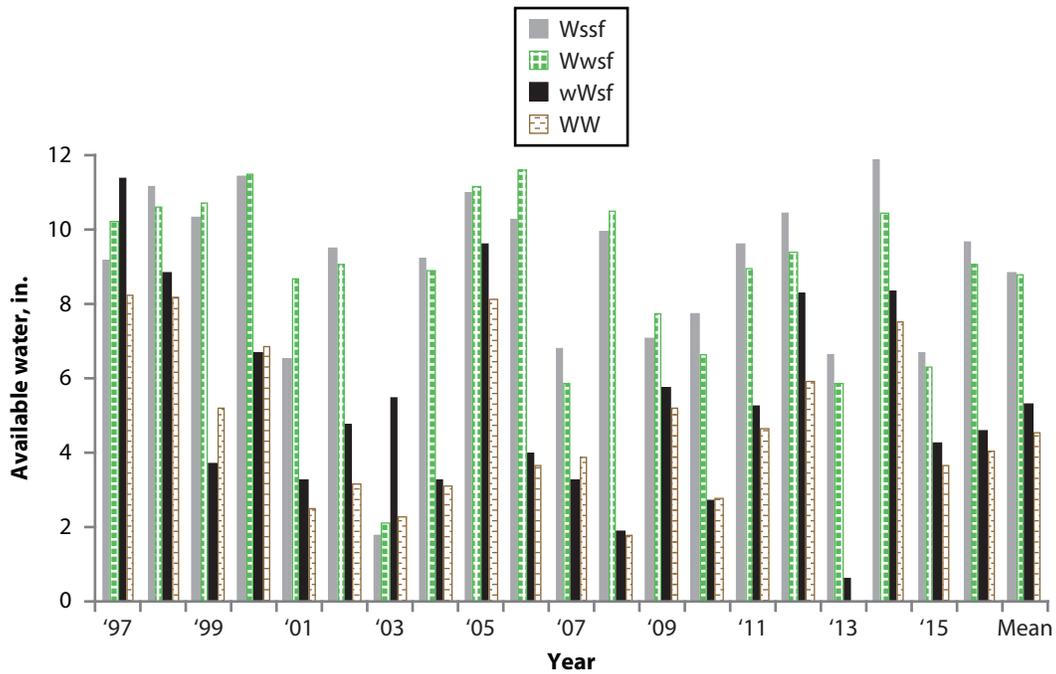


Figure 1. Available soil water in 6-ft profile at planting of wheat in several rotations at Tribune, KS, 1997–2016. Capital letter denotes current crop in rotation (W, wheat; S, sorghum). The last set of bars (Mean) is the average across years. Wheat-sorghum-sorghum-fallow (WSSF), wheat-wheat-sorghum-fallow (WWSF), and continuous wheat (WW).

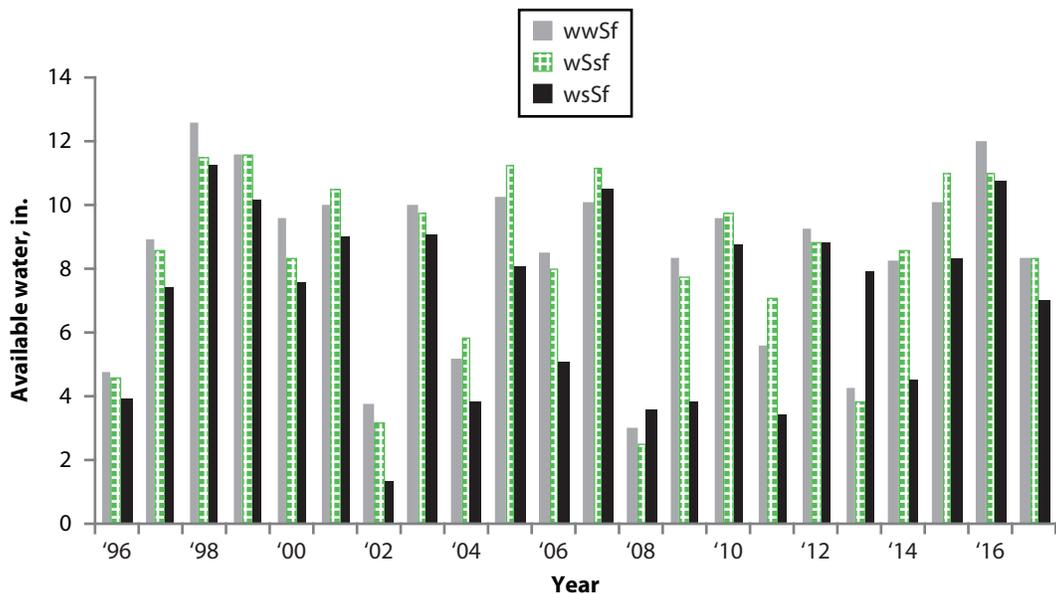


Figure 2. Available soil water in 6-ft profile at planting of sorghum in several rotations at Tribune, KS, 1996–2016. Capital letter denotes current crop in rotation (W, wheat; S, sorghum). The last set of bars (Mean) is the average across years. Wheat-sorghum-sorghum-fallow (WSSF) and wheat-wheat-sorghum-fallow (WWSF).

Seeding Rate for Dryland Wheat

A. Schlegel, J. Holman, and L. Haag

Summary

Four winter wheat varieties (PlainsGold Byrd, Limagrain T158, Syngenta TAM 111, and WestBred Winterhawk) were planted at five seeding rates (30, 45, 60, 75, and 90 lb/a) in the fall of 2014 and 2015 at Colby, Garden City, and Tribune, KS. The objective of the study was to identify appropriate seeding rates for dryland winter wheat in western Kansas. Averaged across varieties, a seeding rate of 60 lb/a seemed to be adequate at all locations in 2015. However, with higher yields in 2016, a higher seeding rate (75 lb/a) was beneficial. The wheat variety T158 was the highest yielding (or in the highest group) at all locations in 2015. Other varieties may have been affected by differential response to stripe rust and winter injury resulting in lower yields. In 2016, the highest yielding variety varied by location. Variety selection appears to have more effect on wheat yields than seeding rate.

Introduction

The purpose of this project is to determine appropriate seeding rates for dryland winter wheat in western Kansas. In recent years, there appears to be an increase in seeding rate without corresponding increase in grain yields. A preliminary study conducted in 2014 found no yield benefit from increasing seeding rates from 30 to 75 lb seed/a for 4 wheat varieties at Tribune, while a similar study at Garden City suffered severe hail damage, causing yields to be less than 10 bu/a. The objective is to evaluate seeding rates on grain yield of several popular wheat varieties under dryland conditions at three sites in western Kansas.

Experimental Procedures

Four winter wheat varieties (Byrd, T158, TAM 111, and Winterhawk) were planted at five seeding rates (30, 45, 60, 75, and 90 lb/a) in the fall of 2014 and 2015 at Colby, Garden City, and Tribune, KS. The date of seeding was October 20, 2014, and October 14, 2015, at Colby; October 9, 2014, and October 9, 2015, at Garden City; and September 26, 2014, and October 13, 2015, at Tribune. Seed size in 2015 was 15,839, 15,479, 17,627, and 12,921 seed/lb for Byrd, T158, TAM 111, and Winterhawk, respectively. All plots were planted on no-tillage fallow land. Harvest was done on July 4, 2015, and July 10, 2016, at Colby; June 29, 2015, and June 22, 2016, at Garden City; and June 30, 2015, and July 4, 2016, at Tribune. Growing season precipitation (October through June) for 2015 wheat was 14.03 in. at Colby, 12.18 in. at Garden City, and 12.83 in. at Tribune. For 2016, growing season precipitation was 12.36 in. at Colby, 11.31 in. at Garden City, and 14.32 in. at Tribune. Starter fertilizer was applied (5.5-26-0 (nitrogen, N; phosphorus, P; and potassium, K)) at Garden City and (6-20-0) at Tribune in 2015 and 2016. The wheat was topdressed with 90 lb N/a at Colby, 30 lb N/a at Garden City, and 60 lb N/a at Tribune in 2015. In 2016, wheat was fertilized pre-plant with 90 lb N/a at Colby, and topdressed with 100 lb N/a at Garden City and 80 lb N/a at Tribune. Herbicides were applied in the spring for weed control: Ally Extra (0.5 oz/a) at Colby in 2015, and Huskie (15 oz/a) + Dicamba (2 oz/a) + Zidua (2 oz/a) in 2016; Starane Ultra (0.4 pt/a) + MCPA (0.75 pt/a) + Ally (0.1 oz/a) at

Garden City in 2015 and 2016; and dicamba (4 oz/a) + Ally (0.1 oz/a) at Tribune in 2015 and 2016. Plot size was 7.5- by 30-ft at Garden City, and 5- by 40-ft at Colby and Tribune. Fungicide was applied for control of stripe rust at flag leaf emergence at Colby and Tribune in 2016. All treatments were replicated four times. Grain yields were determined by harvesting with a plot combine with moisture corrected to 13%.

Results and Discussion

Growing season precipitation was near normal for Garden City and Tribune and above normal for Colby in 2015. However, this was created by a wet May (6.38 in. in Garden City, 6.16 in. at Tribune, and 6.42 in. at Colby), making up for a dry winter and early spring. For 2016, rainfall was above normal for Tribune, slightly below normal for Garden City, and below normal at Colby. April was wet, with 5.16 in. at Tribune, 4.59 in. at Garden City, and 5.64 in. at Colby.

In 2015, averaged across seeding rates at Tribune, T158 and Winterhawk produced the greatest yields, with TAM 111 producing the lowest yields (Table 1). At both Colby and Garden City in 2015, T158 produced significantly higher yields than all other varieties. Stripe rust was prevalent in the 2015 growing season. Resistance ratings from the Kansas State University Department of Plant Pathology (publication MF991, Wheat Variety Disease and Insect Ratings 2016), with a scale of 1 being resistant to 10 being susceptible, were 8, 2, 8, and 6 for Byrd, T158, TAM111, and Winterhawk, respectively. Stripe rust infestation and associated yield reductions at Colby (and other locations) were consistent with these ratings.

At all sites averaged across varieties in 2015, there was a positive yield response to increased seeding rates, with greatest response when increasing from 30 up to 60 lb/a and minimal response above 60 lb/a.

Wheat yields were very good at all locations in 2016 (Table 2). The response to variety and seeding rate varied greatly across locations. Averaged across seeding rates, Byrd produced the greatest yields at Tribune, while it produced the lowest yields at Garden City. Winterhawk and T158 were the lowest yielding at Tribune, while they were the highest yielding at Garden City and Colby. There was a significant positive yield response to increased seeding rate at Tribune and Colby but no significant response to seeding rate at Garden City.

Based on 2015 results, it appears that a seeding rate of 60 lb/a was adequate for all locations. However, based on 2016 results and higher wheat yields (>70 bu/a), it appears that a seeding rate of 75 lb/a produced near maximum yields, with little benefit from a 90 lb/a seeding rate. Variety selection had a significant effect on yield but was inconsistent across locations and years. There was no variety by seeding rate interaction at any location in 2016, showing that the seeding rate decision could be made independently of variety selection.

CROPPING AND TILLAGE SYSTEMS

Table 1. Dryland wheat response to variety and seeding rate at three locations in 2015

Variety	Seeding rate	Grain yield			
		Tribune	Garden City	Colby	Average
	lb/a	bu/a			
Byrd	30	47	38	23	36
	45	53	42	25	40
	60	60	50	27	46
	75	54	51	29	45
	90	59	53	28	46
T158	30	59	72	45	59
	45	60	71	53	61
	60	64	79	56	67
	75	70	71	53	65
	90	71	65	55	64
TAM 111	30	39	34	20	31
	45	41	40	25	35
	60	43	44	28	39
	75	46	50	32	43
	90	45	52	34	43
Winterhawk	30	60	31	21	37
	45	67	41	25	44
	60	68	42	29	47
	75	64	51	34	50
	90	68	50	35	51

continued

CROPPING AND TILLAGE SYSTEMS

Table 1. Dryland wheat response to variety and seeding rate at three locations in 2015

Variety	Seeding rate lb/a	Grain yield			
		Tribune	Garden City	Colby	Average
		----- bu/a -----			
ANOVA (P>F)					
Variety		0.001	0.001	0.001	0.001
Seeding rate		0.001	0.001	0.001	0.001
Variety × seeding rate		0.046	0.001	0.731	0.124
Location		---	---	---	0.001
Location × variety		---	---	---	0.001
Location × seeding rate		---	---	---	0.743
Location × variety × seeding rate		---	---	---	0.001
MEANS¹					
Variety					
Byrd		55b	47b	26b	43c
T158		65a	72a	53a	63a
TAM 111		43c	44bc	28b	38d
Winterhawk		65a	43c	29b	46b
LSD _{0.05}		2	3	3	2
Seeding rate (lb/a)					
30		51c	44c	27c	41c
45		55b	49b	32b	45b
60		59a	54a	35ab	49a
75		59a	56a	37a	50a
90		61a	55a	38a	51a
LSD _{0.05}		3	4	4	2

¹ Means within a column with the same letter are not statistically different at $P = 0.05$.

ANOVA = analysis of variance.

LSD = least significant difference.

CROPPING AND TILLAGE SYSTEMS

Table 2. Dryland wheat response to variety and seeding rate at three locations in 2016

Variety	Seeding rate	Grain yield			
		Tribune	Garden City	Colby	Average
	lb/a	bu/a			
Byrd	30	70	78	89	79
	45	76	79	100	85
	60	81	76	103	87
	75	86	79	116	94
	90	90	78	103	90
T158	30	60	107	102	90
	45	67	109	115	97
	60	69	110	107	95
	75	74	114	111	99
	90	73	115	115	101
TAM 111	30	63	89	95	82
	45	65	91	91	82
	60	72	90	106	89
	75	75	95	108	93
	90	77	96	110	94
Winterhawk	30	61	95	94	83
	45	65	99	100	88
	60	67	101	112	94
	75	70	105	111	95
	90	74	103	114	97

continued

CROPPING AND TILLAGE SYSTEMS

Table 2. Dryland wheat response to variety and seeding rate at three locations in 2016

Variety	Seeding rate lb/a	Grain yield			
		Tribune	Garden City	Colby	Average
		----- bu/a -----			
ANOVA (P>F)					
Variety		0.001	0.001	0.029	0.001
Seeding rate		0.001	0.205	0.001	0.001
Variety × seeding rate		0.361	0.999	0.190	0.584
Location		---	---	---	0.015
Location × variety		---	---	---	0.001
Location × seeding rate		---	---	---	0.058
Location × variety × seeding rate		---	---	---	0.594
MEANS¹					
Variety					
Byrd		81a	78d	102b	90c
T158		68bc	111a	110a	96a
TAM 111		71b	92c	102b	88c
Winterhawk		68c	101b	106ab	91b
LSD _{0.05}		2	5	6	3
Seeding rate (lb/a)					
30		63d	92	95c	84d
45		68c	95	102b	88c
60		72b	94	107ab	91b
75		76a	98	112a	95a
90		78a	98	111a	96a
LSD _{0.05}		2	6	6	3

¹ Means within a column with the same letter are not statistically different at $P = 0.05$.

ANOVA = analysis of variance.

LSD = least significant difference.

Occasional Tillage in a Wheat-Sorghum-Fallow Rotation

A. Schlegel and J. Holman

Summary

Beginning in 2012, research was conducted in Garden City and Tribune, KS, to determine the effect of a single tillage operation every 3 years on grain yields in a wheat-sorghum-fallow (WSF) rotation. Grain yields of wheat and grain sorghum were not affected by a single tillage operation every 3 years in a WSF rotation. Grain yield varied greatly by year from 2014 to 2016. Wheat yields ranged across years from mid-20s to 80 bu/a at Tribune, and about 10 (hail damage) to near 60 bu/a at Garden City. Grain sorghum yields ranged from less than 60 to greater than 130 bu/a, depending upon year and location. In no year or location were grain yields significantly affected by a single tillage operation. This indicates that if a single tillage operation is needed to control troublesome weeds, grain yields will not be significantly affected.

Introduction

Previous research has shown lower dryland wheat and grain sorghum yields with reduced tillage compared with no-tillage in a wheat-sorghum-fallow (WSF) rotation. The reduced tillage systems generally used four or more tillage operations in the 3-yr rotation. With increased incidence of herbicide-resistant weeds, the use of a complete no-tillage system may not be economical, and tillage may be needed for effective control. The objective of the research project is to determine the effect of a single tillage operation every 3 years on grain yields in a WSF rotation.

Experimental Procedures

Research on occasional tillage intensities in a predominantly no-tillage WSF rotation at the Kansas State University Southwest Research-Extension Center research stations at Garden City and Tribune was initiated in 2012. The three tillage treatments in this study were a single tillage in May or June during fallow, a single tillage after wheat harvest, and a complete no-tillage system. A sweep plow was used for all tillage operations. When needed, herbicides were used to control weeds during fallow for all treatments. All treatments used herbicides for in-crop weed control. All other cultural practices (variety/hybrid, seeding rate, fertilization, etc.) were the same for all treatments.

Results and Discussion

At Tribune, wheat yields were 75 to 80 bu/a in 2016, compared with 23 to 28 bu/a in 2014 and 2015 (Table 1). There were no significant yield differences among tillage treatments in any year or across years. Grain sorghum yields were similar in 2015 and 2016 at 118 to 133 bu/a, respectively, which were considerably greater than 2014 with yields of 77 to 84 bu/a (Table 2). Similar to wheat, there were no significant yield differences among tillage treatments in any year or averaged across years.

At Garden City, wheat yields were greater in 2016 than earlier years (Table 3). Wheat yields in 2014 were severely reduced by hail. There were no significant yield differences

among tillage treatments in any year or averaged across years. Favorable growing conditions caused grain sorghum yields in 2016 to be about twice the yields of 2014 and 2015 (Table 4). Similar to wheat, there were no significant yield differences among tillage treatments in any year or averaged across years.

In other research, reduced tillage systems produced lower yields than a complete no-tillage system in a WSF rotation. However, in this study, a single tillage operation in a 3-yr WSF rotation did not affect wheat or grain sorghum yields from 2014 to 2016 at Garden City or Tribune, KS.

Reference

Shlegel, A. (2017) "Tillage Intensity in a Long-Term Wheat-Sorghum-Fallow Rotation," *Kansas Agricultural Experiment Station Research Reports*: Vol. 3 Iss. 5.

Acknowledgment

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CROPPING AND TILLAGE SYSTEMS

Table 1. Grain yield response of dryland wheat to a single tillage operation (sweep plow) in a 3 year wheat-sorghum-fallow rotation grown from 2014 to 2016 near Tribune, KS

Tillage	Year			Average
	2014	2015	2016	
	----- bu/a -----			
No-tillage	28	24	75	42
June in fallow	26	25	80	44
July post-harvest	24	23	75	41
ANOVA (P > F)				
No-tillage vs. tillage	0.381	0.983	0.350	0.899
June vs. July	0.551	0.555	0.053	0.078
Year	--	--	--	0.001
Year × tillage	--	--	--	0.434

ANOVA = analysis of variance.

Table 2. Grain yield response of dryland grain sorghum to a single tillage operation (sweep plow) in a 3-year wheat-sorghum-fallow rotation grown from 2014 to 2016 near Tribune, KS

Tillage	Year			Average
	2014	2015	2016	
	----- bu/a -----			
No-tillage	77	133	129	113
June in fallow	84	124	131	113
July post-harvest	79	118	129	109
ANOVA (P > F)				
No-tillage vs. tillage	0.445	0.095	0.852	0.469
June vs. July	0.395	0.404	0.617	0.192
Year	--	--	--	0.001
Year × tillage	--	--	--	0.019

ANOVA = analysis of variance.

Table 3. Grain yield response of dryland wheat to a single tillage operation (sweep plow) in a 3-year wheat-sorghum-fallow rotation grown from 2014 to 2016 near Garden City, KS

Tillage	Year			Average
	2014	2015	2016	
	----- bu/a -----			
No-tillage	8	34	55	32
June in fallow	8	37	58	34
July post-harvest	10	33	56	33
ANOVA (P > F)				
No-tillage vs. tillage	0.767	0.686	0.460	0.394
June vs. July	0.222	0.101	0.200	0.230
Year	--	--	--	0.001
Year × tillage	--	--	--	0.097

ANOVA = analysis of variance.

Table 4. Grain yield response of dryland grain sorghum to a single tillage operation (sweep plow) in a 3-year wheat-sorghum-fallow rotation grown from 2014 to 2016 near Garden City, KS

Tillage	Year			Average
	2014	2015	2016	
	----- bu/a -----			
No-tillage	58	63	116	79
June in fallow	57	64	123	81
July post-harvest	53	71	121	81
ANOVA (P>F)				
No-tillage vs. tillage	0.602	0.478	0.115	0.475
June vs. July	0.485	0.204	0.362	0.971
Year	--	--	--	0.001
Year × tillage	--	--	--	0.428

ANOVA = analysis of variance.

Alternative Cropping Systems with Limited Irrigation

A. Schlegel

Summary

A limited irrigation study involving four cropping systems and evaluating four crop rotations was initiated at the Southwest Research-Extension Center near Tribune, KS, in 2012. The cropping systems were two annual systems (continuous corn [C-C] and continuous grain sorghum [GS-GS]) and two 2-year systems (corn-grain sorghum [C-GS]) and corn-winter wheat [C-W]). In 2016, corn yields were similar in all rotations, as were grain sorghum yields. This tended to agree with the 4-yr average yields, except for average grain sorghum yields being higher following corn than grain sorghum.

Experimental Procedures

A crop rotation study under sprinkler irrigation at the Kansas State University Southwest Research-Extension Center near Tribune was initiated in the spring of 2012. The study evaluates four different crop rotations with a limited irrigation allocation. The rotations include 1- and 2-year rotations. The crop rotations are 1) continuous corn; 2) corn-winter wheat; 3) corn-grain sorghum; and 4) continuous grain sorghum (a total of 6 treatments). All rotations are limited to 10 inches of irrigation water annually. All crops are grown no-till, while other cultural practices (hybrid selection, fertility practices, weed control, etc.) are selected to optimize production. All phases of each rotation are present each year and replicated four times. Irrigations are scheduled to supply water at the most critical stress periods for the specific crops and limited to 1.5 inches/week. Soil water is measured at planting, during the growing season, and at harvest in 1-ft increments to a depth of 8 ft. Grain yields are determined by machine harvest. Nitrogen fertilizer (UAN) was surface applied (stream) in March to all crops (240 lb N/a for corn, 160 lb N/a for grain sorghum, and 120 lb N/a for wheat). Corn was planted on April 28, 2016, and harvested on September 15, 2016. Grain sorghum was planted on June 1, 2016, and harvested on October 20, 2016. Wheat was planted on September 29, 2015, and harvested on July 8, 2016.

Results and Discussion

Weather conditions were good for crop production in 2016. Precipitation was above normal for April, July, August, and September. Open pan evaporation was 13% below normal from April through September. Corn yields in 2016 were similar for all rotations with a range of 174 to 186 bu/a (Table 1). Wheat yields in 2016 (82 bu/a) were greater than the multi-year average yield of 64 bu/a (Table 2). Grain sorghum yields were similar following corn or grain sorghum at about 150 bu/a. Averaged across four years, continuous grain sorghum yields were 10 bu/a less than following corn. Available soil water at corn planting and harvest was similar for all rotations in 2016 (Table 3). Fallow efficiency was less following wheat than following either corn or grain sorghum. For wheat, available soil water at planting and harvest was greater than the 4-yr average (Table 4). The only difference observed with grain sorghum was more fallow accumulation for grain sorghum following corn than following grain sorghum. This

was consistent with the average fallow accumulation for the past 4 years. Average crop water use was similar for all rotations for corn and both rotations with grain sorghum.

Acknowledgment

The project was funded in part by Western Kansas Groundwater Management District No. 1.

Table 1. Grain yield of three crops under limited irrigation as affected by rotation in 2016

Rotation	Corn	Wheat	Grain sorghum
	----- bu/a -----		
Continuous corn	174	---	---
Continuous grain sorghum	---	---	149
Corn-wheat	181	82	---
Corn-grain sorghum	186	---	154
Least significant difference _(0.05)	17	---	25

Table 2. Grain yields of three crops under limited irrigation as affected by rotation across years 2013 - 2016

Rotation	Corn	Wheat	Grain sorghum
	----- bu/a -----		
Continuous corn	170b ¹	---	---
Continuous grain sorghum	---	---	137b
Corn-wheat	184a	64	---
Corn-grain sorghum	183a	---	147a
Least significant difference _(0.05)	12	---	9

¹ Means within a column with the same letter are not statistically different at $P = 0.05$.

CROPPING AND TILLAGE SYSTEMS

Table 3. Profile available soil water, crop water use, and fallow accumulation for crop rotations under limited irrigation, Tribune, KS, 2016

Crop	Rotation	Available water			Crop water use	Fallow accumulation	Fallow efficiency
		Previous harvest	Planting	Harvest			
		----- inches -----					%
Corn	C-C	10.03	16.15	14.85	28.72	6.13	63a ¹
	C-W	10.74	15.27	15.94	26.75	4.53	31b
	C-GS	10.28	15.10	15.27	27.24	4.82	72a
LSD _{0.05}		4.14	2.78	3.95	2.57	2.18	21
<u>ANOVA (P > F)</u>							
System		0.915	0.630	0.800	0.229	0.242	0.008
Wheat	C-W	9.58	9.58	12.69	19.59	0	---
<u>ANOVA (P > F)</u>							
System		---	---	---	---	---	---
Grain sorghum	C-GS	7.69b	15.50	11.37	24.52	7.80a	52
	GS-GS	10.57a	15.54	11.32	24.61	4.97b	41
LSD _{0.05}		1.86	1.38	1.46	1.24	2.70	21
<u>ANOVA (P > F)</u>							
System		0.016	0.923	0.934	0.837	0.044	0.213

Note: All crops received ~10 inches of irrigation.

In season rainfall for corn (4/28/16 – 9/15/16) = 17.91 inches; grain sorghum (6/01/16 – 10/20/16) = 12.61 inches; and wheat (9/29/15 – 7/08/16) = 20.29 inches.

C = corn.

W = wheat.

GS = grain sorghum.

LSD = least significant difference.

ANOVA = analysis of variance.

¹ Means within a column with the same letter are not statistically different at $P = 0.05$.

CROPPING AND TILLAGE SYSTEMS

Table 4. Profile available soil water, crop water use, and fallow accumulation for crop rotations under limited irrigation across years, Tribune, KS, 2013-2016

Crop	Rotation	Available water			Crop water use	Fallow accumulation	Fallow efficiency
		Previous harvest	Planting	Harvest			
		----- inches -----					%
Corn	C-C	10.51a ¹	13.68a	12.02a	25.16	3.17ab	36b
	C-W	10.09ab	13.71a	12.13a	25.08	3.62a	24c
	C-GS	9.21b	11.89b	10.20b	25.19	2.68b	53a
LSD _(0.05)		1.19	1.00	1.14	0.99	0.56	8
ANOVA (P > F)							
System		0.091	0.001	0.002	0.972	0.007	0.001
Year		0.001	0.001	0.001	0.001	0.001	0.001
System × year		0.001	0.004	0.014	0.001	0.001	0.001
Wheat	C-W	10.41	10.41	10.76	20.01	0	---
ANOVA (P > F)							
System		---	---	---	---	---	---
Year		0.001	0.001	0.003	0.001	---	---
System × year		---	---	---	---	---	---
Grain sorghum	C-GS	8.08	12.55	10.64	23.31	4.47a	39
	GS-GS	9.08	12.18	10.60	22.98	3.10b	37
LSD _(0.05)		1.14	1.05	1.07	0.68	0.78	11
ANOVA (P>F)							
System		0.082	0.462	0.937	0.314	0.002	0.818
Year		0.001	0.001	0.001	0.001	0.001	0.001
System × year		0.001	0.009	0.787	0.123	0.001	0.392

Note: All crops received ~10 inches of irrigation each year.

C = corn.

W = wheat.

GS = grain sorghum.

LSD = least significant difference.

ANOVA = analysis of variance.

¹ Means within a column with the same letter are not statistically different at $P = 0.05$.

2015 Kansas Summer Annual Forage Hay and Silage Variety Trial

J. Holman, J. Lingenfelter, A. Obour, A. Esser, J. Moyer, G. Cramer, T. Roberts, and S. Maxwell

Summary

In 2015 summer annual forage variety trials were conducted across Kansas near Garden City, Hays, Hutchinson, Mound Valley, and Scandia. All sites evaluated hay and silage entries, except Hutchinson, which only evaluated hay entries. Companies were able to enter varieties into any possible combinations of research sites, so not all sites had all varieties. Across the sites, a total of 30 hay varieties and 22 silage varieties were evaluated.

Introduction

In 2014 there was a total of 34,455,000 acres of hay and haylage harvested in the United States for a total of 95,372,000 dry matter tons of production. Yields averaged 2.77 tons of dry matter per acre. Of this total, about 13,580,000 acres were alfalfa, which averaged 3.76 dry matter tons per acre, and all other crops averaged 2.13 dry matter tons/a.

In Kansas, there were 2,420,000 acres of hay and haylage harvested, with an average yield of 2.24 dry matter tons per acre in 2014. Of this total, 650,000 acres were alfalfa with an average yield of 3.72 dry matter tons per acre, and 1,770,000 acres were crops other than alfalfa, with an average yield of 1.69 dry matter tons/a. Kansas was ranked 6th in the United States for hay and haylage production, which largely supports the state dairy (ranked 19th in the US and valued at \$482,765,000), and cattle (feedlot, background, and cow/calf) industries (ranked second in the US and valued at \$10,153,087,000). Dairy and beef cattle represented 58% of the total agriculture product of Kansas in 2014. Hay and grain commodities that support these two industries are critical for the state.

Study Objectives

The objectives of the Kansas Summer Annual Forage Variety Trial are to evaluate the performance of released and experimental varieties, determine where these varieties are best adapted, and increase the visibility of summer annual forages in Kansas. Breeders, marketers, and producers use data collected from the trials to make informed variety selections. The Summer Annual Forage Variety Trial is planted at locations across Kansas based on the interest of those entering varieties into the test.

Procedures

The Summer Annual Forage Variety Trial was conducted near Garden City, Hays, Hutchinson, Mound Valley, and Scandia. All of the sites evaluated hay and silage entries, except Hutchinson, which only evaluated hay entries. Companies were able to enter varieties into any possible combinations of research sites, so not all sites had all varieties. In the hay test, there were 13 entries at Garden City, 25 at Hays, 19 at Hutchinson, 15 at Mound Valley, and 16 at Scandia. In the silage test, there were 21 entries at Garden City, 17 at Hays, 10 at Hutchinson, 8 at Mound Valley, and 10 at

Scandia. Across the sites, a total of 30 hay varieties and 22 silage varieties were evaluated (Tables 1 and 2).

Management guidelines were provided to cooperators; however, previous growing experience influenced final management decisions. All trials were planted in small research plots (approximately 225 ft²) with three replications. Cultural practices (Table 3), growing season temperature, and precipitation (Figures 1-5) are provided for each site. Emergence date was determined when plant stand was visibly apparent. Stand vigor and percent stand establishment were determined two weeks after planting using a visual assessment. Stand vigor was rated on a scale of 1 through 10, with 10 being the most vigorous and percent stand establishment was rated on a scale of 0 through 100. Lodging was determined by visual assessment. Days to heading and days to soft dough were determined when 50% of stand reached maturity. All hay entries were harvested when the earliest variety reached heading. Silage entries were harvested when they reached soft dough. Late maturing silage varieties and photoperiod sensitive varieties (PPS) were harvested at the last silage harvest. Results are listed alphabetically by seed supplier. Forage samples were dried, ground, and analyzed for nutrient contents using NIR (near infrared reflectance) by SDK Laboratories in Hutchinson, KS.

2015 Growing Conditions

Temperature and precipitation (Figures 1-5) for each site is shown. Thick black lines on the temperature graphs represent long-term average high and low temperatures (°F) for the location. The upper thin line represents actual daily high temperatures, and the lower thin line represents actual daily low temperatures. On the precipitation graph, the line labeled “normal” represents long-term average precipitation (1981-2010), and the line labeled “2015” represents actual precipitation.

In general, the 2015 growing season saw favorable moisture conditions throughout, although conditions were drier than normal at Hays. The Hutchinson site had poor establishment due to herbicide carryover.

Results and Discussion

Since all entries were not evaluated across all sites, data was analyzed by location. All locations had a control entry of Rox Orange (Waconia) and Sumac for the hay test, and a control entry of Kansas Orange for the silage test.

Hay Test

At Garden City all entries were in the top LSD (Least Significant Difference at $P \leq 0.05$) group in the first cutting, except AS6401 and AS9302 (Table 4). In the second cutting more separation occurred between entries, and AS6201, AS6501, and AS9301 were in the highest yielding LSD group. Crude protein averaged 10.4% and TDN (Total Digestible Nutrients) was 50.5%.

There was only one hay cutting at Hays due to dry conditions. In the forage sorghum test Rox Orange, Sumac, Canex, and Canex BMR 210 were in the top LSD group, and in the sorghum sudan test AS5201 was the highest yielding entry (Table 5). Forage sorghum crude protein averaged 10.11% and TDN was 52.75%, sorghum sudan crude protein averaged 10.1% and TDN was 52.9%.

At Hutchinson, the first harvest was later than normal so there was only one hay cutting. Averaged across forage sorghum and sorghum sudan there were no significant differences in yield among the varieties (Table 6). Due to cutting later than normal, forage quality was lower, crude protein averaged 9.2%, and TDN was 60.0%.

At Mound Valley, AS5201, AS6201, AS9301, AS9302, Sweet Sioux WMR, Sweet Sioux BMR, B-52, 747, Wondergreen, and Sweet Six BMR were in the top LSD group (Table 7). The first cutting averaged 2722 lb/a, the second cutting averaged 2229 lb/a, and the third cutting averaged 2111 lb/a. Crude protein from the first cutting averaged 14.3% and TDN was 55.1%.

At Scandia, all entries were in the top LSD group, except AS6401, Canex BMR 600, and Rox Orange (Table 8). Crude protein averaged 10.6% and TDN was 54.1%.

Silage Test

At Garden City, AF8301, EJ7281, and SPX27614 were in the top LSD group for silage (Table 9). Crude protein averaged 8.0%, total starch was 9.4%, milk was 1884 (lb/ton), and IVTDMD (in vitro true dry matter digestibility) at 48 h was 71.4%.

At Hays, DS7853, EJ7281, Canex BMR525, and Canex BMR600 were in the top LSD group for silage (Table 10). Crude protein averaged 6.8%, total starch was 10.1%, milk was 1962 (lb/ton), and IVTDMD at 48 h was 73.9%.

At Mound Valley, AF7401 and AF8301 were in the top LSD group for silage (Table 11). Crude protein averaged 8.9%, total starch was 7.2%, milk was 1804 (lb/ton), and IVTDMD at 48 h was 68.3%.

At Scandia, AF7201, AF7401, and Silo Pro BMR were in the top LSD group for silage (Table 12). Crude protein averaged 8.0%, total starch was 9.6%, milk was 2092 (lb/ton), and IVTDMD at 48 h was 74.4%.

Recommendation

Inestimable differences in soil type, weather, and environmental conditions play a part in increasing experimental error; therefore, one should use more than one year of data to make an informed variety selection decision.

Acknowledgments

This work was funded in part by the Kansas Agricultural Experiment Station and seed suppliers. Sincere appreciation is expressed to all participating researchers and seed suppliers who have a vested interest in expanding and promoting annual forage production in the United States.

CROPPING AND TILLAGE SYSTEMS

Table 1. 2015 Hay test entries

No.	Company	Entry	FS*	SS	S	BMR	Dwarf	Male sterile	Dry stalk	PS	Maturity**
1	Alta Seeds	AS5201	N	Y	N	N	N	N	Y	N	M
2	Alta Seeds	AS6201	N	Y	N	Y	N	N	N	N	ME
3	Alta Seeds	AS6401	N	Y	N	Y	N	N	N	N	MF
4	Alta Seeds	AS6402	N	Y	N	Y	Y	N	N	N	F
5	Alta Seeds	AS6501	N	Y	N	Y	N	N	N	Y	F
6	Alta Seeds	AS9301	N	N	Y	Y	N	N	Y	N	M
7	Alta Seeds	AS9302	N	N	Y	Y	Y	N	Y	N	M
8	Browning Seed	747	N	Y	N	N	N	N	N	N	M
9	Browning Seed	B-52	N	Y	N	N	N	N	N	Y	F
10	Browning Seed	Sweet Sioux BMR	N	Y	N	Y	N	N	N	N	M
11	Browning Seed	Sweet Sioux WMR	N	Y	N	N	N	N	Y	N	M
12	Browning Seed	Wondergreen	N	Y	N	N	N	N	N	N	ME
13	CERES, Inc.	CB7290	N	Y	N	N	N	N	N	Y	F
14	CERES, Inc.	F2P134	N	Y	N	N	N	N	N	Y	F
15	Gayland Ward Seed	GW 2120	Y	N	N	N	N	Y	N	N	M
16	Gayland Ward Seed	GW 400 BMR	Y	N	N	Y	N	Y	N	N	ME
17	Gayland Ward Seed	Nutra King BMR6	N	Y	N	Y	N	N	N	N	ME
18	Gayland Ward Seed	Super Sugar	N	Y	N	N	N	N	N	N	E
19	Gayland Ward Seed	Super Sugar (DM)	N	Y	N	N	N	N	N	N	L
20	Gayland Ward Seed	Sweet Forever BMR	N	Y	N	Y	N	N	N	Y	L
21	Gayland Ward Seed	Sweet Six BMR	N	Y	N	Y	N	N	Y	N	E
22	KSU	Kansas Orange	Y	N	N	N	N	N	N	N	M
23	KSU	Sumac	Y	N	N	N	N	N	N	N	M
24	Sharp Brothers	Canex	Y	N	N	N	N	N	N	N	ME
25	Sharp Brothers	Canex BMR 208	Y	N	N	Y	N	N	N	N	M
26	Sharp Brothers	Canex BMR 210	Y	N	N	Y	N	N	N	N	M
27	Sharp Brothers	Canex BMR 600	Y	N	N	Y	N	N	N	N	ML
28	Sharp Brothers	Grazex BMR 301	N	Y	N	Y	N	N	N	N	M
29	Sharp Brothers	Grazex BMR 715	N	Y	N	Y	N	N	N	N	M
30	Sharp Brothers	Grazex BMR 801	N	Y	N	Y	N	N	N	N	M

*Abbreviations: Forage Sorghum (FS), Sorghum Sudan (SS), Sorghum (S), Brown Mid-Rib (BMR), and Photoperiod Sensitive (PS).

** Maturity Groups: Early (E), Medium Early (ME), Medium (M), Medium Late (ML), Late (L), and Full (F).

Hybrid information was provided by seed companies.

CROPPING AND TILLAGE SYSTEMS

Table 2. 2015 Silage test entries

No.	Company	Entry	FS*	SS	BMR	Dwarf	Male sterile	Dry stalk	PS	Maturity**
1	Alta Seeds	AF7101	Y	N	Y	N	N	Y	N	E
2	Alta Seeds	AF7102	Y	N	Y	Y	N	N	N	E
3	Alta Seeds	AF7201	Y	N	Y	N	N	Y	N	ME
4	Alta Seeds	AF7202	Y	N	Y	Y	N	N	N	ME
5	Alta Seeds	AF7301	Y	N	Y	N	Y	N	N	M
6	Alta Seeds	AF7401	Y	N	Y	Y	N	N	N	F
7	Alta Seeds	AF8301	Y	N	N	N	N	N	N	M
8	Browning Seed	Avenger	Y	N	N	N	N	N	N	MF
9	CERES, Inc.	EJ7281	Y	N	N	N	N	N	N	L
10	CERES, Inc.	DS7853	N	Y	N	N	N	N	Y	F
11	Chromatin, Inc.	SPX28414	Y	N	N	N	N	N	Y	F
12	Chromatin, Inc.	SP3903BD	Y	N	Y	N	N	N	N	MF
13	Chromatin, Inc.	SPX27614	Y	N	N	N	N	N	Y	F
14	Gayland Ward Seed	Sweet Forever BMR	N	Y	Y	N	N	N	Y	L
15	Gayland Ward Seed	Silo Pro BMR	Y	N	Y	Y	N	N	N	M
16	Gayland Ward Seed	GW 600 BMR	Y	N	Y	N	N	Y	N	M
17	KSU	Rox Orange	Y	N	N	N	N	N	N	M
18	Sharp Brothers	Canex BMR 210	Y	N	Y	N	N	N	N	M
19	Sharp Brothers	Canex BMR 525	Y	N	Y	Y	N	N	N	ML
20	Sharp Brothers	Canex BMR 600	Y	N	Y	N	N	N	N	ML
21	Sharp Brothers	Canex BMR 555	Y	N	Y	Y	N	N	N	ML
22	Sharp Brothers	Canex BMR 550	Y	N	Y	Y	N	N	N	ML

*Abbreviations: Forage Sorghum (FS), Sorghum Sudan (SS), Brown Mid-Rib (BMR), and Photoperiod Sensitive (PS).

** Maturity Groups: Early (E), Medium Early (ME), Medium (M), Medium Late (ML), Late (L), and Full (F).

Hybrid information was provided by seed companies.

CROPPING AND TILLAGE SYSTEMS

Table 3. Irrigation, planting, harvesting, and fertilizing details for hay and silage variety tests near Garden City, Hays, Hutchinson, Mound Valley, and Scandia, KS, in 2015

Location	Irrigation	Planting date	1st harvest date	2nd harvest date	3rd harvest date	Seeding rate	Harvest area	Fertilizer	
								N/a	P ₂ O ₅ /a
							ft ²	----- lb -----	
Hay Test									
Garden City	10.03	16-Jun	17-Aug	26-Oct	-*	15 (lb/a)	90	160	0
Hays	-	11-Jun	10-Aug	-	-	15 (lb/a)	90	50	30
Hutchinson	-	14-Jul	27-Oct	-	-	20 (lb/a)	42	50	0
Mound Valley	-	5-Jun	26-Jul	27-Aug	16-Oct	20 (lb/a)	80	150	60
Scandia	-	24-Jun	1-Sep	-	-	20 (lb/a)	60	50	0
Silage Test									
Garden City	10.03	17-Jun	-**	-	-	60,000 (seeds/a)	202.5	160	0
Hays	-	11-Jun	-	-	-	50,000 (seeds/a)	12.5	50	30
Hutchinson***	-	-	-	-	-	-	-	-	-
Mound Valley	-	5-Jun	-	-	-	100,000 (seeds/a)	100	150	60
Scandia	-	25-Jun	-	-	-	92,400 (seeds/a)	12.5	50	0

*Based on growing conditions and plant regrowth, some sites were cut more than others.

**Silage entries harvested at soft dough or end of season for varieties that did not reach soft dough.

***Hutchinson did not have a silage test.

CROPPING AND TILLAGE SYSTEMS

Table 4. Hay performance test near Garden City

Brand	Name	Yield 1	Yield 2	Total yield	Height
		----- lb DM/a -----			in.
					Sorghum sudan
Alta Seeds	AS5201	9,167	2,334	11,501	108
Alta Seeds	AS6201	8,537	3,822	12,359	114
Alta Seeds	AS6401	6,986	3,189	10,175	101
Alta Seeds	AS6402	8,489	2,955	11,444	92
Alta Seeds	AS6501	8,046	3,193	11,239	123
Alta Seeds	AS9301	8,431	3,573	12,004	105
Alta Seeds	AS9302	7,746	2,104	9,850	93
CERES, Inc.	CB7290	9,417	1,574	10,991	117
CERES, Inc.	F2P134	9,422	1,482	10,904	120
Gayland Ward Seed	Sweet Forever BMR	9,289	1,317	10,606	122
Gayland Ward Seed	Sweet Six BMR	9,293	2,001	11,294	118
					Forage sorghum
KSU	Rox Orange	8,455	1,607	10,063	93
KSU	Sumac	8,550	1,575	10,125	100
	Average	8,602	2,363	10,966	108
	LSD (0.05)	1,204	629		

continued

Plant date: 6/16/2015

*Days to harvest: Yield 1 = *65; Yield 2 = 70

CROPPING AND TILLAGE SYSTEMS

Table 5. Hay performance test near Hays

Brand	Name	Yield	Height
		lb DM/a	in.
Forage sorghum			
Gayland Ward Seed	GW 2120	6,384	69
Gayland Ward Seed	GW 400 BMR	6,745	76
KSU	Rox Orange	7,091	75
KSU	Sumac	8,533	70
Sharp Bros	Canex	7,529	76
Sharp Bros	Canex BMR 208	5,780	79
Sharp Bros	Canex BMR 210	6,864	78
Sharp Bros	Canex BMR 600	6,573	67
Average		6,937	74
LSD (0.05)		1,705	5
Sorghum sudan			
Alta Seeds	AS5201	9,368	81
Alta Seeds	AS6201	6,962	82
Alta Seeds	AS6401	7,137	82
Alta Seeds	AS6402	7,316	66
Alta Seeds	AS6501	6,653	86
Alta Seeds	AS9301	7,643	73
Alta Seeds	AS9302	7,464	64
CERES, Inc.	CB7290	6,882	83
CERES, Inc.	F2P134	6,755	80
Sharp Bros	Grazex BMR 301	7,353	80
Sharp Bros	Grazex BMR 715	6,827	88
Sharp Bros	Grazex BMR 801	7,197	90
Gayland Ward Seed	Sweet Forever BMR	7,227	80
Gayland Ward Seed	Sweet Six BMR	7,870	81
Gayland Ward Seed	Nutra King BMR6	7,298	80
Gayland Ward Seed	Super Sugar	8,144	83
Gayland Ward Seed	Sugar Sugar (DM)	8,001	88
Average		7,418	80
LSD (0.05)		1,192	9

continued

Plant Date: 6/11/2015

*Days to harvest: *57

Table 5. Hay performance test near Hays, continued

Brand	Name	Forage quality											RFQ	TDN	
		ADF	aNDF	IVTDMD		NDFD		NDFn	NEG	NEL	NEM	NFC			Protein crude
				@48	Lignin	@48									
Forage sorghum															
Gayland Ward Seed	GW 2120	39.02	60.66	72.65	2.91	56.90	56.41	0.22	0.52	0.55	17.28	10.19	95.04	51.84	
Gayland Ward Seed	GW 400 BMR	40.42	60.81	75.17	3.01	60.23	56.55	0.23	0.53	0.56	16.03	10.81	94.62	52.19	
KSU	Rox Orange	40.42	61.18	73.65	3.19	59.35	56.90	0.24	0.54	0.57	19.26	9.11	95.38	53.03	
KSU	Sumac	39.46	61.08	76.00	2.24	60.87	56.81	0.25	0.54	0.57	18.03	9.98	99.56	53.62	
Sharp Bros	Canex	40.91	62.04	74.03	2.71	58.63	57.69	0.23	0.53	0.56	18.29	9.03	92.31	52.33	
Sharp Bros	Canex BMR 208	39.55	61.51	77.07	2.19	60.90	57.21	0.24	0.54	0.57	16.45	10.94	99.36	53.13	
Sharp Bros	Canex BMR 210	39.47	62.21	76.60	2.23	60.75	57.85	0.24	0.53	0.56	16.54	10.45	97.78	52.73	
Sharp Bros	Canex BMR 600	39.85	61.49	78.27	2.27	63.43	57.18	0.24	0.54	0.57	15.60	10.42	98.29	53.12	
	Average	39.89	61.37	75.43	2.59	60.13	57.08	0.24	0.53	0.56	17.18	10.11	96.54	52.75	
	LSD (0.05)														
Sorghum sudan															
Alta Seeds	AS5201	40.59	62.44	71.07	3.21	55.87	58.07	0.22	0.52	0.55	17.74	9.31	91.26	51.63	
Alta Seeds	AS6201	39.58	60.12	76.10	2.29	62.53	55.91	0.25	0.54	0.58	19.39	8.66	98.12	53.87	
Alta Seeds	AS6401	41.17	61.18	77.90	2.43	64.50	56.89	0.24	0.53	0.56	15.69	10.09	95.46	52.86	
Alta Seeds	AS6402	39.62	61.50	77.10	2.48	61.60	57.19	0.25	0.54	0.57	16.32	11.02	100.24	53.39	
Alta Seeds	AS6501	41.81	61.44	77.25	2.63	63.85	57.13	0.22	0.52	0.55	14.96	10.02	91.13	51.87	
Alta Seeds	AS9301	38.50	59.30	75.00	2.40	60.20	55.15	0.25	0.54	0.58	19.20	9.81	101.05	53.78	
Alta Seeds	AS9302	38.61	61.35	75.85	2.56	61.30	57.06	0.26	0.55	0.58	16.80	11.23	104.74	54.29	
CERES, Inc.	CB7290	41.87	62.45	75.05	2.77	61.80	58.07	0.22	0.52	0.55	15.69	9.61	90.44	51.82	
CERES, Inc.	F2P134	39.30	60.31	75.50	2.52	60.47	56.09	0.24	0.54	0.57	18.05	10.24	99.54	53.30	
Sharp Bros	Grazex BMR 301	39.17	60.71	75.73	2.56	61.20	56.46	0.24	0.54	0.57	17.02	10.81	100.44	53.37	
Sharp Bros	Grazex BMR 715	39.74	61.56	74.97	2.42	59.47	57.25	0.24	0.53	0.56	17.31	9.93	96.73	52.77	
Sharp Bros	Grazex BMR 801	39.35	61.49	75.03	2.31	59.37	57.19	0.23	0.53	0.56	16.83	10.41	97.10	52.63	
Gayland Ward Seed	Sweet Forever BMR	38.91	60.58	77.33	2.35	62.37	56.34	0.25	0.54	0.57	16.29	11.06	101.34	53.51	
Gayland Ward Seed	Sweet Six BMR	39.86	61.14	75.10	2.85	61.27	56.86	0.25	0.54	0.58	18.17	9.63	98.86	53.74	
Gayland Ward Seed	Nutra King BMR6	40.57	62.34	76.10	2.48	62.03	57.97	0.24	0.53	0.57	16.89	9.47	95.51	52.94	
Gayland Ward Seed	Super Sugar	42.98	62.87	73.67	3.32	59.50	58.47	0.21	0.51	0.54	15.38	9.67	85.28	50.76	
Gayland Ward Seed	Sugar Sugar (DM)	38.73	60.55	74.43	2.18	59.37	56.31	0.24	0.54	0.57	18.44	10.26	99.44	53.34	
	Average	40.02	61.25	75.48	2.57	60.98	56.97	0.24	0.53	0.57	17.07	10.07	96.86	52.93	
	LSD (0.05)														

CROPPING AND TILLAGE SYSTEMS

Table 6. Hay performance test near Hutchinson

Brand	Name	Yield
		lb DM/a
Forage sorghum		
KSU	Rox Orange	10,968
KSU	Sumac	12,016
Sharp Bros	Canex	13,835
Sharp Bros	Canex BMR 208	12,821
Sharp Bros	Canex BMR 210	14,257
Sharp Bros	Canex BMR 600	13,451
Sorghum sudan		
Alta Seeds	AS5201	12,007
Alta Seeds	AS6201	12,504
Alta Seeds	AS6401	10,711
Alta Seeds	AS6402	11,584
Alta Seeds	AS6501	12,287
Alta Seeds	AS9301	10,744
Alta Seeds	AS9302	12,226
Gayland Ward Seed	Super Sugar	12,149
Gayland Ward Seed	Super Sugar (DM)	14,433
Gayland Ward Seed	Sweet Six BMR	12,232
Sharp Brothers	Grazex BMR 301	11,551
Sharp Brothers	Grazex BMR 715	11,857
Sharp Brothers	Grazex BMR 801	13,092
		Average
		12,354
		LSD (0.05)
		4,363
<i>continued</i>		

Plant Date: 7/14/2015

*Days to harvest: *105

Table 6. Hay performance test near Hutchinson, continued

Brand	Name	Forage quality											RFQ	TDN
		ADF	aNDF	IVTDMD @48	Lignin	NDFD @48	NDFn	NEG	NEL	NEM	NFC	Protein crude		
Forage sorghum														
KSU	Rox Orange	32.42	51.56	76.33	1.33	59.27	47.95	0.37	0.64	0.69	34.34	7.84	131.25	62.53
KSU	Sumac	32.88	52.85	77.83	1.48	59.30	49.15	0.34	0.62	0.67	30.00	9.36	129.70	60.69
Sharp Bros	Canex	34.19	53.68	76.60	1.51	59.47	49.93	0.33	0.61	0.66	30.60	8.14	121.41	60.20
Sharp Bros	Canex BMR 208	33.89	54.29	77.37	1.24	60.63	50.49	0.35	0.63	0.67	31.08	7.90	125.32	61.18
Sharp Bros	Canex BMR 210	32.20	54.21	78.37	0.99	60.20	50.42	0.36	0.63	0.68	30.94	8.89	133.72	61.84
Sharp Bros	Canex BMR 600	33.37	54.62	79.27	1.30	62.13	50.80	0.35	0.63	0.68	29.29	9.14	133.37	61.44
Sorghum sudan														
Alta Seeds	AS5201	35.58	55.85	73.13	1.50	54.83	51.94	0.33	0.61	0.66	29.77	8.75	122.29	59.74
Alta Seeds	AS6201	33.66	54.27	75.43	1.89	57.43	50.47	0.33	0.61	0.65	28.83	9.48	125.77	59.61
Alta Seeds	AS6401	33.92	55.24	76.70	1.53	60.60	51.38	0.32	0.61	0.65	25.42	11.06	129.20	59.42
Alta Seeds	AS6402	34.44	55.93	77.10	1.83	59.80	52.02	0.34	0.62	0.66	27.47	9.84	129.39	60.28
Alta Seeds	AS6501	32.62	53.94	77.70	1.62	60.37	50.16	0.33	0.61	0.66	26.84	11.10	132.64	60.08
Alta Seeds	AS9301	34.18	54.85	74.87	1.73	58.13	51.01	0.32	0.61	0.65	28.42	9.29	124.23	59.41
Alta Seeds	AS9302	35.83	58.13	73.33	2.33	56.37	54.06	0.30	0.59	0.63	25.39	9.09	115.79	57.69
Gayland Ward Seed	Super Sugar	33.89	54.57	74.53	1.34	56.93	50.75	0.32	0.61	0.65	28.85	8.91	122.71	59.35
Gayland Ward Seed	Super Sugar (DM)	34.04	55.10	74.43	1.75	56.50	51.24	0.33	0.61	0.66	30.14	8.57	123.70	60.01
Gayland Ward Seed	Sweet Six BMR	34.09	54.87	74.07	2.12	56.03	51.03	0.31	0.60	0.64	28.77	8.95	119.45	58.57
Sharp Brothers	Grazex BMR 301	32.41	53.65	75.50	0.72	56.33	49.90	0.34	0.62	0.67	30.09	10.02	131.92	60.69
Sharp Brothers	Grazex BMR 715	33.33	55.24	75.63	1.69	57.40	51.37	0.33	0.61	0.65	29.38	8.55	122.46	59.60
Sharp Brothers	Grazex BMR 801	33.16	56.73	73.90	1.66	54.87	52.76	0.31	0.60	0.64	28.00	9.10	119.17	58.63
	Average	33.69	54.71	75.90	1.56	58.24	50.88	0.33	0.61	0.66	29.14	9.16	125.97	60.05
	LSD (0.05)													

CROPPING AND TILLAGE SYSTEMS

Table 7. Hay performance test near Mound Valley

Brand	Name	Yield 1	Yield 2	Yield 3	Total	Rust*
		----- lb DM/a -----				0-10
		Sorghum sudan				
Alta Seeds	AS5201	3,388	2,815	3,469	9,672	1.3
Alta Seeds	AS6201	3,038	2,124	1,952	7,114	2.3
Alta Seeds	AS6401	2,321	1,993	3,273	7,587	3.0
Alta Seeds	AS6402	2,478	1,856	1,965	6,299	1.7
Alta Seeds	AS6501	2,333	2,104	1,109	5,546	4.7
Alta Seeds	AS9301	2,915	2,544	2,456	7,915	2.0
Alta Seeds	AS9302	3,115	2,288	3,520	8,923	2.0
Browning Seed	Sweet Sioux WMR	2,585	2,947	3,678	9,210	3.3
Browning Seed	Sweet Sioux BMR	2,762	2,597	1,393	6,752	3.7
Browning Seed	B-52	2,929	2,180	2,311	7,420	1.3
Browning Seed	747	3,494	2,124	2,379	7,996	3.0
Browning Seed	Wondergreen	3,035	2,348	950	6,333	4.0
Gayland Ward Seed	Sweet Six BMR	3,213	2,119	2,497	8,528	2.0
KSU	Kansas Orange	2,504	2,349	865	5,718	6.0
		Forage sorghum				
KSU	Rox Orange	1,511	1,560	1,090	4,161	4.7
KSU	Sumac	1,933	1,714	870	4,517	5.3
	Average	2,722	2,229	2,111	7,106	3.1
	LSD (0.05)	986				

continued

Plant date: 6/5/2015

Days to harvest: Yield 1 = *41; Yield 2 = 32; Yield 3 = 50

*Visual scale: 0= no rust observed; 10= all plants/plot exhibit rust

Table 7. Hay performance test near Mound Valley, continued

Brand	Name	Forage quality											RFQ	TDN
		ADF	aNDF	IVTDMD @48	Lignin	NDFD @48	NDFn	NEG	NEL	NEM	NFC	Protein crude		
Sorghum sudan														
Alta Seeds	AS5201	36.67	59.28	78.10	3.23	61.90	55.13	0.27	0.56	0.60	14.27	15.81	104.10	55.24
Alta Seeds	AS6201	37.95	58.96	79.03	2.97	63.30	54.84	0.27	0.56	0.59	15.16	14.27	105.83	55.03
Alta Seeds	AS6401	38.38	58.70	80.37	2.84	64.50	54.59	0.28	0.57	0.60	16.53	13.95	107.48	55.84
Alta Seeds	AS6402	37.00	58.94	80.93	2.82	65.40	54.81	0.28	0.57	0.61	15.68	14.54	112.48	56.44
Alta Seeds	AS6501	37.54	58.22	80.60	2.84	64.07	54.15	0.27	0.56	0.60	14.97	15.30	105.61	55.56
Alta Seeds	AS9301	37.11	58.96	79.00	2.66	63.70	54.84	0.27	0.56	0.60	16.01	14.19	108.37	55.51
Alta Seeds	AS9302	37.53	59.15	79.07	2.89	63.33	55.01	0.27	0.56	0.59	15.11	14.31	106.83	55.04
Browning Seed	Sweet Sioux WMR	38.03	59.27	77.40	3.25	60.67	55.12	0.26	0.55	0.59	16.60	13.87	105.82	54.73
Browning Seed	Sweet Sioux BMR	37.08	58.42	78.97	2.78	62.00	54.33	0.27	0.56	0.59	15.75	14.67	105.79	54.90
Browning Seed	B-52	39.13	60.55	75.30	3.12	57.90	56.31	0.24	0.54	0.57	16.98	12.44	100.07	53.26
Browning Seed	747	40.04	61.57	75.13	3.09	58.93	57.26	0.25	0.54	0.57	16.49	12.24	99.62	53.50
Browning Seed	Wondergreen	38.20	60.18	77.00	3.09	60.60	55.97	0.27	0.56	0.59	16.38	14.02	106.01	54.93
Gayland Ward Seed	Sweet Six BMR	37.64	59.20	79.43	2.81	63.23	55.05	0.28	0.57	0.60	15.66	14.84	108.63	55.80
KSU	Kansas Orange	36.25	58.51	79.73	2.78	62.10	54.42	0.28	0.57	0.60	15.10	16.14	107.46	55.83
Forage sorghum														
KSU	Rox Orange	36.96	59.75	78.43	2.71	62.07	55.57	0.26	0.56	0.59	14.55	14.95	105.86	54.83
KSU	Sumac	37.72	60.86	77.90	2.66	60.53	56.60	0.26	0.56	0.59	15.97	14.00	106.80	54.92
	Average	37.70	59.41	78.53	2.91	62.14	55.25	0.27	0.56	0.59	15.70	14.35	106.05	55.09
	LSD (0.05)													

CROPPING AND TILLAGE SYSTEMS

Table 8. Hay performance test near Scandia

Brand	Name	Yield
		lb DM/a
		Sorghum sudan
Alta Seeds	AS5201	7,742
Alta Seeds	AS6201	7,240
Alta Seeds	AS6401	5,932
Alta Seeds	AS6402	7,340
Alta Seeds	AS6501	8,078
Alta Seeds	AS9301	6,588
Alta Seeds	AS9302	6,892
Gayland Ward Seed	Nutra King BMR6	7,448
Gayland Ward Seed	Sugar Sugar (DM)	6,600
Gayland Ward Seed	Sweet Six BMR	6,634
Sharp Bros	Grazex BMR 715	6,954
Sharp Bros	Grazex BMR 801	7,774
		Forage sorghum
Sharp Bros	Canex BMR 210	6,091
Sharp Bros	Canex BMR 600	4,919
KSU	Rox Orange	6,061
KSU	Sumac	6,914
	Average	6,825
	LSD (0.05)	1,566
		<i>continued</i>

Plant date: 6/24/2015

*Days to harvest: 62

Table 8. Hay performance test near Scandia, continued

Brand	Name	Forage quality											RFQ	TDN
		ADF	aNDF	IVTDMD @48	Lignin	NDFD @48	NDFn	NEG	NEL	NEM	NFC	Protein crude		
Sorghum sudan														
Alta Seeds	AS5201	42.09	61.17	72.40	3.72	57.50	56.89	0.24	0.53	0.56	18.62	9.39	92.81	52.78
Alta Seeds	AS6201	39.93	59.56	77.33	2.82	63.60	55.39	0.27	0.56	0.59	17.92	11.12	105.82	55.12
Alta Seeds	AS6401	41.31	60.52	76.33	3.25	63.00	56.28	0.25	0.55	0.58	16.62	11.10	98.11	54.06
Alta Seeds	AS6402	38.02	58.78	80.37	2.03	65.43	54.67	0.28	0.57	0.61	15.29	14.75	109.54	56.26
Alta Seeds	AS6501	41.32	60.04	76.80	2.86	63.17	55.84	0.25	0.54	0.57	16.51	11.19	97.83	53.63
Alta Seeds	AS9301	40.27	60.41	76.17	2.92	61.77	56.18	0.26	0.55	0.59	17.37	11.26	102.15	54.46
Alta Seeds	AS9302	40.53	60.38	76.83	3.14	63.83	56.15	0.27	0.56	0.60	18.78	9.77	104.23	55.43
Gayland Ward Seed	Nutra King BMR6	39.90	59.35	77.13	2.91	62.90	55.20	0.26	0.55	0.59	17.10	11.96	103.66	54.56
Gayland Ward Seed	Sugar Sugar (DM)	41.39	62.03	75.90	2.93	62.47	57.69	0.25	0.54	0.57	17.33	9.23	95.67	53.55
Gayland Ward Seed	Sweet Six BMR	40.01	60.41	75.60	3.16	60.73	56.18	0.27	0.56	0.60	19.74	10.46	105.63	55.38
Sharp Bros	Grazex BMR 715	41.46	62.29	74.80	3.23	60.17	57.93	0.24	0.54	0.57	17.50	9.55	95.76	53.40
Sharp Bros	Grazex BMR 801	43.70	64.38	73.13	3.46	59.53	59.88	0.21	0.51	0.54	14.93	8.79	84.41	51.09
Forage sorghum														
Sharp Bros	Canex BMR 210	39.55	60.08	77.83	2.55	64.50	55.87	0.27	0.56	0.59	18.54	9.79	104.73	55.04
Sharp Bros	Canex BMR 600	41.48	60.66	74.23	3.31	60.17	56.41	0.24	0.54	0.57	17.98	9.91	96.24	53.36
KSU	Rox Orange	39.22	59.35	77.07	3.18	63.53	55.20	0.27	0.56	0.60	18.03	11.09	107.22	55.39
KSU	Sumac	41.63	60.91	72.60	3.84	59.53	56.65	0.24	0.53	0.56	17.68	9.54	93.38	52.73
	Average	40.74	60.72	76.06	3.02	62.06	56.47	0.25	0.55	0.58	17.44	10.59	99.76	54.15
	LSD (0.05)													

Table 9. Silage performance test near Garden City

Brand	Variety	Yield lb DM/a	Stand %	Vigor	Flowering date	Days to soft dough	Days to harvest	Height ft	Lodging %	1000 seed wt
Alta Seeds	AF7101	13,892	55	3	8/21/15	102	106	9	0	37
Alta Seeds	AF7102	10,892	62	3	8/21/15	102	106	7	50	25
Alta Seeds	AF7201	13,851	43	3	8/28/15	102	106	9	0	31
Alta Seeds	AF7202	11,624	71	4	8/28/15	102	106	7	100	23
Alta Seeds	AF7301	14,659	58	4	9/4/15	102	106	8	0	33
Alta Seeds	AF7401	14,623	58	3	9/18/15	119	123	8	0	26
Alta Seeds	AF8301	19,428	65	4	9/8/15	119	123	9	0	32
Browning Seeds	Avenger	13,935	49	4	9/18/15	127	131	8	0	29
CERES, Inc.	DS7853	14,395	68	4	--	--	106	10	0	40
CERES, Inc.	EJ7281	17,260	71	4	9/18/15	102	106	11	50	28
Chromatin	SP3903BD	13,070	53	4	9/18/15	127	131	7	0	28
Chromatin	SPX27614	19,782	59	4	9/18/15	102	106	12	0	28
Chromatin	SPX28414	15,382	55	3	--	--	106	11	0	28
KSU	Kansas Orange	13,952	42	2	9/8/15	122	126	12	0	18
Sharp Brothers	Canex BMR210	11,069	42	3	9/8/15	102	106	9	67	20
Sharp Brothers	Canex BMR525	15,387	54	3	9/11/15	127	131	8	0	26
Sharp Brothers	Canex BMR550	13,120	32	3	9/11/15	127	131	9	0	33
Sharp Brothers	Canex BMR555	13,422	45	3	9/18/15	127	131	7	0	30
Ward Seed	GW600BMR	15,222	71	3	8/17/15	102	106	9	0	34
Ward Seed	Silo Pro BMR	14,617	63	4	9/14/15	119	123	9	0	34
Ward Seed	Sweet Forever BMR	13,801	71	4	--	--	106	10	0	29
	Average	14,447	57	3	9/7/15	113	115	9	13	29
	LSD (0.05)	3,911								

continued

Planting Date: 6/17/15

Emergence Date: 6/22/15

Table 9. Silage performance test near Garden City, continued

Brand	Variety	Forage quality											Total starch	
		ADF	aNDF	IVTDMD @48	Lignin	Milk	NDFD @48	NDFn	NEL	NFC	Protein crude	RFQ		TDN
		----- % -----				lb/ton	----- % -----							
Alta Seeds	AF7101	40.70	57.58	70.77	3.55	1946.00	50.80	53.55	0.50	26.90	7.33	98.62	53.07	9.47
Alta Seeds	AF7102	40.33	55.64	72.33	4.00	1941.00	52.37	51.75	0.50	26.87	8.31	105.45	53.37	9.01
Alta Seeds	AF7201	39.85	56.64	72.60	3.20	1975.33	52.67	52.68	0.50	26.06	8.42	101.96	53.77	9.35
Alta Seeds	AF7202	38.94	54.15	74.47	3.23	2001.00	54.73	50.36	0.51	27.64	8.27	109.28	54.40	9.26
Alta Seeds	AF7301	38.34	55.31	73.87	3.44	2136.00	54.67	51.44	0.52	27.41	8.89	111.51	56.20	10.90
Alta Seeds	AF7401	37.07	52.67	75.17	3.58	1798.67	54.03	48.99	0.48	29.83	8.76	107.21	52.03	10.83
Alta Seeds	AF8301	42.90	62.77	67.13	4.59	1693.00	47.87	58.37	0.47	23.39	6.24	79.86	49.17	7.60
Browning Seeds	Avenger	39.32	57.14	72.73	3.59	2015.00	54.90	53.14	0.51	26.87	7.13	105.74	54.67	8.67
CERES, Inc.	DS7853	43.33	66.16	66.30	5.30	1458.00	50.07	61.53	0.43	17.29	8.17	73.99	46.50	5.81
CERES, Inc.	EJ7281	41.17	61.89	68.27	4.76	1877.33	51.73	57.55	0.49	22.89	7.54	90.29	52.23	9.77
Chromatin	SP3903BD	36.48	54.57	75.53	3.03	2133.33	57.33	50.75	0.53	26.24	9.21	115.40	56.63	9.52
Chromatin	SPX27614	42.74	67.35	65.00	5.49	1494.33	47.97	62.63	0.43	18.89	7.46	70.56	46.47	7.09
Chromatin	SPX28414	41.71	64.34	67.57	4.96	1631.67	50.63	59.84	0.45	20.12	8.19	80.42	48.87	8.37
KSU	Kansas Orange	40.60	60.60	66.58	4.88	1798.20	44.68	56.36	0.48	28.70	5.67	80.23	49.94	11.04
Sharp Brothers	Canex BMR210	40.58	58.88	70.70	4.55	1986.00	52.27	54.76	0.51	25.69	7.99	98.03	53.73	9.43
Sharp Brothers	Canex BMR525	35.20	52.97	75.03	3.32	1971.00	54.97	49.26	0.50	29.53	8.53	112.11	54.27	11.46
Sharp Brothers	Canex BMR550	33.58	49.26	75.63	3.12	2000.00	53.61	45.81	0.51	33.09	8.24	118.50	54.47	12.38
Sharp Brothers	Canex BMR555	36.48	53.44	75.23	3.30	2104.00	56.07	49.70	0.52	28.77	8.21	116.50	56.10	10.44
Ward Seed	GW600BMR	41.18	58.48	69.70	4.16	1608.33	49.47	54.38	0.45	26.16	7.22	86.68	48.93	9.38
Ward Seed	Silo Pro BMR	35.35	52.76	75.33	3.06	2153.00	55.53	49.07	0.53	27.82	9.57	118.05	56.57	10.50
Ward Seed	Sweet Forever BMR	41.28	62.15	69.87	5.10	1841.00	55.10	57.80	0.48	20.84	8.66	94.77	52.50	8.15
	Average	39.39	57.85	71.42	4.01	1883.91	52.45	53.80	0.49	25.76	8.00	98.82	52.57	9.45
	LSD (0.05)													

Table 10. Silage performance test near Hays

Brand	Variety	Yield lb DM/a	Yield tons/a	Flowering date	Days to soft dough	Days to harvest	Height in.	1000 seed wt
Alta Seeds	AF7101	7,358	3.7	8/17/15	98	98	83	37.28
Alta Seeds	AF7102	7,417	3.7	8/12/15	98	98	76	25.27
Alta Seeds	AF7201	7,475	3.7	8/12/15	91	91	87	31.17
Alta Seeds	AF7202	7,417	3.7	8/18/15	98	98	68	22.69
Alta Seeds	AF7301	6,720	3.4	8/12/15	91	91	88	32.69
Alta Seeds	AF7401	9,856	4.9	9/10/15	111	111	60	25.69
Alta Seeds	AF8301	9,508	4.8	8/24/15	98	98	68	31.53
CERES, Inc.	DS7853	19,672	9.8	--	141	141	90	39.56
CERES, Inc.	EJ7281	22,169	11.1	9/26/15	132	132	94	27.62
KSU	Kansas Orange	8,172	4.1	8/20/15	98	98	113	18.04
Sharp Brothers Seed Co.	Canex BMR210	7,010	3.5	8/20/15	98	98	94	20.00
Sharp Brothers Seed Co.	Canex BMR525	16,245	8.1	9/10/15	132	132	66	26.11
Sharp Brothers Seed Co.	Canex BMR555	10,030	5.0	9/18/15	132	132	64	30.15
Sharp Brothers Seed Co.	Canex BMR600	18,580	9.3	9/30/15	132	132	87	28.35
Ward Seed	Silo Pro BMR	9,101	4.6	9/18/15	132	132	64	34.10
Ward Seed	Sweet Forever BMR	13,167	6.6	9/4/15	111	111	95	28.61
	Average	11,487	5.7	8/30/15	113	113	81	28.68
	LSD (0.05)	4,717						

continued

Plant Date: 6/11/2015

Table 10. Silage performance test near Hays, continued

Brand	Variety	Forage quality												
		IVTDMD				NDFD				Protein				Total starch
		ADF	aNDF	@48	Lignin	Milk	@48	NDFn	NEL	NFC	crude	RFQ	TDN	
----- % -----				lb/ton	----- % -----									
Alta Seeds	AF7101	43.27	62.98	69.80	2.97	1684.33	51.50	58.57	0.46	24.02	5.25	85.88	49.80	7.66
Alta Seeds	AF7102	40.26	56.76	74.50	2.28	1960.67	54.77	52.79	0.50	29.05	6.42	105.76	54.03	10.31
Alta Seeds	AF7201	41.79	60.84	71.70	2.53	1802.33	54.10	56.58	0.47	26.07	5.35	94.81	51.87	8.10
Alta Seeds	AF7202	37.14	50.56	75.50	1.98	2002.33	50.20	47.02	0.51	35.05	7.93	111.06	54.00	13.25
Alta Seeds	AF7301	39.46	57.92	76.50	2.04	2097.00	59.53	53.86	0.52	27.53	6.04	114.11	56.60	9.62
Alta Seeds	AF7401	33.80	51.83	77.40	2.28	2089.33	56.23	48.20	0.51	31.50	9.00	119.73	55.93	11.26
Alta Seeds	AF8301	40.93	62.68	70.83	3.58	1827.33	53.13	58.30	0.48	24.64	5.55	90.82	51.93	7.77
CERES, Inc.	DS7853	38.58	59.09	72.47	3.62	1753.67	53.50	54.95	0.47	27.80	5.43	93.76	50.80	8.52
CERES, Inc.	EJ7281	35.00	50.34	75.53	2.07	1990.00	50.47	46.82	0.51	34.87	8.01	112.86	54.00	13.69
KSU	Kansas Orange	38.10	56.20	72.20	3.07	2059.67	49.47	52.27	0.52	32.35	7.06	100.14	54.23	12.34
Sharp Brothers Seed Co.	Canex BMR210	40.27	59.47	71.97	3.05	1955.33	53.00	55.31	0.50	28.18	6.24	99.63	53.70	9.72
Sharp Brothers Seed Co.	Canex BMR525	35.09	51.65	75.53	2.86	1854.33	52.27	48.03	0.48	33.44	8.03	108.98	52.57	11.43
Sharp Brothers Seed Co.	Canex BMR555	35.38	54.29	76.40	2.19	2112.33	56.77	50.49	0.52	29.35	7.98	116.35	56.30	10.82
Sharp Brothers Seed Co.	Canex BMR600	37.32	58.54	74.73	2.88	2087.33	58.10	54.45	0.52	26.68	6.67	110.14	56.13	8.73
Ward Seed	Silo Pro BMR	38.04	59.45	73.20	2.90	2022.67	55.87	55.29	0.51	26.15	6.60	104.33	54.87	8.45
Ward Seed	Sweet Forever BMR	37.72	56.79	75.43	2.93	2100.33	57.13	52.82	0.52	28.46	7.31	112.02	56.13	9.80
	Average	38.26	56.84	73.98	2.70	1962.44	54.13	52.86	0.50	29.07	6.80	105.02	53.93	10.09
	LSD (0.05)													

Table 11. Silage performance test near Mound Valley

Brand	Variety	Yield	Stand	Flowering date	Days to harvest	Height	Lodging	1000 seed wt
		lb DM/a	%			in.	%	
Alta Seeds	AF7101	10,052	81	7/31/15	90	78	18	37.28
Alta Seeds	AF7102	8,830	85	8/3/15	90	64	27	25.27
Alta Seeds	AF7201	9,367	69	8/3/15	90	67	9	31.17
Alta Seeds	AF7202	8,064	97	8/4/15	90	63	42	22.69
Alta Seeds	AF7301	8,821	62	8/6/15	90	70	12	32.69
Alta Seeds	AF7401	14,173	75	9/5/15	112	66	1	25.69
Alta Seeds	AF8301	16,641	81	8/30/15	112	68	10	31.53
KSU	Kansas Orange	11,737	64	8/12/15	90	94	25	18.04
	Average	10,961	77	8/11/15	96	71	18	28
	LSD (0.05)	2,161						

Plant Date: 6/5/2015

Brand	Variety	Forage quality													
		ADF	aNDF	IVTDMD		Lignin	Milk	NDFD			NFC	Protein crude	RFQ	TDN	Total starch
				@48		lb/ton	@48	NDFn	NEL						
				%				%							
Alta Seeds	AF7101	39.82	61.01	68.53	4.12	1860.67	50.53	56.74	0.49	23.44	7.56	89.52	51.90	7.47	
Alta Seeds	AF7102	38.78	56.13	69.97	4.60	1899.00	49.77	52.20	0.49	25.56	9.10	96.78	52.37	7.35	
Alta Seeds	AF7201	39.16	57.93	67.43	5.83	1729.33	46.60	53.88	0.47	22.40	10.35	85.50	49.60	5.82	
Alta Seeds	AF7202	40.48	59.93	68.13	4.93	1823.67	50.53	55.74	0.48	21.84	8.53	90.28	51.43	4.76	
Alta Seeds	AF7301	38.56	58.37	69.53	4.85	1881.00	50.57	54.29	0.49	20.86	11.18	94.09	52.27	5.01	
Alta Seeds	AF7401	35.99	55.09	73.73	3.46	2125.67	53.77	51.24	0.53	28.02	9.44	109.97	55.87	11.07	
Alta Seeds	AF8301	39.98	59.88	65.17	5.58	1533.00	40.90	55.69	0.45	25.69	7.67	72.72	45.93	8.58	
KSU	Kansas Orange	41.58	63.64	64.00	5.56	1584.00	41.67	59.19	0.46	23.65	7.65	68.00	46.50	7.86	
	Average	39.29	59.00	68.31	4.87	1804.54	48.04	54.87	0.48	23.93	8.94	88.36	50.73	7.24	
	LSD (0.05)														

Table 12. Silage performance test near Scandia

Brand	Variety	Yield lb DM/a	Stand %	Vigor	Days to soft dough	Days to harvest	Height ft	1000 seed wt
Alta Seeds	AF7101	10,873	10	10	81	89	8	37.28
Alta Seeds	AF7102	11,637	7	8	88	89	5	25.27
Alta Seeds	AF7201	13,243	8	8	81	89	8	31.17
Alta Seeds	AF7202	10,918	7	7	88	89	6	22.69
Alta Seeds	AF7301	11,497	10	9	88	89	6	32.69
Alta Seeds	AF7401	14,134	7	8	109	134	5	25.69
Alta Seeds	AF8301	10,225	9	9	109	134	7	31.53
KSU	Kansas Orange	10,119	6	7	95	134	9	18.04
Ward Seed	GW 600 BMR	10,563	10	9	81	89	9	33.98
Ward Seed	Silo Pro BMR	12,738	9	8	116	134	4	34.10
	Average	11,595	8	8	94	107	7	29.24
	LSD (0.05)	2,351						

Plant Date: 6/25/15

Emergence Date: 7/1/15

Brand	Variety	Forage quality												Total starch
		ADF	aNDF	IVTDMD		Lignin	Milk	NDFD		NEL	NFC	Protein crude	RFQ	
		----- % -----				lb/ton	----- % -----							
Alta Seeds	AF7101	41.04	59.70	73.37	3.21	1983.67	55.00	55.52	0.50	24.41	8.06	101.52	54.23	7.59
Alta Seeds	AF7102	38.20	56.48	77.33	2.91	2238.33	59.70	52.53	0.54	24.85	9.40	120.03	58.30	8.19
Alta Seeds	AF7201	40.47	57.41	73.37	2.89	2002.00	52.50	53.39	0.51	27.79	7.52	100.99	54.03	9.43
Alta Seeds	AF7202	36.20	53.04	78.03	2.67	2232.67	58.00	49.32	0.54	28.70	9.80	123.73	57.97	10.03
Alta Seeds	AF7301	37.69	56.65	76.50	2.92	2255.67	58.43	52.68	0.54	26.72	9.06	118.28	58.37	9.75
Alta Seeds	AF7401	38.78	54.02	76.03	2.83	2152.67	54.90	50.24	0.53	30.77	8.00	114.75	56.50	11.38
Alta Seeds	AF8301	42.07	61.10	69.93	4.10	1823.67	48.33	56.82	0.48	26.16	6.36	85.78	50.97	8.31
KSU	Kansas Orange	39.52	59.41	69.07	3.68	1953.33	46.17	55.25	0.50	30.03	6.61	87.85	52.17	12.30
Ward Seed	GW 600 BMR	41.51	61.12	73.33	3.82	2007.00	56.60	56.85	0.50	24.60	6.56	102.21	54.90	7.56
Ward Seed	Silo Pro BMR	35.54	54.40	77.20	2.62	2271.33	57.57	50.59	0.54	29.51	8.55	121.31	58.37	11.99
	Average	39.10	57.33	74.42	3.16	2092.03	54.72	53.32	0.52	27.35	7.99	107.64	55.58	9.65
	LSD (0.05)													

CROPPING AND TILLAGE SYSTEMS

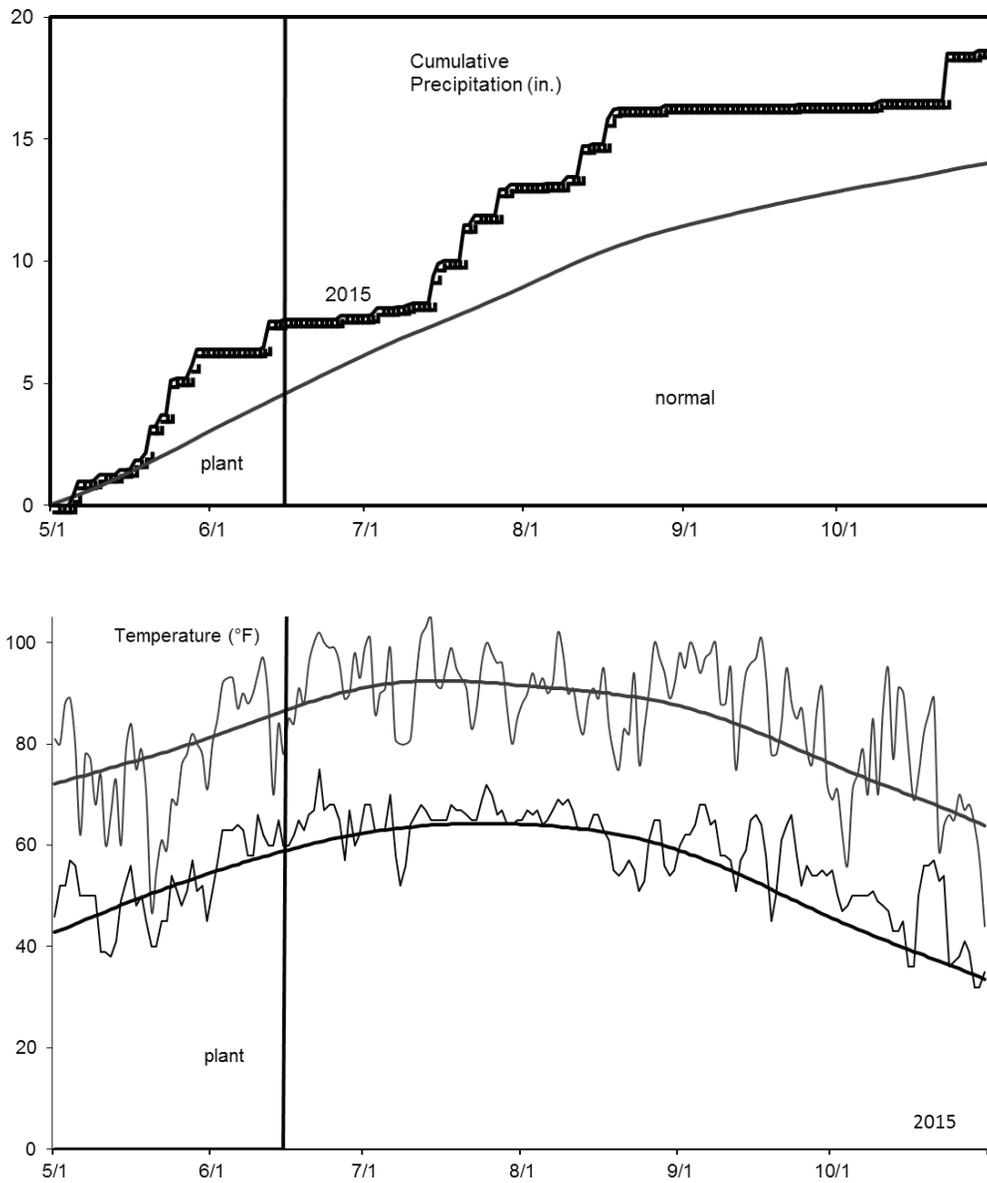


Figure 1. Precipitation and temperature during the growing season near Garden City, KS. Top pane: daily and mean (1981 to 2010) cumulative precipitation. Bottom pane: daily and mean (1981 to 2010) high and low temperature.

CROPPING AND TILLAGE SYSTEMS

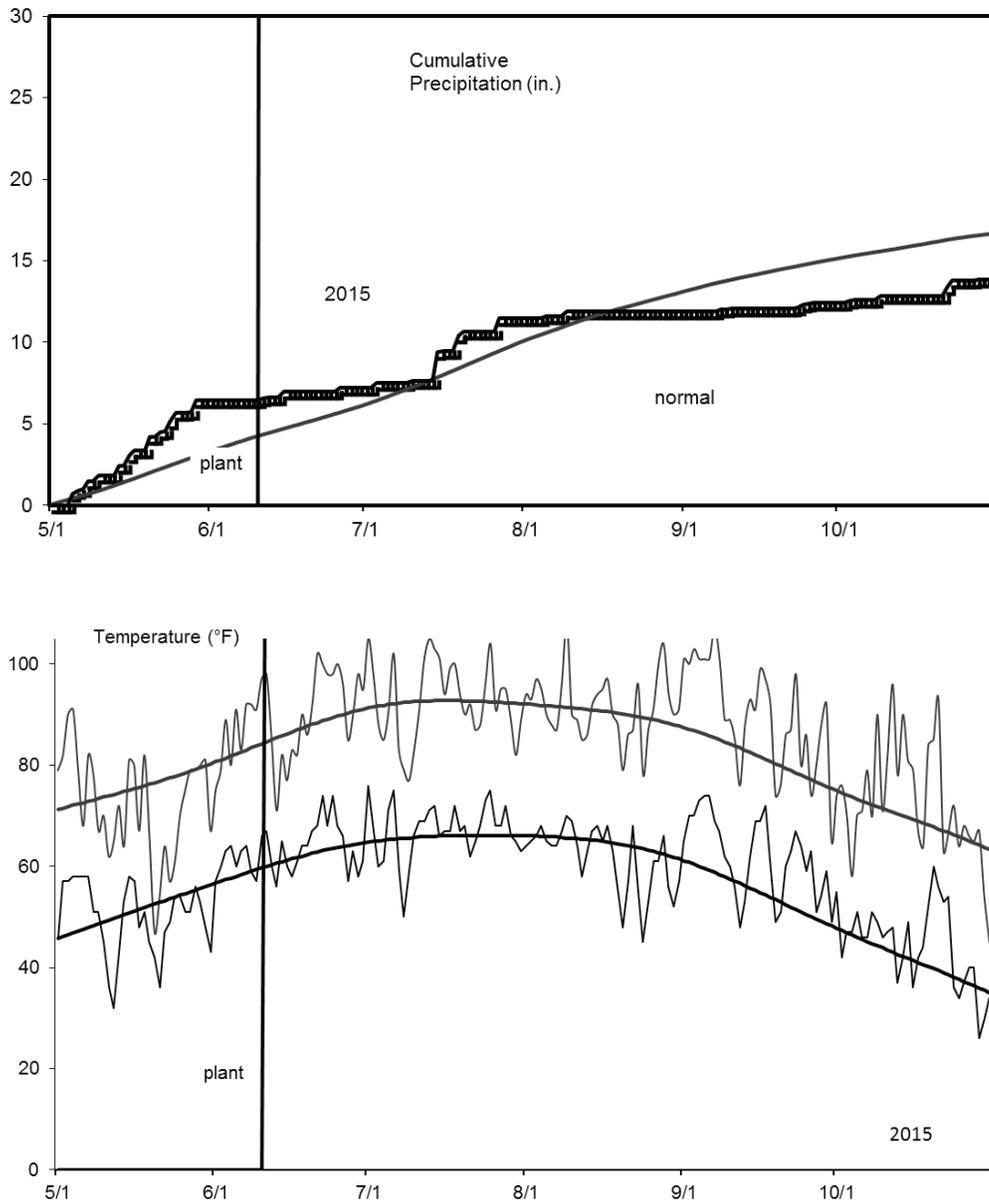


Figure 2. Precipitation and temperature during the growing season near Hays, KS. Top pane: daily and mean (1981 to 2010) cumulative precipitation. Bottom pane: daily and mean (1981 to 2010) high and low temperature.

CROPPING AND TILLAGE SYSTEMS

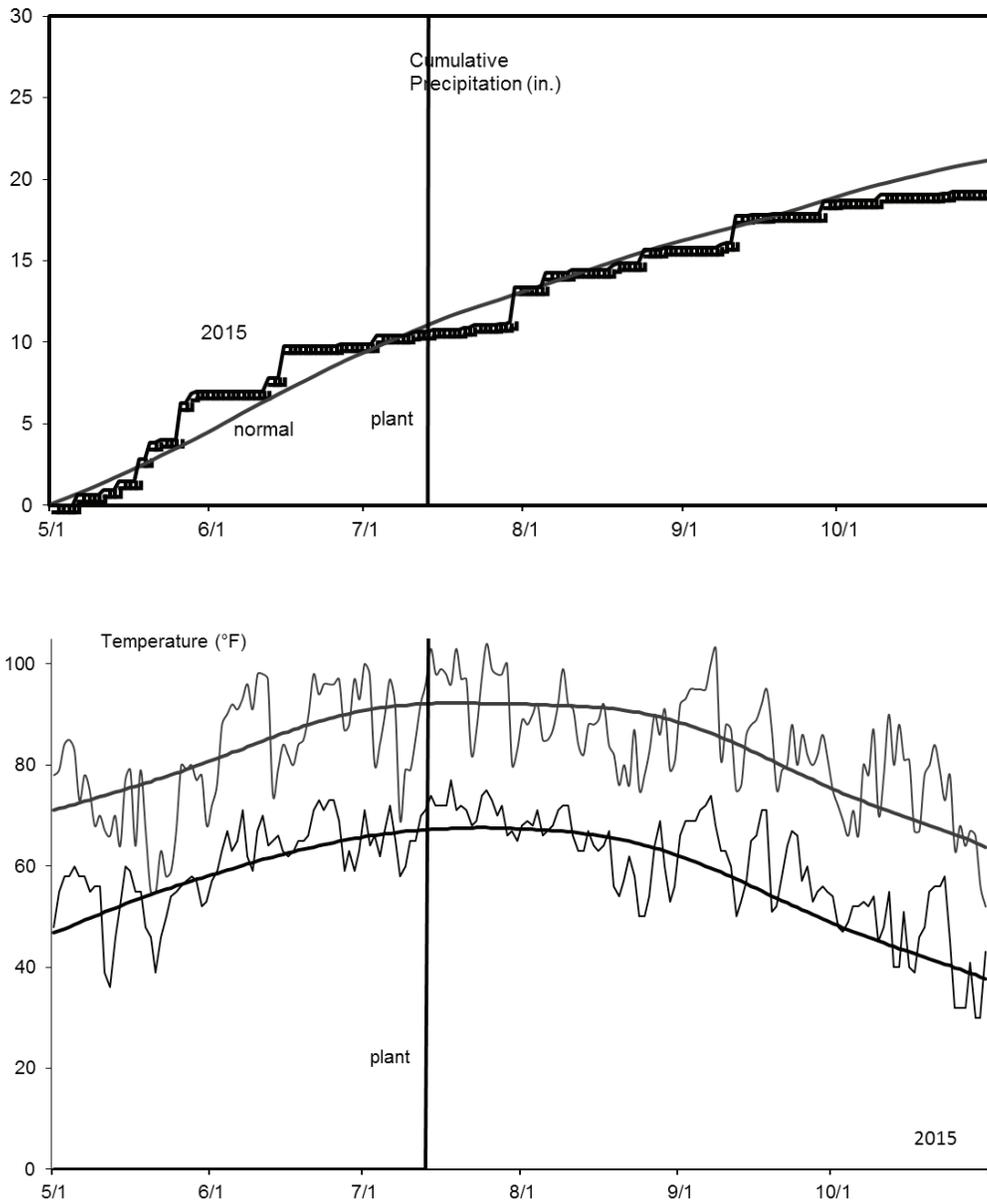


Figure 3. Precipitation and temperature during the growing season near Hutchinson, KS. Top pane: daily and mean (1981 to 2010) cumulative precipitation. Bottom pane: daily and mean (1981 to 2010) high and low temperature.

CROPPING AND TILLAGE SYSTEMS

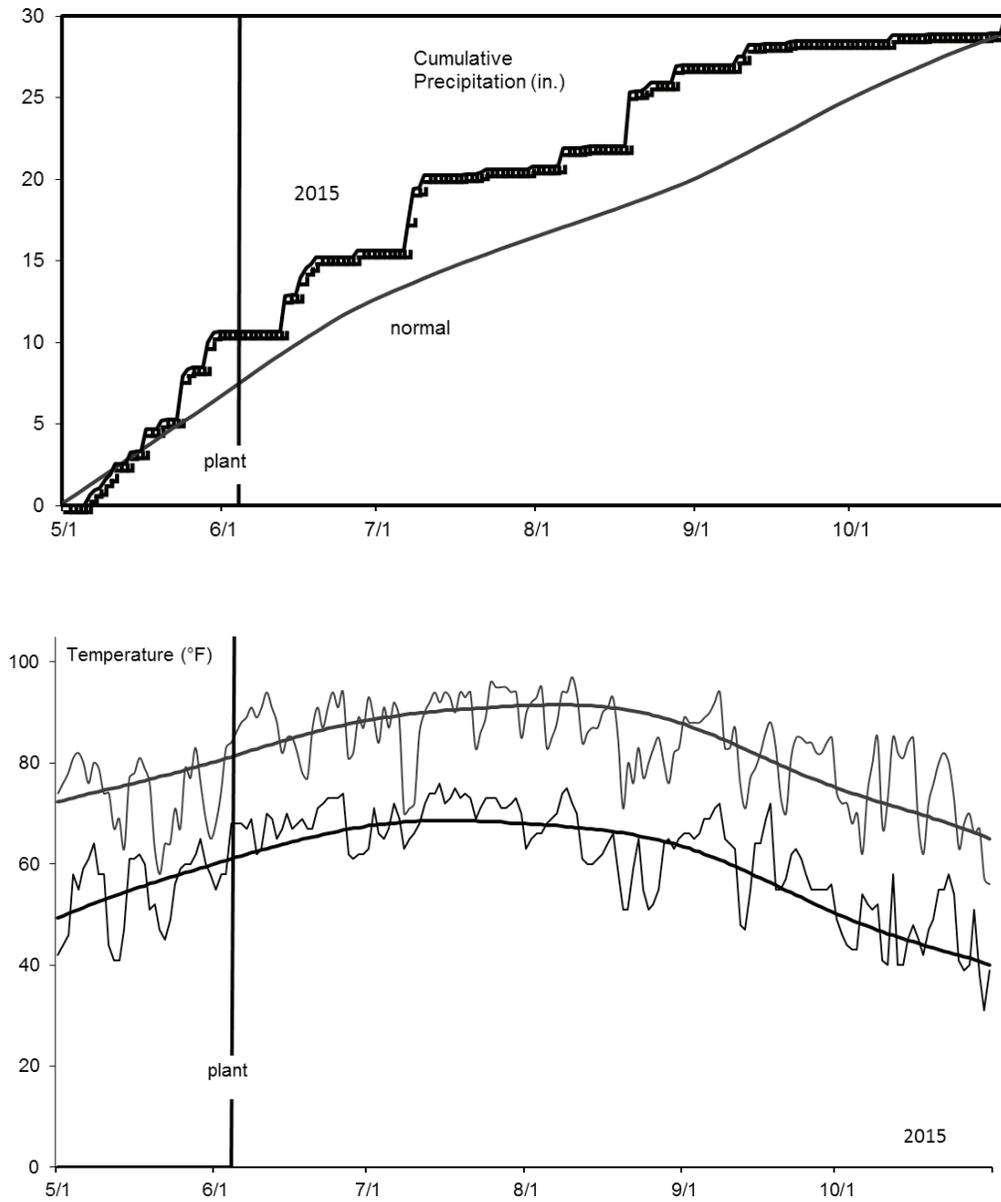


Figure 4. Precipitation and temperature during the growing season near Mound Valley, KS. Top pane: daily and mean (1981 to 2010) cumulative precipitation. Bottom pane: daily and mean (1981 to 2010) high and low temperature.

CROPPING AND TILLAGE SYSTEMS

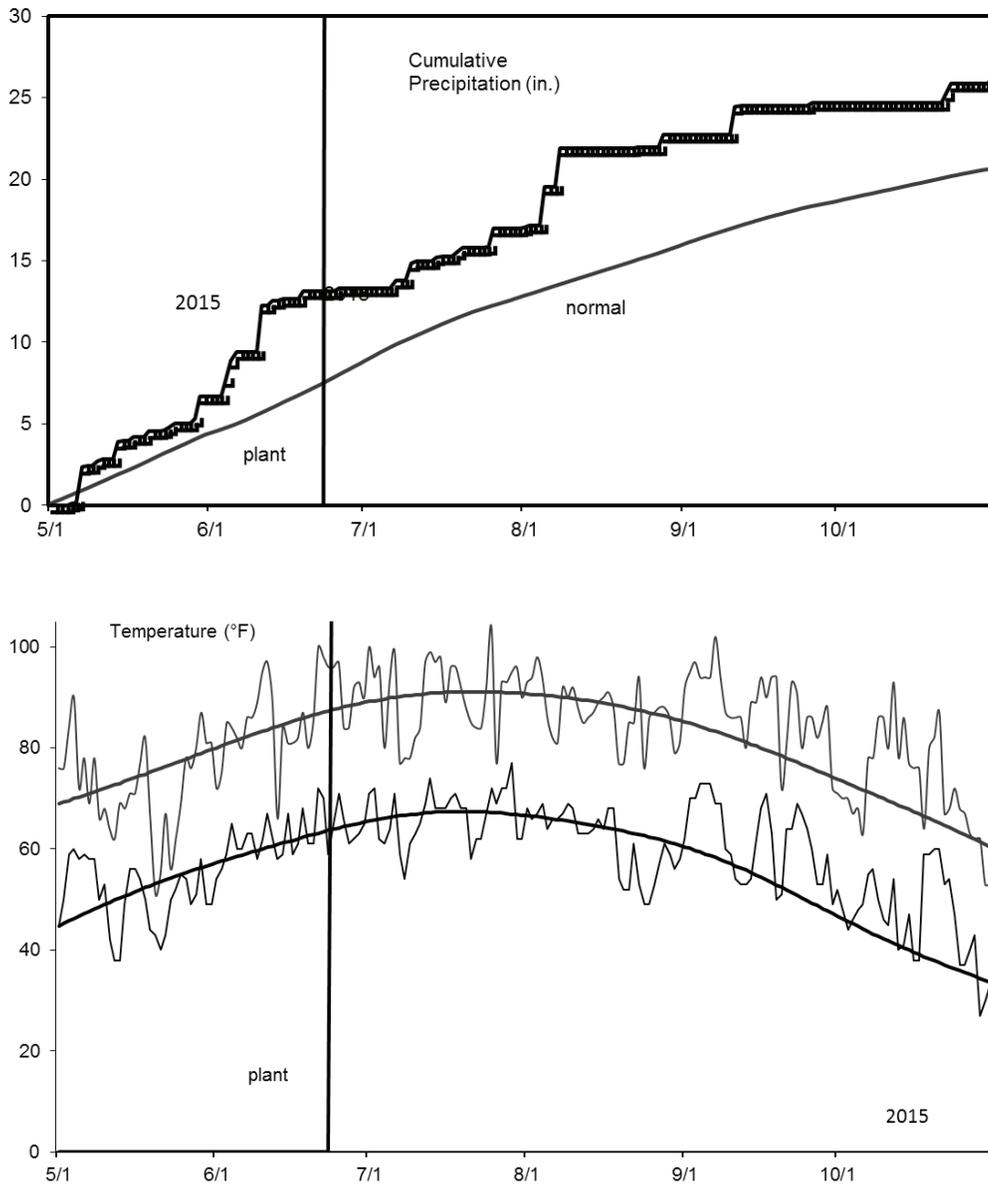


Figure 5. Precipitation and temperature during the growing season near Scandia, KS. Top pane: daily and mean (1981 to 2010) cumulative precipitation. Bottom pane: daily and mean (1981 to 2010) high and low temperature.

2016 Kansas Summer Annual Forage Hay and Silage Variety Trial

J. Holman, G. Cramer, A. Esser, J. Lingenfelter, S. Maxwell, J. Moyer, A. Obour, and T. Roberts

Summary

In 2016 summer annual forage variety trials were conducted across Kansas near Garden City, Hays, Hutchinson, Mound Valley, and Scandia. All sites evaluated hay and silage entries. Companies were able to enter varieties into any possible combinations of research sites, so not all sites had all varieties. Across the sites, a total of 99 hay varieties and 99 silage varieties were evaluated.

Introduction

In 2014 there was a total of 34,455,000 acres of hay and haylage harvested in the United States for a total of 95,372,000 dry matter tons of production. Yields averaged 2.77 tons of dry matter per acre. Of this total, about 13,580,000 acres were alfalfa, which averaged 3.76 dry matter tons per acre, and all other crops averaged 2.13 dry matter tons/a.

In Kansas, there were 2,420,000 acres of hay and haylage harvested with an average yield of 2.24 dry matter tons per acre in 2014. Of this total, 650,000 acres were alfalfa, with an average yield of 3.72 dry matter tons per acre, and 1,770,000 acres were crops other than alfalfa, with an average yield of 1.69 dry matter tons/a. Kansas was ranked 6th in the United States for hay and haylage production, which largely supports the state dairy (ranked 19th in the US and valued at \$482,765,000), and cattle (feedlot, background, and cow/calf) industries (ranked second in the US and valued at \$10,153,087,000). Dairy and beef cattle represented 58% of the total agriculture product of Kansas in 2014. Hay and grain commodities that support these two industries are critical for the state.

Study Objectives

The objectives of the Kansas Summer Annual Forage Variety Trial are to evaluate the performance of released and experimental varieties, determine where these varieties are best adapted, and increase the visibility of summer annual forages in Kansas. Breeders, marketers, and producers use data collected from the trials to make informed variety selections. The Summer Annual Forage Variety Trial is planted at locations across Kansas based on the interest of those entering varieties into the test.

Procedures

The Summer Annual Forage Variety Trial was conducted near Garden City, Hays, Hutchinson, Mound Valley, and Scandia. All of the sites evaluated hay and silage entries. Companies were able to enter varieties into any possible combinations of research sites, so not all sites had all varieties. In the hay test, there were 34 entries at Garden City, 24 at Hays, 4 at Hutchinson, 14 at Mound Valley, and 23 at Scandia. In the silage test, there were 48 entries at Garden City, 22 at Hays, 5 at Hutchinson, 9 at Mound

Valley, and 15 at Scandia (Table 1). Across the sites, a total of 99 hay varieties and 99 silage varieties were evaluated. Information on the varieties is shown in Tables 2 and 3.

Management guidelines were provided to cooperators; however, previous growing experience influenced final management decisions. All trials were planted in small research plots (approximately 225 ft²) with three replications. Cultural practices (Table 4), growing season temperature, and precipitation (Figures 1-5) are provided for each site. Results are listed alphabetically by seed supplier. Forage samples were dried, ground, and analyzed for nutrient contents using NIR (near infrared reflectance) by SDK Laboratories in Hutchinson, KS. Nutrient contents measured were acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro true dry matter digestibility after 48 hours (IVTDMD@48hr), lignin, percent of NDF digestible after 48 hours (NDFD@48hr), nitrogen free NDF (NDFn), net energy for gain (NEG), net energy for lactation (NEL), net energy for maintenance (NEM), non-fibrous carbohydrates (NFC), crude protein, relative forage quality (RFQ), total digestible nutrients (TDN), and starch (silage only).

2016 Growing Conditions

Temperature and precipitation (Figures 1-5) for each site are shown. Thick black lines on the temperature graphs represent long-term average high and low temperatures (°F) for the location. The upper thin line represents actual daily high temperatures, and the lower thin line represents actual daily low temperatures. On the precipitation graph, the line labeled “normal” represents long-term average precipitation (1981-2010), and the line labeled “2016” represents actual precipitation.

In general, the 2016 growing season saw favorable moisture conditions throughout, although conditions were dry in the spring at Garden City and below normal at Scandia. Supplemental irrigation at Garden City negated any dry conditions, and precipitation at Scandia was still greater than the two western locations (Garden City and Hays).

Results and Discussion

Since all entries were not evaluated across all sites, data were analyzed by location. All locations had a control entry of Rox Orange (Waconia) and Sumac for the hay test, and a control entry of Kansas Orange for the silage test.

Hay Test

Averaged across locations, forage sorghum yielded slightly more than sorghum sudan, sudan, or millet at the first cutting, but in subsequent cuttings sorghum sudan yielded more (Table 5). Brown mid-rib (BMR) forage sorghum and sorghum sudan yields were comparable or greater than non-BMR types at the first cutting; in subsequent cuttings non-BMR types tended to yield more than BMR types. The BMR types had more IVTDMD, NDFD, and RFQ, and less lignin than non-BMR types.

At Garden City, Sweetleaf II, Grazex BMR 301, and Super Sugar DM were in the top LSD (Least Significant Difference at $P \leq 0.05$) group in the first cutting (Table 6). In the second cutting more separation occurred between entries, and Sweetleaf II, Canex, Sordan Headless, Grazex BMR 301, Grazex BMR 801, 121 BMR, and Super Sugar

were in the highest yielding LSD group. Crude protein averaged 9.6% and TDN was 48.6%.

At Hays, Bruiser BMR had the greatest yield, and all varieties except Sumac, Waconia, Canex BMR 600, Drylander BMR, Arrow Experimental 1, Honey Graze V, Greentreat 1922, Nutrimax BMR, SSX1, Super Sugar DM, and Sweet Forever BMR, were in the top LSD group in the first cutting (Table 7). In the second cutting AS6402, Nutri King BMR, Super Sugar, and Sweet Six BMR were in the highest yielding LSD group. Crude protein averaged 10.7% and TDN was 54.5%.

At Hutchinson, there were no differences in yield or forage quality amongst the varieties (Table 8). Due to cutting later than normal, forage quality was lower, crude protein averaged 7.5%, and TDN was 61.7%.

At Mound Valley, AS6401, Cadan 99B, Sweet Sioux BMR, Wondergreen, S4B224, and S5C201 were in the top LSD group at the first cutting (Table 9). In the second cutting, Cadan 99B, Sweet Sioux WMR, Wondergreen, Super Sugar DM, and Sweet Six BMR were in the top LSD group. In the third and final cutting, Cadan 99B, Sweet Sioux WMR, and Wondergreen were in the top LSD group. Crude protein from the first cutting averaged 19.1% and TDN was 53.7%.

At Scandia, dry conditions limited regrowth, so only the first cutting was harvested. In the first cutting, Arrow Experimental 2, Canex, Drylander BMR, AS6401, Grazex BMR 301, Grazex BMR 801, Bruiser BMR, Nutrimax BMR, SSX1, Nutri King BMR, Super Sugar, Super Sugar DM, Sweet Forever BMR, and Sweet Six BMR were in the top LSD group (Table 10). Crude protein averaged 11.0% and TDN was 51.5%.

Silage Test

Averaged across locations, non-BMR forage sorghum types (14,700 lb/a) yielded slightly more than BMR sorghum types (12,600 lb/a) (Table 11). The BMR types had more IVTDMD, NDFD, NEG, NEL, NEM, NFC, crude protein, RFQ, TDN, and starch, while having less ADF, NDF, and lignin than non-BMR types.

At Garden City, AF8301, NK300, SP1615, SP1880, SS304, SS405, X5063, X5129, Canex BMR 540, 4-EVERgreen, and GW 400 BMR were in the top LSD group for silage (Table 12). Crude protein averaged 6.5%, TDN was 53%, and starch was 11.5%.

At Hays, AF7102, SiloMor II, F4C204, GW 400 BMR, GW 600 BMR, and 3701 were in the top LSD group for silage (Table 13). Crude protein averaged 5.3%, TDN was 55.8%, and starch was 24%.

At Hutchinson, Kansas Orange, AF7401, and AF8301 were in the top LSD group for silage (Table 14). No forage quality data were available.

At Mound Valley, AF8301 was in the top LSD group for silage (Table 15). Crude protein averaged 7.1%, TDN was 52.7%, and starch was very low due to little or no grain production.

At Scandia, 3701 was in the top LSD group for silage (Table 16). Crude protein averaged 5.7%, TDN was 51.5%, and starch was 11.4%.

Recommendation

Inestimable differences in soil type, weather, and environmental conditions play a part in increasing experimental error, therefore one should use more than one year of data to make an informed variety selection decision.

Acknowledgments

This work was funded in part by the Kansas Agricultural Experiment Station and seed suppliers. Sincere appreciation is expressed to all participating researchers and seed suppliers who have a vested interest in expanding and promoting annual forage production in the United States.

Table 1. Number of hay and silage entries for each location

Location	Silage	Hay
Garden City	48	34
Hays	22	24
Hutchinson	5	4
Mound Valley	9	14
Scandia	15	23
Total	99	99

Table 2. 2016 Hay Entries. Hybrid information was provided by seed companies

No.	Company	Variety/entry	Type ¹	BMR	Dwarf	Male sterile	Dry stalk	Photo-period sensitive	Maturity ²	Greenbug resistance
1	Advanta Seeds	AS6401	SS	Y	N	N	N	N	ML	N
2	Advanta Seeds	AS6402	SS	Y	Y	N	N	N	L	N
3	Arrow Seed	1st Choice BMR	SS	Y	N	N	N	N	ME	N
4	Arrow Seed	Arrow EXP1	SS	Y	N	N	N	N	L	N
5	Arrow Seed	Arrow EXP2	FS	Y	N	N	N	N	L	N
6	Arrow Seed	Honey Graze V	SS	N	N	N	N	N	L	N
7	Browning Seed	Cadan 99B	SS	N	N	N	Y	N	M	N
8	Browning Seed	SweetSioux BMR	SS	Y	N	N	N	N	M	N
9	Browning Seed	SweetSioux WMR	SS	N	N	N	Y	N	M	N
10	Browning Seed	Wondergreen	SS	N	N	N	Y	N	ME	N
11	CERES, Inc.	S4B224	SS	Y	N	N	N	N	L	N
12	CERES, Inc.	S5C201	SS	N	N	N	N	Y	L	N
13	Chromatin	CHR12FS0012	FS	N	N	N	N	N	M	N
14	Chromatin	HiKane II	FS	N	N	N	N	N	M	N
15	Chromatin	Millet BMF	MT	Y	N	N	N	N	E	N
16	Chromatin	Millex 32	MT	N	N	N	N	N	E	N
17	Chromatin	Sordan Headless	SS	N	N	N	N	Y	L	Y
18	Chromatin	SP4105	SS	Y	N	N	N	Y	L	Y
19	Chromatin	SP455	SS	Y	N	N	N	N	M	N
20	Chromatin	SP6205	SS	Y	Y	N	N	N	ML	N
21	Croplan	Greentreat 1731	SS	Y	Y	N	N	N	E	N
22	Croplan	Greentreat 1922	SS	Y	N	N	N	Y	L/PPS	N
23	Croplan	Greentreat Rocket	SU	Y	Y	N	N	N	M	N
24	KSU	Sumac	FS	N	N	N	N	N	M	N

continued

Table 2. 2016 Hay Entries. Hybrid information was provided by seed companies

No.	Company	Variety/entry	Type ¹	BMR	Dwarf	Male sterile	Dry stalk	Photo-period sensitive	Maturity ²	Greenbug resistance
25	KSU	Waconia	FS	N	N	N	N	N	M	N
26	Monsanto	BMR45S	SS	Y	N	Y	N	N	M	N
27	Monsanto	Nutri-Cane II	FS	N	N	Y	N	N	M	N
28	Monsanto	Sweetleaf II	FS	N	N	Y	N	N	M	N
29	Sharp Bros Seed	Canex	FS	N	N	Y	N	N	ME	N
30	Sharp Bros Seed	Canex BMR 210	FS	Y	N	N	N	N	M	N
31	Sharp Bros Seed	Canex BMR 600	FS	Y	N	Y	N	N	ML	N
32	Sharp Bros Seed	Canex BMR 600 w/ PO	FS	Y	N	N	N	N	ML	N
33	Sharp Bros Seed	Grazex BMR 301	SS	Y	N	Y	N	N	M	N
34	Sharp Bros Seed	Grazex BMR 801	SS	Y	N	Y	N	N	M	N
35	Star Seed	Bruiser BMR	SS	Y	N	Y	N	N	M	N
36	Star Seed	Drylander BMR	FS	Y	N	N	N	Y	L	N
37	Star Seed	Nutrimax BMR	SS	Y	N	N	N	N	L	N
38	Star Seed	SSX1	SS	Y	N	N	N	N	L	N
39	Sudax	111BMR	SS	Y	N	N	N	N	E	N
40	Sudax	121BMR	SS	Y	N	N	N	Y	L	N
41	Walter Moss Seed	Mega green	SS	N	N	N	N	Y	L	Y
42	Ward Seed	Nutri King BMR	SS	Y	N	N	N	N	ME	N
43	Ward Seed	Super Sugar	SS	N	N	N	N	N	E	N
44	Ward Seed	Super Sugar DM	SS	N	N	N	N	N	L	N
45	Ward Seed	Sweet Forever BMR	SS	Y	N	N	N	Y	L	N
46	Ward Seed	Sweet Six BMR	SS	Y	N	N	Y	N	E	N

¹ Abbreviations: Forage sorghum (FS), sorghum sudan (SS), sudan grass (SN), millet (MT).

² Maturity groups: Early (E), medium early (ME), medium (M), medium late (ML), late (L), and full (F).

Table 3. 2016 Silage Entries. Hybrid information was provided by seed companies

No.	Company	Variety/entry	Type ¹	BMR	Dwarf	Male sterile	Dry stalk	Photo-period sensitive	Maturity ²	Greenbug resistance	1,000 seed weight
											g
1	Advanta Seeds	AF7101	FS	Y	N	N	Y	N	E	N	36.67
2	Advanta Seeds	AF7102	FS	Y	Y	N	N	N	E	N	24.17
3	Advanta Seeds	AF7401	FS	Y	Y	N	N	N	L	N	22.95
4	Advanta Seeds	AF8301	FS	N	Y	N	N	N	ML	N	32.12
5	Arrow Seed	SiloMor II	FS	N	N	N	N	N	L	N	30.53
6	Arrow Seed	SiloMor II BMR	FS	Y	N	N	N	N	L	N	28.74
7	CERES, Inc.	F4C204	FS	N	N	N	N	N	E	N	26.25
8	CERES, Inc.	F4C207	FS	N	N	N	N	N	ML	N	28.31
9	Chromatin	CHR12FS0012	FS	N	N	N	N	N	M	N	26.67
10	Chromatin	CHR14FB0240	FS	Y	N	N	N	N	M	N	33.37
11	Chromatin	HiKane II	FS	N	N	N	N	N	M	N	22.64
12	Chromatin	NK300	FS	N	N	N	N	N	ME	N	32.96
13	Chromatin	Red Top+BMT	FS	Y	N	N	N	N	M	N	30.17
14	Chromatin	Sordan Headless	SS	N	N	N	N	Y	L	N	29.96
15	Chromatin	SP1615	FS	N	N	N	N	Y	L	N	26.58
16	Chromatin	SP1880	FS	N	N	N	N	N	L	N	32.27
17	Chromatin	SP2774BMR	FS	Y	N	N	N	N	M	N	26.39
18	Chromatin	SP2876BMR	FS	Y	N	N	N	N	M	N	23.94
19	Chromatin	SP3902BD	FS	Y	Y	N	N	N	L	N	33.48
20	Chromatin	SP3903BD	FS	Y	Y	N	N	N	ML	N	30.55
21	Chromatin	SP4105BMR	SS	Y	N	N	N	Y	L	N	28.15
22	Chromatin	SS304	FS	N	N	N	N	N	L	N	24.71
23	Chromatin	SS405	FS	N	N	N	N	N	L	N	27.04
24	Croplan	3701	FS	N	N	N	N	N	L	N	26.61
25	Croplan	BMR 3411	FS	Y	N	N	N	N	ME	N	33.44
26	Croplan	BMR 3561	FS	Y	N	Y	N	N	M	N	26.16
27	Croplan	BMR 3631	FS	Y	Y	N	N	N	ML	N	32.75

continued

Table 3. 2016 Silage Entries. Hybrid information was provided by seed companies

No.	Company	Variety/entry	Type ¹	BMR	Dwarf	Male sterile	Dry stalk	Photo-period sensitive	Maturity ²	Greenbug resistance	1,000 seed weight g
28	KSU	Kansas Orange	FS	N	N	N	N	N	M	N	18.62
29	Monsanto	Nutri-Choice II	FS	N	N	Y	N	N	ML	N	33.71
30	Scott Seed Co	X50610	FS	Y	Y	N	N	N	L	N	30.08
31	Scott Seed Co	X5063	FS	Y	N	Y	N	N	M	N	26.99
32	Scott Seed Co	X50711	FS	N	N	N	N	N	L	N	37.18
33	Scott Seed Co	X50712	FS	N	N	N	N	N	M	N	30.66
34	Scott Seed Co	X5129	FS	N	N	N	N	Y	L	N	23.50
35	Scott Seed Co	X51410	FS	Y	Y	N	N	N	L	N	33.13
36	Scott Seed Co	X51423	FS	Y	N	N	N	N	M	N	32.58
37	Scott Seed Co	X5143	FS	Y	N	Y	N	N	M	N	30.04
38	Sharp Bros Seed	Canex BMR 210	FS	Y	N	N	N	N	M	N	26.91
39	Sharp Bros Seed	Canex BMR 540	FS	Y	Y	N	N	N	ML	N	30.21
40	Sharp Bros Seed	Canex BMR 550	FS	Y	Y	N	N	N	ML	N	33.25
41	Sharp Bros Seed	Canex BMR 600 w/ PO	FS	Y	N	N	N	N	ML	N	27.64
42	Sharp Bros Seed	Silex BMR 503	FS	Y	Y	N	N	N	ML	N	29.40
43	Star Seed	Magnum Ultra BMR	FS	Y	N	Y	N	N	L	N	26.76
44	Sudax	331BMR	FS	Y	Y	N	N	N	ML	N	31.33
45	Sudax	ESP1601	FS	Y	N	N	N	N	ME	N	33.48
46	Walter Moss Seed	4EVERgreen	FS	N	N	N	N	Y	L	Y	27.52
47	Ward Seed	EXP: 10216	FS	Y	N	Y	Y	N	E	N	26.15
48	Ward Seed	GW 400 BMR	FS	Y	N	Y	N	N	ME	N	25.11
49	Ward Seed	GW 600 BMR	FS	Y	N	N	Y	N	M	N	32.40
50	Ward Seed	GW-2120	FS	N	N	Y	N	N	M	N	24.26
51	Ward Seed	Silo Pro BMR	FS	Y	Y	N	N	N	M	N	32.62

¹ Abbreviations: Forage sorghum (FS), sorghum sudan (SS), sorghum (S).² Maturity groups: Early (E), medium early (ME), medium (M), medium late (ML), late (L), and full (F).

CROPPING AND TILLAGE SYSTEMS

Table 4. Irrigation, planting, harvesting, and fertilizing details for hay and silage variety tests near Garden City, Hays, Hutchinson, Mound Valley, and Scandia, KS, in 2016

Location	Irrigation	Planting date	1st	2nd	3rd	Seeding rate	Harvest area	Fertilizer	
			harvest date	harvest date	harvest date			N	P ₂ O ₅
						lb/a	ft ²	----- lb/a -----	
Hay test									
Garden City	10.49	3-Jun	4-Aug	22-Sep	-*	20	225	180	0
Hays	-	6-Jun	18-Aug	17-Oct	-	15	90	50	30
Hutchinson	-	10-Jun	10-Aug	19-Sep	-	20	54	50	0
Mound Valley	-	9-Jun	13-Jul	18-Aug	4-Oct	20	45	150	60
Scandia	-	10-Jun	10-Aug	-	-	30	60	50	0

Location	Irrigation	Planting date	1st	2nd	3rd	Seeding rate	Harvest area	Fertilizer	
			harvest date	harvest date	harvest date			N	P ₂ O ₅
						seeds/a	ft ²	----- lb/a -----	
Silage test									
Garden City	10.49	15-Jun	-**	-	-	80,000	225	180	0
Hays	-	7-Jun	-	-	-	50,000	12.5	50	30
Hutchinson	-	10-Jun	-	-	-	50,000	87	100	0
Mound Valley	-	9-Jun	-	-	-	100,000	100	150	60
Scandia	-	9-Jun	-	-	-	92,400	12.5	50	0

*Based on growing conditions and plant regrowth, some sites were cut more than others.

**Silage entries were harvested at soft dough or end of season for varieties that did not reach soft dough.

Table 5. Hay performance across locations summary

Type	Performance			Forage quality												
	1st cut- ting	2nd cut- ting	Total yield	ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ	TDN
	----- lb DM/a -----			----- % -----												
Forage Sorghum (26)*	7,245	1,942	9,187	40.36	62.58	73.30	7.66	55.16	58.20	0.24	0.53	0.56	18.39	10.34	94.08	52.65
Sorghum Sudan (68)	7,069	2,596	9,664	40.69	62.19	74.53	7.72	55.94	57.84	0.22	0.52	0.55	15.90	11.86	88.95	51.80
Sudan (3)	6,320	2,093	8,413	41.40	60.71	75.72	7.28	58.23	56.46	0.21	0.51	0.54	14.49	12.12	88.88	51.02
Millet (2)	6,101	133	6,234	42.37	65.36	70.45	8.99	51.63	60.78	0.19	0.49	0.51	14.26	10.96	81.79	48.95
Forage Sorghum BMR (9)	7,255	1,836	9,091	40.95	63.23	75.79	7.29	57.94	58.80	0.23	0.53	0.56	16.77	10.08	94.48	52.52
Forage Sorghum Non-BMR (17)	7,211	2,291	9,502	40.05	62.23	71.97	7.84	53.68	57.88	0.24	0.53	0.56	19.25	10.47	93.87	52.73
Sorghum Sudan BMR (53)	7,093	2,526	9,619	40.83	62.37	74.63	7.66	56.45	58.00	0.23	0.52	0.55	16.09	11.45	89.89	51.93
Sorghum Sudan Non-BMR (15)	6,766	3,428	10,194	40.16	61.54	74.18	7.91	54.16	57.24	0.22	0.52	0.55	15.26	13.31	85.62	51.38

*Number in parenthesis is the number of variety × location entries across the state of Kansas.

Table 6a. Hay performance test near Garden City

Brand	Name	Performance						
		1st cutting	2nd cutting	Total yield	1st cutting	2nd cutting	1st height	2nd height
		lb DM/a			% moisture		in.	
Forage sorghum								
Chromatin	CHR12FS0012	5,213	2,843	8,055	0.86	0.86	84	61
Chromatin	HiKane II	10,263	3,312	13,574	0.85	0.85	92	63
KSU	Sumac	7,862	2,894	10,757	0.86	0.86	86	54
KSU	Waconia	8,671	1,617	10,288	0.87	0.87	86	55
Monsanto	Nutri-Cane II	7,504	2,140	9,644	0.88	0.88	92	54
Monsanto	Sweetleaf II	12,504	4,830	17,334	0.78	0.78	102	90
Sharp Bros Seed	Canex	8,784	3,976	12,759	0.85	0.85	84	68
Sharp Bros Seed	Canex BMR 600	7,158	2,303	9,462	0.88	0.88	102	58
Star Seed	Drylander BMR	5,791	962	6,753	0.90	0.90	97	56
Millet								
Chromatin	Millex 32	7,253	0	7,253	0.83	0.83	102	0
Chromatin	Millex BMR	4,949	266	5,215	0.86	0.86	70	15
Sorghum sudan								
Advanta Seeds	AS6401	7,949	3,055	11,004	0.87	0.87	104	71
Advanta Seeds	AS6402	6,956	3,023	9,979	0.85	0.85	85	54
Chromatin	Sordan Headless	7,779	3,836	11,614	0.88	0.88	106	76
Chromatin	SP4105	7,143	1,912	9,056	0.88	0.88	82	53
Chromatin	SP455	8,734	2,941	11,675	0.85	0.85	99	73
Chromatin	SP6205	6,582	1,830	8,412	0.85	0.85	88	55
Croplan	Greentreat 1731	6,105	1,985	8,090	0.85	0.85	85	52

continued

Table 6a. Hay performance test near Garden City

Brand	Name	Performance						
		1st cutting	2nd cutting	Total yield	1st cutting	2nd cutting	1st height	2nd height
		lb DM/a			% moisture		in.	
Sorghum sudan, continued								
Croplan	Greentreat 1922	5,146	2,724	7,870	0.90	0.90	84	58
Monsanto	BMR45S	10,039	3,227	13,266	0.83	0.83	100	75
Sharp Bros Seed	Grazex BMR 301	11,353	3,665	15,018	0.83	0.83	110	81
Sharp Bros Seed	Grazex BMR 801	9,908	3,423	13,331	0.83	0.83	104	75
Star Seed	Bruiser BMR	7,009	1,721	8,730	0.86	0.86	90	55
Star Seed	Nutrimax BMR	6,592	2,347	8,939	0.87	0.87	98	57
Star Seed	SSX1	6,542	1,795	8,337	0.88	0.88	96	59
Sudax	111 BMR	7,417	2,150	9,567	0.81	0.86	98	67
Sudax	121 BMR	6,025	3,428	9,453	0.90	0.90	87	60
Walter Moss Seed	Mega green	8,567	2,792	11,359	0.88	0.88	104	73
Ward Seed	Nutri King BMR	9,880	2,877	12,757	0.85	0.85	94	71
Ward Seed	Super Sugar	8,723	3,689	12,413	0.83	0.83	100	76
Ward Seed	Super Sugar DM	10,784	3,066	13,850	0.85	0.85	110	76
Ward Seed	Sweet Forever BMR	8,370	2,645	11,015	0.88	0.88	106	78
Ward Seed	Sweet Six BMR	9,035	2,839	11,874	0.83	0.83	102	74
Sudan								
Croplan	Greentreat Rocket	7,048	2,749	9,798	0.89	0.89	80	55
	Average	7,931	2,614	10,544	0.86	0.86	94.39	61.70
	LSD (0.05)	1,954	1,416	2,269				

Plant date: 6/3/2016

Days to harvest:

62

49

Table 6b. Hay performance test near Garden City

Brand	Name	Forage quality												
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ	TDN
----- % -----														
Forage sorghum														
Chromatin	CHR12FS0012	43.94	66.17	66.87	9.10	47.17	61.54	0.16	0.47	0.49	16.14	9.34	74.28	47.30
Chromatin	HiKane II	43.48	64.99	65.80	9.33	47.83	60.44	0.17	0.48	0.50	17.31	8.49	75.05	47.64
KSU	Sumac	41.72	63.81	67.93	8.60	50.53	59.34	0.20	0.50	0.53	19.36	8.31	82.72	50.00
KSU	Waconia	41.98	64.98	67.70	8.82	51.30	60.43	0.19	0.50	0.52	16.95	9.05	82.59	49.39
Monsanto	Nutri-Cane II	42.17	64.26	67.87	9.17	51.00	59.77	0.18	0.49	0.51	16.56	9.15	80.54	48.70
Monsanto	Sweetleaf II	45.45	69.12	63.37	10.15	44.17	64.28	0.15	0.46	0.48	15.41	8.66	68.93	46.38
Sharp Bros Seed	Canex	41.04	63.06	68.33	9.10	49.30	58.65	0.21	0.51	0.54	20.47	8.67	86.64	50.73
Sharp Bros Seed	Canex BMR 600	42.39	65.21	70.90	8.77	53.50	60.65	0.19	0.49	0.52	15.52	9.13	81.21	49.09
Star Seed	Drylander BMR	44.46	66.91	72.80	8.74	55.90	62.23	0.18	0.48	0.51	13.29	8.67	75.46	48.36
Millet														
Chromatin	Millex 32	45.06	67.56	64.95	9.96	45.25	62.83	0.15	0.46	0.48	14.66	9.51	69.68	46.09
Chromatin	Millex BMR	39.69	63.20	74.55	8.41	56.30	58.77	0.22	0.52	0.54	13.86	12.31	92.89	51.22
Sorghum sudan														
Advanta Seeds	AS6401	42.33	63.45	71.93	8.93	53.50	59.01	0.18	0.49	0.51	14.44	11.12	81.72	48.77
Advanta Seeds	AS6402	41.91	62.87	73.23	8.15	56.33	58.47	0.19	0.50	0.52	13.41	11.83	84.36	49.57
Chromatin	Sordan Headless	44.75	65.34	68.20	9.56	50.15	60.77	0.15	0.46	0.48	14.04	9.44	70.57	46.17
Chromatin	SP4105	44.26	64.03	73.57	8.05	59.03	59.55	0.18	0.49	0.51	12.93	9.48	77.36	48.61
Chromatin	SP455	42.37	63.56	68.60	8.62	51.23	59.11	0.19	0.49	0.51	16.39	9.87	81.61	48.96
Chromatin	SP6205	42.28	63.82	71.23	8.46	54.03	59.36	0.18	0.48	0.51	13.74	10.89	80.85	48.48
Croplan	Greentreat 1731	42.83	64.86	70.03	8.68	53.53	60.32	0.18	0.49	0.51	14.04	10.28	80.01	48.55

continued

Table 6b. Hay performance test near Garden City

Brand	Name	Forage quality												
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ	TDN
----- % -----														
Croplan	Greentreat 1922	42.35	61.93	74.23	8.09	57.67	57.60	0.18	0.49	0.51	12.53	11.92	81.14	48.76
Monsanto	BMR45S	40.80	63.48	71.13	8.90	52.17	59.04	0.21	0.51	0.54	18.18	9.42	88.73	50.84
Sharp Bros Seed	Grazex BMR 301	44.24	67.86	65.00	10.06	47.05	63.11	0.16	0.46	0.48	15.16	8.23	71.11	46.67
Sharp Bros Seed	Grazex BMR 801	44.22	66.81	66.33	9.63	46.90	62.14	0.16	0.47	0.49	15.70	8.80	72.52	46.89
Star Seed	Bruiser BMR	41.41	64.69	72.97	7.82	57.00	60.16	0.22	0.52	0.55	16.06	9.47	89.92	51.50
Star Seed	Nutrimax BMR	42.24	63.81	72.30	8.63	54.53	59.35	0.19	0.49	0.52	15.94	9.05	82.08	49.38
Star Seed	SSX1	43.60	64.71	71.90	9.07	53.63	60.18	0.17	0.48	0.50	13.93	9.56	76.16	47.69
Sudax	111 BMR	43.25	64.32	72.40	7.95	57.80	59.81	0.19	0.50	0.52	13.68	9.96	79.94	49.49
Sudax	121 BMR	43.18	63.50	73.50	8.31	58.65	59.05	0.19	0.50	0.52	14.29	9.29	80.93	49.48
Walter Moss Seed	Mega green	45.13	66.61	68.30	9.34	49.97	61.95	0.15	0.46	0.48	13.72	9.35	69.82	46.33
Ward Seed	Nutri King BMR	43.04	64.40	69.30	8.90	52.60	59.89	0.19	0.49	0.51	16.14	9.21	80.22	49.01
Ward Seed	Super Sugar	42.29	64.57	67.63	8.78	48.37	60.05	0.19	0.49	0.51	17.42	9.47	80.96	48.91
Ward Seed	Super Sugar DM	44.76	66.87	66.37	9.73	47.27	62.19	0.15	0.46	0.48	15.14	8.81	70.52	46.44
Ward Seed	Sweet Forever BMR	44.21	65.89	70.30	9.56	52.03	61.28	0.16	0.47	0.49	14.07	9.29	73.89	47.30
Ward Seed	Sweet Six BMR	43.15	64.75	67.93	9.26	50.70	60.22	0.19	0.49	0.51	16.83	9.14	79.71	48.92
----- Sudan -----														
Croplan	Greentreat Rocket	41.97	61.35	74.30	8.19	57.30	57.05	0.19	0.49	0.51	13.40	11.83	82.51	49.03
	Average	41.97	64.79	69.76	8.91	52.17	60.25	0.18	0.49	0.51	15.32	9.62	79.02	48.55
	LSD (0.05)	1.68	2.02	2.68	0.68	3.19	1.88	0.03	0.02	0.03	2.02	1.40	7.49	2.04

Table 7a. Hay performance test near Hays

Brand	Name	Performance						
		1st cutting	2nd cutting	Total yield	1st cutting	2nd cutting	1st height	2nd height
		----- lb DM/a -----			----- % moisture -----		----- in. -----	
Forage sorghum								
Arrow Seed	Arrow EXP2	8,076	1,007	9,083	0.75	0.49	80	27
KSU	Sumac	7,375	1,323	8,697	0.75	0.60	64	21
KSU	Waconia	7,628	1,507	9,135	0.75	0.49	71	31
Sharp Bros Seed	Canex	9,347	985	10,332	0.72	0.62	65	28
Sharp Bros Seed	Canex BMR 210	8,869	584	9,453	0.75	0.50	79	24
Sharp Bros Seed	Canex BMR 600	6,087	1,089	7,176	0.78	0.52	82	25
Star Seed	Drylander BMR	7,100	701	7,802	0.78	0.60	90	33
Sorghum sudan								
Advanta Seeds	AS6401	8,246	1,699	9,944	0.74	0.62	83	27
Advanta Seeds	AS6402	8,188	1,767	9,955	0.73	0.57	76	32
Arrow Seed	1st Choice BMR	8,630	1,201	9,831	0.73	0.56	73	27
Arrow Seed	Arrow EXP1	6,556	973	7,529	0.79	0.58	85	24
Arrow Seed	Honey Graze V	5,741	1,477	7,217	0.76	0.65	86	33
Croplan	Greentreat 1922	6,617	1,556	8,173	0.77	0.51	83	23

continued

Table 7a. Hay performance test near Hays

Brand	Name	Performance						
		1st cutting	2nd cutting	Total yield	1st cutting	2nd cutting	1st height	2nd height
		lb DM/a			% moisture		in.	
Sorghum sudan, continued								
Sharp Bros Seed	Grazex BMR 301	7,960	1,045	9,005	0.71	0.62	77	27
Sharp Bros Seed	Grazex BMR 801	9,533	1,710	11,243	0.72	0.57	86	30
Star Seed	Bruiser BMR	9,945	865	10,811	0.72	0.57	82	25
Star Seed	Nutrimax BMR	6,861	923	7,783	0.78	0.59	85	21
Star Seed	SSX1	6,733	832	7,565	0.78	0.62	82	28
Ward Seed	Nutri King BMR	9,365	2,290	11,654	0.73	0.60	71	29
Ward Seed	Super Sugar	8,784	1,935	10,719	0.69	0.59	68	33
Ward Seed	Super Sugar DM	7,690	1,673	9,363	0.74	0.59	80	31
Ward Seed	Sweet Forever BMR	7,251	1,118	8,369	0.76	0.59	92	27
Ward Seed	Sweet Six BMR	9,367	2,501	11,868	0.71	0.60	90	34
Sudan								
Croplan	Greentreat Rocket	6,689	1,436	8,125	0.78	0.62	86	30
	Average	7,860	1,342	9,201	0.75	0.58	79.88	27.90
	LSD (0.05)	2,187	768	2,370				
Plant date: 6/6/2016								
Days to harvest:		73	60					

Table 7b. Hay performance test near Hays

Brand	Name	Forage quality												RFQ	TDN
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein			
----- % -----															
Forage sorghum															
Arrow Seed	Arrow EXP2	41.54	62.44	75.57	7.18	57.87	58.07	0.22	0.52	0.55	16.83	9.68	91.16	51.88	
KSU	Sumac	36.32	56.87	76.87	6.14	59.53	52.89	0.29	0.58	0.62	23.16	10.80	117.15	57.05	
KSU	Waconia	36.69	59.05	75.03	6.33	58.57	54.91	0.28	0.57	0.61	21.57	10.77	113.42	56.26	
Sharp Bros Seed	Canex	34.47	54.40	78.10	6.50	59.27	50.59	0.32	0.60	0.64	27.02	10.32	125.12	58.91	
Sharp Bros Seed	Canex BMR 210	37.02	59.50	77.97	6.19	61.67	55.34	0.30	0.58	0.62	22.22	9.81	116.21	57.41	
Sharp Bros Seed	Canex BMR 600	38.13	61.01	76.63	6.48	59.50	56.74	0.26	0.55	0.59	18.36	10.75	105.73	54.57	
Star Seed	Drylander BMR	38.65	61.34	77.73	6.31	60.10	57.05	0.26	0.55	0.59	18.71	10.12	105.01	54.74	
Sorghum sudan															
Advanta Seeds	AS6401	38.44	58.86	78.03	6.22	62.37	54.74	0.27	0.56	0.60	19.02	11.35	108.80	55.58	
Advanta Seeds	AS6402	39.27	59.90	76.43	6.37	60.80	55.71	0.26	0.56	0.59	18.28	11.23	105.64	54.85	
Arrow Seed	1st Choice BMR	36.94	58.61	78.10	6.00	62.90	54.50	0.29	0.58	0.62	20.26	10.97	116.05	56.88	
Arrow Seed	Arrow EXP1	40.16	60.54	76.30	6.84	57.57	56.30	0.23	0.52	0.55	16.97	10.86	93.74	51.92	
Arrow Seed	Honey Graze V	39.91	60.77	73.97	7.04	56.60	56.52	0.24	0.53	0.56	17.77	10.78	97.08	52.68	
Croplan	Greentreat 1922	42.16	62.35	75.53	6.82	59.03	57.99	0.21	0.51	0.54	14.06	10.92	87.94	50.96	

continued

Table 7b. Hay performance test near Hays

Brand	Name	Forage quality												
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ	TDN
----- % -----														
Sorghum sudan, continued														
Sharp Bros Seed	Grazex BMR 301	37.69	59.78	74.77	6.41	58.07	55.60	0.26	0.55	0.59	18.94	11.27	106.66	54.78
Sharp Bros Seed	Grazex BMR 801	38.44	60.24	74.52	6.52	57.52	56.03	0.26	0.55	0.59	19.03	10.81	104.95	54.51
Star Seed	Bruiser BMR	35.91	58.12	77.83	6.21	61.70	54.05	0.29	0.58	0.62	20.70	11.25	117.73	56.92
Star Seed	Nutrimax BMR	41.19	63.15	76.03	7.08	58.13	58.73	0.23	0.53	0.56	18.20	8.65	92.12	52.64
Star Seed	SSX1	41.40	63.06	76.17	6.99	57.63	58.65	0.23	0.52	0.55	16.92	9.61	91.80	52.04
Ward Seed	Nutri King BMR	38.84	59.80	74.33	6.78	57.83	55.62	0.25	0.55	0.58	19.74	10.21	102.08	54.04
Ward Seed	Super Sugar	37.04	59.19	73.93	6.61	55.93	55.04	0.26	0.55	0.59	19.49	11.88	108.82	54.80
Ward Seed	Super Sugar DM	38.95	61.14	73.27	6.99	55.43	56.86	0.26	0.55	0.58	20.23	10.21	102.33	54.20
Ward Seed	Sweet Forever BMR	40.25	60.75	75.60	7.26	55.60	56.50	0.24	0.54	0.57	18.67	10.91	97.68	53.05
Ward Seed	Sweet Six BMR	38.06	59.85	74.70	6.38	58.93	55.66	0.26	0.55	0.59	18.40	11.54	106.01	54.68
Sudan														
Croplan	Greentreat Rocket	38.20	57.33	76.23	6.39	60.13	53.32	0.25	0.54	0.58	17.25	12.33	102.78	53.65
	Average	38.57	59.92	75.99	6.59	58.86	55.73	0.26	0.55	0.59	19.24	10.71	104.83	54.54
	LSD (0.05)	2.72	3.23	2.43	0.84	3.60	3.00	0.03	0.03	0.03	2.87	1.97	12.54	2.57

Table 8a. Hay performance test near Hutchinson

Brand	Name	Performance						
		1st cutting	2nd cutting	Total yield	1st cutting	2nd cutting	1st height	2nd height
		lb DM/a			% moisture		in.	
Forage sorghum								
KSU	Sumac	5,500	1,534	7,034	0.69	0.73	68	46
KSU	Waconia	7,279	970	8,249	0.73	0.72	74	25
Sorghum sudan								
Advanta Seeds	AS6401	5,961	1,282	7,243	0.70	0.74	71	38
Advanta Seeds	AS6402	5,939	1,454	7,393	0.68	0.75	76	35
	Average	6,170	1,310	7,480	0.70	0.73	72	36
	LSD (0.05)	3,270	709	3,033				
Plant date: 6/9/2016								
Days to harvest:		91	42					

Table 8b. Hay performance test near Hutchinson

Brand	Name	Forage quality												
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ	TDN
		----- % -----												
		Forage sorghum												
KSU	Sumac	37.10	59.63	76.70	5.95	61.83	55.45	0.33	0.61	0.66	26.52	7.87	118.97	60.01
KSU	Waconia	36.48	59.55	77.63	5.12	65.17	55.38	0.37	0.65	0.70	30.00	6.80	130.00	63.26
		Sorghum sudan												
Advanta Seeds	AS6401	36.81	59.71	77.73	5.46	64.60	55.53	0.35	0.63	0.68	28.10	7.01	122.87	61.72
Advanta Seeds	AS6402	35.24	56.59	78.67	6.19	64.50	52.63	0.36	0.63	0.68	28.54	8.18	125.95	61.78
	Average	36.41	58.87	77.68	5.68	64.03	54.75	0.35	0.63	0.68	28.29	7.47	124.45	61.69
	LSD (0.05)	NS	NS	NS	0.74	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 9a. Hay performance test near Mound Valley

Brand	Name	Performance						
		1st cutting	2nd cutting	3rd cutting	Total yield	1st cutting	2nd cutting	3rd cutting
		----- lb DM/a -----				----- % moisture -----		
Forage sorghum								
KSU	Sumac	2,260	2,012	1,173	5,445	0.90	0.83	0.73
KSU	Waconia	2,381	2,246	913	5,540	0.90	0.80	0.65
Sorghum sudan								
Advanta Seeds	AS6401	4,130	3,847	3,862	11,839	0.90	0.82	0.83
Advanta Seeds	AS6402	3,708	2,695	2,994	9,397	0.88	0.80	0.76
Browning Seed	Cadan 99B	4,663	5,157	6,366	16,186	0.88	0.79	0.79
Browning Seed	Sweet Sioux BMR	4,363	3,387	5,086	12,836	0.89	0.82	0.81
Browning Seed	Sweet Sioux WMR	3,797	5,708	6,700	16,206	0.88	0.78	0.77
Browning Seed	Wondergreen	4,119	5,233	6,103	15,455	0.88	0.78	0.79
CERES, Inc.	S4B224	4,405	2,789	3,295	10,488	0.88	0.81	0.78
CERES, Inc.	S5C201	4,280	2,831	2,520	9,631	0.90	0.82	0.82
Ward Seed	Nutri King BMR	3,702	3,886	1,512	9,100	0.90	0.82	0.70
Ward Seed	Super Sugar DM	2,786	4,518	2,566	9,871	0.89	0.81	0.80
Ward Seed	Sweet Forever BMR	3,460	2,717	1,015	7,192	0.89	0.80	0.71
Ward Seed	Sweet Six BMR	3,084	4,928	2,021	10,033	0.90	0.79	0.72
	Average	3,653	3,711	3,295	10,658	0.89	0.81	0.76
	LSD (0.05)	796	1,606	1,367	2,626			
Plant date: 6/9/2016								
Days to harvest:		34	36	48				

Table 9b. Hay performance test near Mound Valley

Brand	Name	Forage quality											RFQ	TDN
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein		
----- % -----														
Forage sorghum														
KSU	Sumac	36.20	56.86	81.57	6.97	59.00	52.88	0.26	0.55	0.59	13.01	19.71	86.05	54.51
KSU	Waconia	36.48	56.83	80.37	7.14	57.33	52.85	0.25	0.54	0.57	13.58	18.84	87.51	53.56
Sorghum sudan														
Advanta Seeds	AS6401	36.87	57.01	82.20	7.27	60.97	53.02	0.26	0.55	0.59	12.19	19.69	83.85	54.47
Advanta Seeds	AS6402	36.68	57.10	83.57	6.92	62.20	53.10	0.27	0.56	0.60	11.96	20.16	83.69	55.20
Browning Seed	Cadan 99B	37.61	59.60	77.43	7.44	54.30	55.43	0.24	0.54	0.57	13.33	18.34	85.26	53.04
Browning Seed	Sweet Sioux BMR	36.54	57.51	80.23	7.30	57.83	53.48	0.25	0.54	0.58	12.52	19.50	84.28	53.83
Browning Seed	Sweet Sioux WMR	38.47	59.74	77.33	7.75	53.80	55.56	0.23	0.53	0.56	13.17	17.93	82.34	52.13
Browning Seed	Wondergreen	38.77	59.79	76.77	7.75	54.10	55.60	0.23	0.53	0.56	13.97	16.98	86.71	52.27
CERES, Inc.	S4B224	36.16	57.02	81.50	6.97	60.10	53.03	0.26	0.55	0.59	12.22	19.83	85.65	54.61
CERES, Inc.	S5C201	37.80	59.30	78.43	7.55	57.27	55.15	0.24	0.53	0.57	12.56	17.74	87.82	52.97
Ward Seed	Nutri King BMR	36.84	57.46	81.13	7.29	59.47	53.44	0.25	0.54	0.58	12.57	19.28	85.13	53.92
Ward Seed	Super Sugar DM	35.50	56.20	80.27	7.60	55.80	52.27	0.25	0.54	0.57	12.94	20.23	81.38	53.45
Ward Seed	Sweet Forever BMR	36.31	57.55	81.63	7.20	59.33	53.52	0.26	0.55	0.59	12.35	19.76	84.66	54.42
Ward Seed	Sweet Six BMR	37.49	57.38	80.73	7.17	58.60	53.36	0.25	0.54	0.58	12.43	19.31	81.56	53.65
	Average	36.98	57.81	80.23	7.31	57.86	53.76	0.25	0.54	0.58	12.77	19.09	84.71	53.72
	LSD (0.05)	1.83	2.28	2.42	0.64	2.79	2.12	0.03	0.02	0.02	1.52	1.65	7.59	1.81

Plant date: 6/9/2016

CROPPING AND TILLAGE SYSTEMS

Table 10a. Hay performance test near Scandia

Brand	Name	Performance		
		1st cutting		
		lb DM/a	% moisture	in.
		Forage sorghum		
Arrow Seed	Arrow EXP2	7,377	0.81	82
KSU	Sumac	6,510	0.82	76
KSU	Waconia	6,470	0.82	78
Sharp Bros Seed	Canex	7,681	0.81	88
Sharp Bros Seed	Canex BMR 600 w/ PO	6,670	0.82	68
Star Seed	Drylander BMR	8,024	0.82	70
		Sorghum sudan		
Advanta Seeds	AS6401	7,621	0.81	90
Advanta Seeds	AS6402	6,190	0.81	60
Arrow Seed	1st Choice BMR	6,648	0.81	70
Arrow Seed	Arrow EXP1	6,493	0.83	74
Arrow Seed	Honey Graze V	5,791	0.82	96
Croplan	Greentreat 1922	5,207	0.87	62
Sharp Bros Seed	Grazex BMR 301	8,556	0.76	92
Sharp Bros Seed	Grazex BMR 801	8,848	0.78	94
Star Seed	Bruiser BMR	7,476	0.82	62
Star Seed	Nutrimax BMR	7,535	0.82	72
Star Seed	SSX1	7,536	0.82	74
Ward Seed	Nutri King BMR	8,264	0.79	90
Ward Seed	Super Sugar	8,454	0.77	90
Ward Seed	Super Sugar DM	7,468	0.80	84
Ward Seed	Sweet Forever BMR	8,476	0.81	88
Ward Seed	Sweet Six BMR	7,598	0.79	104
		Sudan		
Croplan	Greentreat Rocket	5,223	0.82	64
	Average	7,222	0.81	79
	LSD (0.05)	2,023		

Plant date: 6/10/16

Days to harvest:

61

Table 10b. Hay performance test near Scandia

Brand	Name	Forage quality												
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ	TDN
----- % -----														
Forage sorghum														
Arrow Seed	Arrow EXP2	40.01	63.05	76.20	7.02	56.60	58.64	0.24	0.54	0.57	15.02	12.69	97.88	53.05
KSU	Sumac	41.16	64.26	71.67	7.86	51.20	59.76	0.22	0.52	0.55	16.44	11.92	91.40	51.58
KSU	Waconia	41.00	65.67	71.30	7.87	51.67	61.07	0.23	0.52	0.55	16.80	11.04	93.21	51.89
Sharp Bros Seed	Canex	41.73	65.42	70.10	8.33	50.03	60.84	0.21	0.51	0.54	17.83	9.96	88.35	50.95
Sharp Bros Seed	Canex BMR 600 w/ PO	42.20	65.60	74.70	7.79	55.57	61.01	0.22	0.51	0.54	14.79	10.52	88.78	51.17
Star Seed	Drylander BMR	42.66	63.95	78.40	7.04	59.57	59.47	0.24	0.53	0.56	15.04	10.95	92.66	52.73
Sorghum sudan														
Advanta Seeds	AS6401	42.55	64.55	76.07	7.53	57.63	60.03	0.23	0.52	0.55	14.24	11.44	89.78	52.02
Advanta Seeds	AS6402	41.61	62.90	77.60	7.22	59.43	58.49	0.24	0.53	0.56	14.20	12.31	94.10	52.78
Arrow Seed	1st Choice BMR	41.96	64.06	75.57	7.82	56.83	59.57	0.23	0.53	0.56	15.90	10.64	92.05	52.24
Arrow Seed	Arrow EXP1	42.77	64.49	76.77	7.82	55.63	59.98	0.22	0.51	0.54	14.75	11.09	86.50	51.13
Arrow Seed	Honey Graze V	42.90	64.29	73.03	8.12	52.33	59.79	0.20	0.51	0.53	15.20	11.49	83.12	50.35
Croplan	Greentreat 1922	47.50	66.21	77.77	7.57	61.30	61.57	0.21	0.51	0.54	12.99	8.99	76.57	50.80

continued

Table 10b. Hay performance test near Scandia

Brand	Name	Forage quality											Crude protein	RFQ	TDN
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC				
----- % -----															
Sorghum sudan, continued															
Sharp Bros Seed	Grazex BMR 301	41.33	64.41	71.60	8.13	51.90	55.90	0.22	0.52	0.55	17.11	10.55	90.94	51.53	
Sharp Bros Seed	Grazex BMR 801	45.20	67.54	68.20	8.91	49.13	62.81	0.19	0.49	0.51	16.93	7.93	73.95	48.87	
Star Seed	Bruiser BMR	41.75	63.72	76.90	7.75	57.07	59.26	0.23	0.53	0.56	15.30	11.71	93.36	52.60	
Star Seed	Nutrimax BMR	41.88	63.80	76.80	7.51	55.73	59.34	0.22	0.52	0.55	15.06	11.75	89.22	51.72	
Star Seed	SSX1	42.14	63.79	76.73	7.41	56.50	59.33	0.23	0.52	0.55	16.11	10.60	91.11	52.02	
Ward Seed	Nutri King BMR	41.42	64.62	72.73	7.57	54.53	60.10	0.22	0.52	0.55	14.61	11.68	89.52	51.35	
Ward Seed	Super Sugar	40.91	63.26	70.70	8.26	50.70	58.84	0.21	0.51	0.54	17.86	10.44	89.30	51.02	
Ward Seed	Super Sugar DM	42.03	64.54	72.57	7.95	51.67	60.02	0.21	0.51	0.54	15.55	11.52	87.06	50.59	
Ward Seed	Sweet Forever BMR	39.70	64.24	76.10	7.55	56.43	59.74	0.24	0.54	0.57	15.34	12.03	98.72	53.05	
Ward Seed	Sweet Six BMR	43.14	65.25	72.07	7.72	54.63	60.68	0.21	0.51	0.54	16.08	9.62	84.96	51.04	
Sudan															
Croplan	Greentreat Rocket	43.36	63.07	77.07	7.24	57.07	58.66	0.21	0.51	0.54	13.31	12.50	83.79	50.91	
	Average	42.21	64.46	74.38	7.74	54.92	59.95	0.22	0.52	0.55	15.50	11.02	88.97	51.54	
	LSD (0.05)	4.03	3.72	3.12	0.96	3.19	3.46	0.04	0.03	0.04	2.37	2.98	15.19	2.79	

Table 11. Silage performance across locations summary

Type	Performance		Forage quality												
	Yield lb DM/a	ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ	TDN	Starch
Forage sorghum BMR (64)*	12,613	36.05	58.77	69.50	4.75	45.11	54.65	0.26	0.55	0.59	27.88	6.70	93.83	54.76	13.77
Forage sorghum Non-BMR (36)	14,659	38.71	63.62	64.10	5.91	40.76	59.17	0.21	0.51	0.54	25.46	5.29	75.04	50.77	12.30

*Number in parenthesis is the number of variety*location entries across the state of Kansas.

Table 12a. Silage performance test near Garden City

Brand	Variety	Performance							
		Yield lb DM/a	Harvest moisture %	Stand	Vigor	Flowering date	Days to harvest	Height in.	Lodging %
Advanta Seeds	AF7101	14,170	0.71	8	9	8/11/16	91	152	0
Advanta Seeds	AF7102	14,376	0.75	10	9	8/16/16	91	121	0
Advanta Seeds	AF7401	15,120	0.74	9	9	9/6/16	113	125	0
Advanta Seeds	AF8301	17,071	0.71	10	9	8/29/16	113	93	0
CERES, Inc.	F4C204	12,915	0.75	9	9	8/11/16	91	86	0
CERES, Inc.	F4C207	11,399	0.79	8	7	8/29/16	113	112	0
Chromatin	CHR12FS0012	15,469	0.76	10	9	8/11/16	91	132	0
Chromatin	CHR14FB0240	14,143	0.76	10	9	8/16/16	91	142	0
Chromatin	HiKane II	14,668	0.77	10	9	8/11/16	91	123	0
Chromatin	NK300	18,132	0.73	10	9	8/29/16	113	108	0
Chromatin	Red Top+BMT	12,049	0.75	8	7	8/22/16	113	124	0
Chromatin	Sordan Headless	16,171	0.78	10	9	NA	113	102	0
Chromatin	SP1615	17,809	0.76	10	9	NA	113	85	0
Chromatin	SP1880	19,340	0.74	9	9	9/13/16	113	100	0
Chromatin	SP2774BMR	12,505	0.77	9	8	8/16/16	91	119	0
Chromatin	SP2876BMR	13,572	0.77	9	9	8/16/16	91	98	0
Chromatin	SP3902BD	14,759	0.77	9	9	9/6/16	113	131	0
Chromatin	SP3903BD	13,158	0.77	9	8	9/6/16	113	96	0
Chromatin	SP4105BMR	12,854	0.80	10	8	NA	113	125	0
Chromatin	SS304	18,808	0.76	9	10	8/29/16	113	113	0
Chromatin	SS405	17,715	0.72	10	10	9/6/16	113	96	0
Croplan	BMR 3411	13,050	0.74	10	10	8/29/16	113	108	0
Croplan	BMR 3561	16,220	0.78	10	9	8/16/16	91	123	0
KSU	Kansas Orange	14,820	0.72	10	8	8/16/16	91	87	0
Monsanto	Nutri-Choice II	12,834	0.74	10	9	8/29/16	113	119	0
Scott Seed Co	X50610	14,736	0.76	9	8	9/6/16	113	85	0

continued

Table 12a. Silage performance test near Garden City

Brand	Variety	Performance							
		Yield	Harvest moisture	Stand	Vigor	Flowering date	Days to harvest	Height	Lodging
		lb DM/a	%					in.	%
Scott Seed Co	X5063	18,291	0.76	10	10	8/11/16	91	127	0
Scott Seed Co	X50711	14,937	0.75	9	9	9/6/16	113	80	0
Scott Seed Co	X50712	11,888	0.75	9	8	8/11/16	91	109	0
Scott Seed Co	X5129	18,336	0.79	10	9	NA	113	127	0
Scott Seed Co	X51410	15,168	0.76	9	9	9/6/16	113	102	0
Scott Seed Co	X51423	15,772	0.75	9	8	9/6/16	113	102	0
Scott Seed Co	X5143	14,176	0.75	9	8	8/11/16	91	117	0
Sharp Bros Seed	Canex BMR 540	16,856	0.74	9	8	9/6/16	113	114	0
Sharp Bros Seed	Canex BMR 550	15,719	0.76	9	9	9/6/16	113	93	0
Sharp Bros Seed	Canex 210	14,275	0.75	9	8	8/16/16	91	138	0
Sharp Bros Seed	Silex BMR 503	13,860	0.75	8	7	9/6/16	113	92	0
Star Seed	Magnum Ultra BMR	15,671	0.77	9	9	9/13/16	113	127	0
Sudax	BMR 331	15,763	0.73	9	9	9/6/16	113	80	0
Sudax	Exp 1601	15,813	0.76	9	9	8/16/16	91	109	0
Walter Moss Seed	4EVERgreen	17,189	0.79	10	9	NA	113	127	0
Ward Seed	EXP: 10216	14,393	0.73	10	9	8/11/16	91	102	0
Ward Seed	GW 400 BMR	18,451	0.76	9	8	8/11/16	91	102	0
Ward Seed	GW 600 BMR	14,994	0.68	10	10	8/16/16	113	117	0
Ward Seed	GW-2120	14,133	0.77	10	9	8/16/16	91	114	0
Ward Seed	Silo Pro BMR	14,080	0.77	10	10	9/6/16	113	93	0
Croplan	3701	14,274	0.73	9	8	9/6/16	113	138	0
Croplan	BMR 3631	13,761	0.76	10	9	9/6/16	113	92	0
Average		15,118	0.75	9	9	-	105	111	0
LSD (0.05)		3,091	-	-	-	-	-	-	-

Planting Date: 6/6/16
Emergence Date: 6/15/16

Table 12b. Silage performance test near Garden City

Brand	Variety	Forage quality											
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEL	NFC	Crude protein	RFQ	TDN	Starch
----- % -----													
Advanta Seeds	AF7101	34.88	56.40	71.20	4.19	43.73	52.45	0.54	28.52	7.20	94.32	53.91	17.20
Advanta Seeds	AF7102	34.57	56.61	70.10	4.60	41.77	52.65	0.54	30.22	5.59	84.25	53.68	22.13
Advanta Seeds	AF7401	34.98	58.03	70.47	4.49	48.43	53.97	0.57	27.40	6.94	99.36	55.84	9.27
Advanta Seeds	AF8301	37.53	62.84	64.30	5.42	41.67	58.44	0.51	24.15	6.12	79.43	50.75	7.83
CERES, Inc.	F4C204	33.50	56.04	70.00	4.71	41.07	52.12	0.56	31.91	5.92	89.20	54.82	22.10
CERES, Inc.	F4C207	33.67	60.09	67.03	4.94	44.97	55.89	0.54	26.02	7.12	91.86	53.85	7.83
Chromatin	CHR12FS0012	35.64	58.77	68.53	5.21	42.17	54.65	0.54	28.24	6.54	88.91	53.24	17.90
Chromatin	CHR14FB0240	36.33	58.44	70.73	4.83	45.97	54.35	0.55	27.78	6.91	94.90	54.46	16.70
Chromatin	HiKane II	36.09	59.92	67.20	5.44	41.90	55.73	0.53	27.65	6.14	85.09	52.73	16.70
Chromatin	NK300	37.55	61.82	64.33	5.52	41.43	57.49	0.52	25.45	5.73	79.23	51.38	8.43
Chromatin	Red Top+BMT	33.18	57.57	68.57	4.45	46.70	53.54	0.57	30.22	5.76	93.09	56.35	10.47
Chromatin	Sordan Headless	43.83	71.85	58.30	6.82	40.60	66.82	0.45	18.08	4.73	57.51	44.95	3.07
Chromatin	SP1615	43.31	72.18	58.13	6.69	41.83	67.13	0.45	17.66	4.66	58.78	45.67	1.83
Chromatin	SP1880	40.82	69.40	58.93	6.55	40.13	64.54	0.47	20.76	4.79	63.44	47.11	7.11
Chromatin	SP2774BMR	37.82	61.44	68.50	5.40	46.50	57.14	0.53	23.90	7.62	91.42	52.54	10.93
Chromatin	SP2876BMR	38.46	62.46	67.57	5.44	44.60	58.08	0.52	24.08	6.99	86.14	51.74	12.97
Chromatin	SP3902BD	33.48	58.84	69.03	4.12	49.40	54.72	0.57	25.84	7.84	103.96	56.04	6.70
Chromatin	SP3903BD	36.47	61.03	69.23	4.12	48.73	56.76	0.54	22.76	8.42	97.98	53.63	5.47
Chromatin	SP4105BMR	39.97	64.87	68.47	4.83	49.77	60.33	0.51	18.49	8.50	86.89	50.58	1.83
Chromatin	SS304	34.70	61.25	65.37	5.21	42.63	56.96	0.54	28.78	4.55	76.78	53.59	11.23
Chromatin	SS405	39.84	67.69	60.27	6.21	39.70	62.95	0.48	22.98	4.83	66.57	48.21	11.23
Croplan	BMR 3411	32.51	58.07	69.13	3.92	46.33	54.00	0.56	28.73	6.53	94.94	55.65	10.37
Croplan	BMR 3561	34.60	58.94	72.27	3.77	50.87	54.81	0.57	25.98	8.26	106.26	56.02	10.73
KSU	Kansas Orange	37.36	62.81	64.90	5.63	41.33	58.42	0.52	25.50	5.89	79.64	51.26	12.53
Monsanto	Nutri-Choice II	38.32	63.91	62.33	6.20	40.57	59.44	0.51	24.70	5.23	73.67	50.45	7.87
Scott Seed Co	X50610	37.62	62.02	68.57	4.52	48.80	57.68	0.54	22.66	7.49	93.81	53.48	4.53

continued

Table 12b. Silage performance test near Garden City

Brand	Variety	Forage quality											
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEL	NFC	Crude protein	RFQ	TDN	Starch
----- % -----													
Scott Seed Co	X5063	33.88	57.22	71.63	4.26	46.60	53.21	0.56	28.41	7.56	100.93	55.61	15.23
Scott Seed Co	X50711	35.97	60.54	65.67	5.21	40.60	56.31	0.52	28.36	4.81	74.94	51.96	13.23
Scott Seed Co	X50712	37.00	58.50	67.97	5.17	40.40	54.41	0.53	28.80	5.85	83.48	52.60	19.50
Scott Seed Co	X5129	41.93	69.81	60.10	6.57	42.27	64.92	0.47	18.55	5.81	66.63	46.83	4.10
Scott Seed Co	X51410	33.94	58.60	68.93	4.16	48.70	54.50	0.57	25.93	7.89	103.70	55.81	7.13
Scott Seed Co	X51423	32.90	57.88	69.93	4.06	46.90	53.83	0.56	28.06	7.18	98.05	55.37	10.63
Scott Seed Co	X5143	32.83	56.42	71.93	4.35	46.13	52.47	0.57	29.03	7.93	104.75	56.06	17.13
Sharp Bros Seed	Canex BMR 540	35.42	59.36	68.73	4.99	44.33	55.21	0.55	27.39	6.58	91.05	53.94	12.73
Sharp Bros Seed	Canex BMR 550	33.70	57.58	70.17	3.93	48.10	53.55	0.56	26.74	7.89	102.53	55.42	8.37
Sharp Bros Seed	Canex 210	35.76	60.38	68.13	5.06	44.87	56.16	0.55	27.73	6.47	92.52	54.45	16.33
Sharp Bros Seed	Silex BMR 503	34.77	57.79	70.77	4.13	47.30	53.74	0.55	26.56	7.45	97.75	54.70	10.27
Star Seed	Magnum Ultra BMR	35.68	61.54	68.10	4.74	47.50	57.23	0.55	26.80	5.68	88.62	54.75	8.19
Sudax	BMR 331	36.56	61.29	68.77	4.06	49.27	57.00	0.54	22.68	8.06	97.39	53.73	2.70
Sudax	Exp 1601	35.95	58.27	70.60	4.83	46.20	54.19	0.55	27.57	6.92	94.75	54.42	14.50
Walter Moss Seed	4EVERgreen	41.05	69.17	61.03	5.94	43.17	64.33	0.48	20.01	5.60	69.91	48.27	4.73
Ward Seed	EXP: 10216	34.84	56.80	71.80	4.04	44.63	52.82	0.55	28.61	6.96	94.32	54.27	16.97
Ward Seed	GW 400 BMR	32.72	55.10	73.47	3.98	47.20	51.24	0.57	30.37	7.08	101.26	56.40	16.50
Ward Seed	GW 600 BMR	35.64	60.73	66.97	4.34	43.87	56.48	0.54	27.87	5.07	81.38	53.71	11.10
Ward Seed	GW-2120	35.22	59.39	68.30	5.18	42.53	55.23	0.53	27.23	6.48	87.02	52.84	15.17
Ward Seed	Silo Pro BMR	34.70	58.79	69.10	4.36	49.67	54.68	0.56	24.06	8.89	104.34	54.83	5.40
Croplan	3701	40.02	66.15	60.87	7.15	37.20	61.52	0.48	26.24	3.22	57.27	48.24	16.10
Croplan	BMR 3631	34.24	53.68	71.37	4.18	40.50	49.92	0.58	36.54	4.04	83.26	57.01	29.27
Average		36.29	60.80	67.45	4.96	44.57	56.54	0.53	26.08	6.45	87.36	52.98	11.46
LSD (0.05)		2.53	3.48	2.73	0.71	2.86	3.24	0.02	3.03	1.29	10.66	2.18	4.49

Table 13a. Silage performance test near Hays

Brand	Variety	Performance							
		Yield	Harvest moisture	Stand	Vigor	Flowering date	Days to harvest	Height	Lodging
		lb DM/a	%					in.	%
Advanta Seeds	AF7101	11,334	0.67	9	9	7/25/16	91	82	0
Advanta Seeds	AF7102	15,196	0.67	9	10	7/28/16	91	68	0
Advanta Seeds	AF7401	12,681	0.73	9	9	9/4/16	115	70	0
Advanta Seeds	AF8301	13,253	0.69	8	8	8/22/16	115	73	0
Arrow Seed	SiloMor II	15,809	0.71	9	10	9/3/16	115	81	0
Arrow Seed	SiloMor II BMR	10,570	0.70	9	9	8/16/16	115	73	0
CERES, Inc.	F4C204	14,918	0.67	9	9	7/24/16	91	81	0
KSU	KS Orange	11,943	0.69	7	8	8/12/17	91	99	18
Scott Seed Co	X5063	9,198	0.68	4	4	7/26/16	91	73	0
Scott Seed Co	X50712	6,187	0.67	4	5	8/2/16	91	71	0
Scott Seed Co	X5129	10,945	0.73	5	5	NA	129	99	0
Scott Seed Co	X51423	12,522	0.76	8	8	8/27/16	115	106	0
Scott Seed Co	X5143	13,196	0.69	8	9	8/2/16	91	93	0
Sharp Bros Seed	Canex BMR 210	12,772	0.70	9	9	8/12/16	107	89	0
Sharp Bros Seed	Canex BMR 600 w/ PO	12,321	0.71	8	9	NA	129	101	25
Star Seed	Magnum Ultra BMR	13,130	0.73	9	9	9/16/16	129	101	0
Ward Seed	EXP: 10216	12,200	0.69	8	8	7/29/16	91	84	0
Ward Seed	GW 400 BMR	14,390	0.69	9	9	7/28/16	91	80	22
Ward Seed	GW 600 BMR	17,102	0.69	8	8	8/12/16	107	96	0
Ward Seed	Silo Pro BMR	9,495	0.74	9	9	9/16/16	129	82	0
Croplan	3701	16,636	0.70	9	9	9/20/16	129	108	22
Croplan	BMR 3631	11,279	0.72	8	8	9/20/16	129	79	0
Average		12,594	0.70	8	8	*	108	86	4
LSD (0.05)		3,275	-	-	-	-	-	-	-

Planting Date: 6/7/16

Emergence Date: 6/13/16

Table 13b. Silage performance test near Hays

Brand	Variety	Forage quality											
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEL	NFC	Crude protein	RFQ	TDN	Starch
----- % -----													
Advanta Seeds	AF7101	31.20	43.35	74.80	5.04	34.03	40.32	0.63	45.43	6.52	115.77	61.33	44.60
Advanta Seeds	AF7102	32.41	47.94	73.70	5.08	37.20	44.59	0.60	39.77	5.75	99.59	58.52	32.80
Advanta Seeds	AF7401	37.64	59.33	69.60	5.06	43.03	55.18	0.55	29.79	4.30	78.35	54.19	15.67
Advanta Seeds	AF8301	38.25	58.58	66.50	5.96	35.20	54.48	0.52	32.10	3.11	62.98	51.43	24.90
Arrow Seed	SiloMor II	39.23	59.17	66.63	6.24	36.57	55.03	0.52	32.00	2.78	60.99	51.33	25.23
Arrow Seed	SiloMor II BMR	37.80	58.25	68.70	5.69	40.77	54.18	0.55	33.16	3.11	72.06	54.81	24.90
CERES, Inc.	F4C204	34.23	52.66	71.57	5.45	40.97	48.97	0.59	35.86	6.28	103.53	58.00	21.57
KSU	Kansas Orange	38.19	59.96	66.52	6.08	40.70	55.77	0.54	29.61	5.77	86.98	53.85	17.27
Scott Seed Co	X5063	33.34	48.57	72.80	5.63	35.33	45.17	0.58	37.75	6.94	101.29	56.88	31.57
Scott Seed Co	X50712	34.77	51.91	71.23	5.09	36.90	48.28	0.58	37.00	5.97	93.35	56.72	33.70
Scott Seed Co	X5129	38.92	63.54	66.30	6.04	45.20	59.09	0.53	26.42	5.03	78.84	52.55	11.37
Scott Seed Co	X51423	35.14	55.69	74.97	4.48	47.80	51.79	0.59	31.94	6.72	106.65	58.03	12.67
Scott Seed Co	X5143	32.30	50.72	74.17	4.63	42.77	47.17	0.61	36.46	7.28	113.68	59.39	25.47
Sharp Bros Seed	Canex BMR 210	35.89	54.57	71.60	5.27	42.24	50.75	0.58	34.24	6.01	100.05	57.25	25.90
Sharp Bros Seed	Canex BMR 600 w/ PO	37.53	60.70	68.77	5.24	45.67	56.45	0.56	29.29	5.76	91.84	55.38	15.37
Star Seed	Magnum Ultra BMR	38.34	62.90	69.00	5.25	48.90	58.50	0.56	26.58	6.45	95.75	55.41	11.20
Ward Seed	EXP: 10216	35.67	53.40	71.60	5.40	41.40	49.66	0.56	32.44	6.63	94.50	55.07	21.60
Ward Seed	GW 400 BMR	33.19	49.82	74.00	5.15	40.93	46.33	0.60	38.57	5.57	101.92	59.12	29.37
Ward Seed	GW 600 BMR	35.43	52.68	71.77	5.65	39.20	49.00	0.57	36.09	5.55	93.96	56.58	28.50
Ward Seed	Silo Pro BMR	35.39	54.21	71.07	4.38	40.37	50.42	0.57	34.95	4.57	84.49	55.99	27.97
Croplan	3701	41.72	66.15	60.87	7.15	37.20	61.52	0.48	26.24	3.22	57.27	48.24	16.10
Croplan	BMR 3631	34.41	53.68	71.37	4.18	40.50	49.92	0.58	36.54	4.04	83.26	57.01	29.27
Average		35.95	55.35	70.34	5.37	40.59	51.48	0.57	33.74	5.34	89.87	55.78	23.95
LSD (0.05)		3.11	6.28	3.22	0.63	5.66	5.84	0.04	7.51	1.68	14.28	3.68	12.13

Planting Date: 6/7/16
Emergence Date: 6/13/16

Table 14. Silage performance test near Hutchinson

Brand	Variety	Performance							
		Yield	Harvest moisture	Stand	Vigor	Flowering date	Days to harvest	Height	Lodging
		lb DM/a	%					in.	%
KSU	Kansas Orange	10,371	0.58	8	*	*	127	75	0
Advanta Seeds	AF7401	8,708	0.70	7	*	*	127	69	73
Advanta Seeds	AF7101	5,897	0.69	8	*	*	94	90	23
Advanta Seeds	AF8301	10,252	0.60	5	*	*	127	87	73
Advanta Seeds	AF7102	7,059	0.72	9	*	*	94	65	17
Average		8,458	0.66	7.35	*	*	114	77	37
LSD (0.05)		2,443	-	-	-	-	-	-	-

Planting Date: 6/10/16

Emergence Date: 6/15/16

Table 15a. Silage performance test near Mound Valley

Brand	Variety	Performance							
		Yield	Harvest moisture	Stand	Vigor	Flowering date	Days to harvest	Height	Lodging
		lb DM/a	%					in.	%
Advanta Seeds	AF7101	9,071	0.74	10	*	8/2/16	77	74	10
Advanta Seeds	AF7102	10,640	0.78	10	*	8/8/16	82	59	4
Advanta Seeds	AF7401	14,433	0.76	10	*	9/11/16	117	58	3
Advanta Seeds	AF8301	16,633	0.73	10	*	8/29/16	109	70	0
KSU	Kansas Orange	8,849	0.72	7	*	8/19/16	90	96	34
Ward Seed	EXP: 10216	8,567	0.75	10	*	8/8/16	84	80	10
Ward Seed	GW 400 BMR	6,985	0.82	5	*	8/11/16	84	78	26
Ward Seed	GW 600 BMR	9,552	0.72	7	*	8/19/16	90	87	25
Ward Seed	Silo Pro BMR	10,111	0.77	10	*	10/4/16	117	61	2
Average		10,538	0.75	9	*	-	94	74	13
LSD (0.05)		1,170	-	-	-	-	-	-	-

Planting Date: 6/9/16

Emergence Date: 6/15/16

*Starch content was low due to little or no grain production.

Table 15b. Silage performance test near Mound Valley

Brand	Variety	Forage quality											
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEL	NFC	Crude protein	RFQ	TDN	Starch*
----- % -----													
Advanta Seeds	AF7101	40.10	65.89	66.85	5.06	48.43	61.28	0.54	21.11	7.24	90.93	53.19	2.10
Advanta Seeds	AF7102	37.42	60.25	68.56	5.26	45.87	56.03	0.57	27.57	6.76	99.59	56.07	12.37
Advanta Seeds	AF7401	35.17	59.17	70.33	5.27	49.27	55.03	0.56	25.38	8.69	106.96	55.70	5.63
Advanta Seeds	AF8301	37.02	63.07	64.67	6.55	43.30	58.66	0.54	26.24	5.99	85.75	53.11	7.60
KSU	Kansas Orange	41.94	70.96	55.17	6.87	39.23	65.99	0.49	20.89	5.16	69.53	49.14	1.33
Ward Seed	EXP: 10216	38.80	65.10	63.42	4.53	46.37	60.54	0.54	21.20	7.42	92.38	53.15	0.80
Ward Seed	GW 400 BMR	39.35	66.59	60.90	5.38	43.67	61.93	0.51	19.97	6.83	81.89	50.59	0.77
Ward Seed	GW 600 BMR	39.46	65.34	62.60	5.41	44.73	60.77	0.51	19.92	7.38	85.00	50.97	0.53
Ward Seed	Silo Pro BMR	37.93	64.05	64.53	5.35	46.97	59.56	0.53	21.15	8.34	94.19	52.66	0.00
Average		38.58	64.49	64.11	5.52	45.31	59.98	0.53	22.60	7.09	89.58	52.73	3.46
LSD (0.05)		2.42	3.73	2.72	0.94	2.88	3.47	0.03	2.91	1.19	10.01	2.52	3.09

Planting Date: 6/9/16

Emergence Date: 6/15/16

*Starch content was low due to little or no grain production.

Table 16a. Silage performance test near Scandia

Brand	Variety	Performance							
		Yield	Harvest moisture	Stand	Vigor	Flowering date	Days to harvest	Height	Lodging
		lb DM/a	%					in.	%
Advanta Seeds	AF7101	8,543	0.64	10	10	*	103	81	90
Advanta Seeds	AF7102	12,214	0.73	10	10	*	103	77	88
Advanta Seeds	AF7401	12,172	0.62	10	10	*	158	75	0
Advanta Seeds	AF8301	15,510	0.73	10	10	*	103	86	3
Arrow Seed	SiloMor II	10,656	0.69	10	10	*	158	74	47
Arrow Seed	SiloMor II BMR	11,218	0.62	10	10	*	158	72	23
CERES, Inc.	F4C204	9,071	0.75	10	10	*	103	90	82
KSU	Kansas Orange	14,234	0.68	8	10	*	103	98	22
Star Seed	Magnum Ultra BMR	10,804	0.73	10	10	*	158	92	47
Ward Seed	EXP: 10216	11,438	0.67	10	10	*	103	88	20
Ward Seed	GW 400 BMR	10,216	0.73	10	10	*	103	71	87
Ward Seed	GW 600 BMR	11,694	0.67	10	10	*	103	100	30
Ward Seed	GW-2120	11,103	0.69	10	10	*	103	85	73
Ward Seed	Silo Pro BMR	12,114	0.75	10	10	*	103	82	0
Croplan	3701	20,603	0.64	9	10	*	158	143	0
Croplan	BMR 3631	13,507	0.65	10	10	*	158	85	0
Average		12,194	0.69	10	10	*	124	87	38
LSD (0.05)		2,984	-	-	-	-	-	-	-

Planting Date: 6/9/16

Emergence Date: 6/15/16

Table 16b. Silage performance test near Scandia

Brand	Variety	Forage quality											
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEL	NFC	Crude protein	RFQ	TDN	Starch
----- % -----													
Advanta Seeds	AF7101	38.02	60.18	69.20	4.58	44.70	55.96	0.55	26.19	6.18	89.21	53.98	13.80
Advanta Seeds	AF7102	37.99	61.96	69.37	4.75	46.47	57.62	0.55	25.44	6.52	93.12	54.53	13.77
Advanta Seeds	AF7401	38.03	59.73	69.13	4.50	43.10	55.55	0.55	28.15	5.37	85.26	54.01	15.73
Advanta Seeds	AF8301	40.50	64.37	65.40	5.96	40.53	59.86	0.51	24.37	5.21	73.54	50.36	13.93
Arrow Seed	SiloMor II	44.73	71.48	60.57	6.38	40.83	66.48	0.45	16.12	6.00	62.46	45.58	1.50
Arrow Seed	SiloMor II BMR	40.04	64.35	65.73	5.40	42.67	59.85	0.53	25.24	4.99	77.23	52.19	10.47
CERES, Inc.	F4C204	41.01	65.21	65.13	5.50	40.50	60.65	0.50	23.56	4.90	70.54	49.91	13.60
KSU	Kansas Orange	40.07	66.09	63.57	6.30	41.20	61.47	0.50	21.97	6.50	79.09	49.84	9.87
Star Seed	Magnum Ultra BMR	40.20	65.36	66.50	6.05	45.87	60.79	0.53	22.40	6.12	83.00	52.23	5.27
Ward Seed	EXP: 10216	39.00	63.25	66.50	5.35	43.43	58.82	0.52	24.89	5.92	82.71	52.11	14.13
Ward Seed	GW 400 BMR	37.60	59.44	68.30	5.09	41.23	55.28	0.54	27.70	5.64	83.81	53.03	15.83
Ward Seed	GW 600 BMR	38.11	59.84	69.57	4.65	42.27	55.65	0.53	27.15	5.66	82.08	52.75	14.47
Ward Seed	GW-2120	39.38	63.69	64.07	5.95	38.63	59.23	0.51	26.12	4.59	71.82	50.96	15.07
Ward Seed	Silo Pro BMR	37.61	62.93	69.77	4.54	48.40	58.53	0.54	22.15	7.69	93.16	53.05	7.70
Croplan	3701	42.69	72.29	58.47	6.62	40.37	67.23	0.47	20.25	3.60	56.52	46.99	8.93
Croplan	BMR 3631	39.92	64.22	68.17	4.65	46.37	59.72	0.53	23.17	6.20	85.15	52.91	7.63
Average		39.68	64.02	66.21	5.39	42.91	59.54	0.52	24.05	5.69	79.29	51.53	11.36
LSD (0.05)		3.89	6.24	4.25	0.94	3.40	5.80	0.05	6.41	1.60	14.93	4.41	7.71

Planting Date: 6/9/16
Emergence Date: 6/15/16

CROPPING AND TILLAGE SYSTEMS

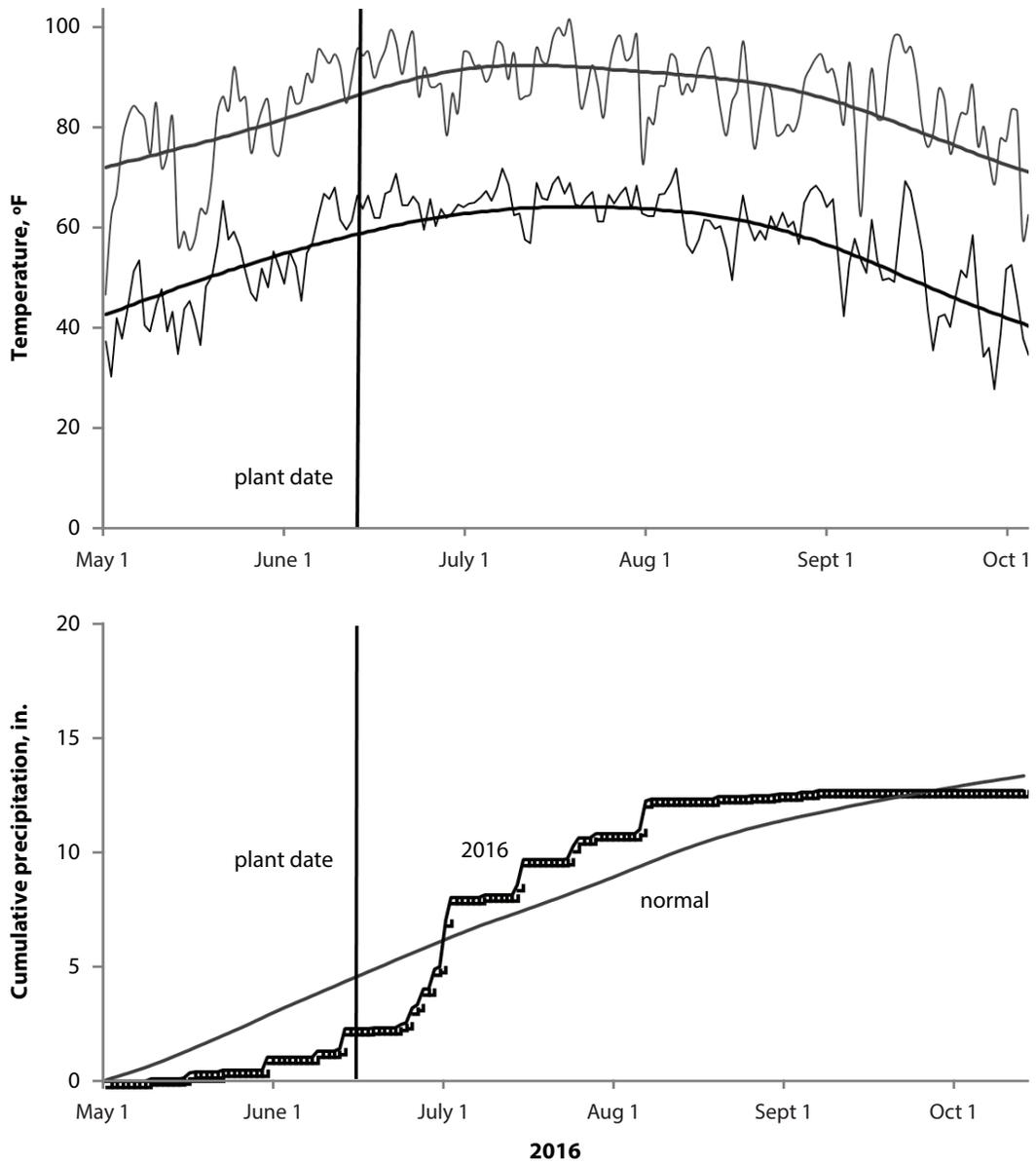


Figure 1. Precipitation and temperature during the growing season near Garden City, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.

CROPPING AND TILLAGE SYSTEMS

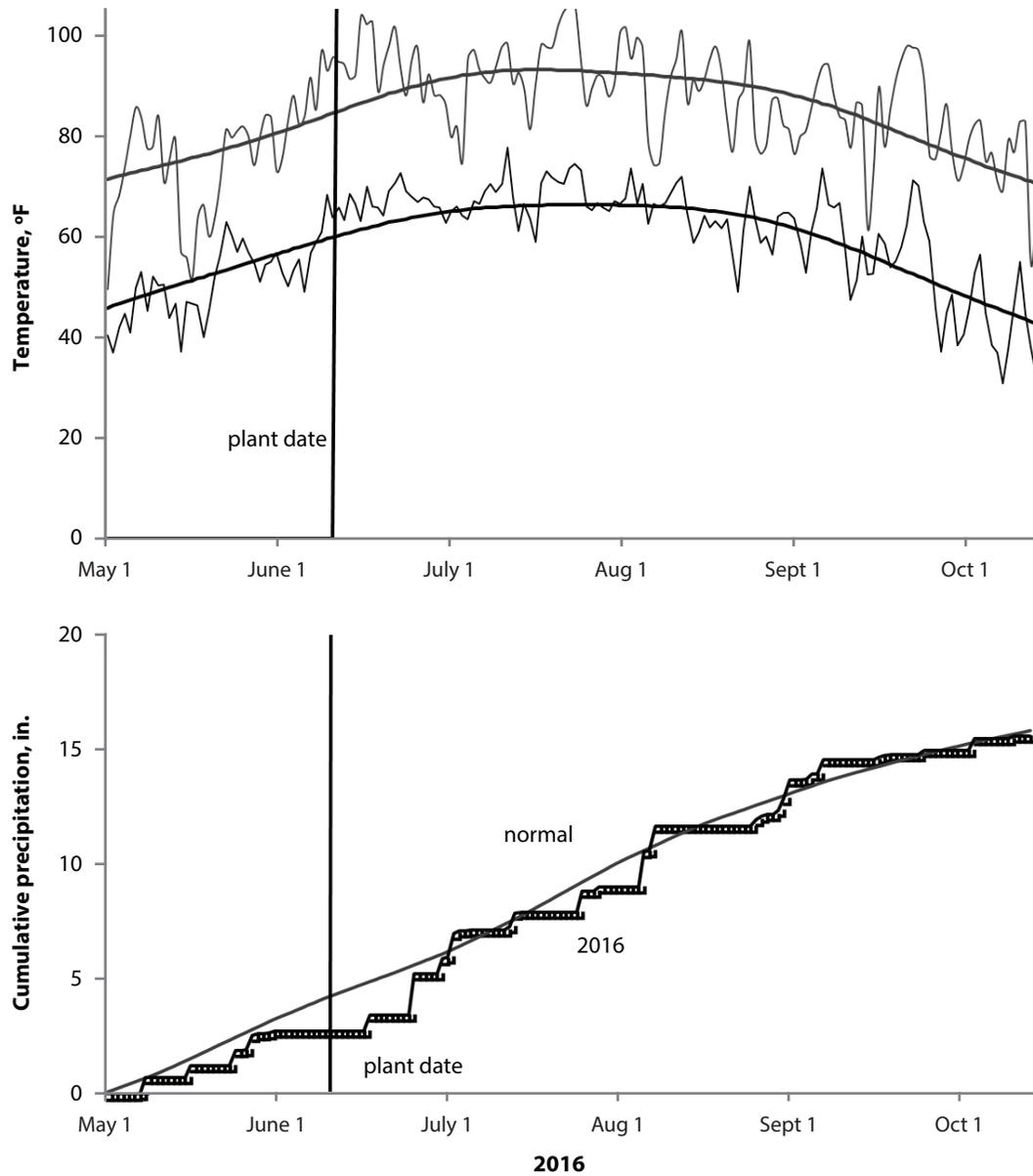


Figure 2. Precipitation and temperature during the growing season near Hays, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.

CROPPING AND TILLAGE SYSTEMS

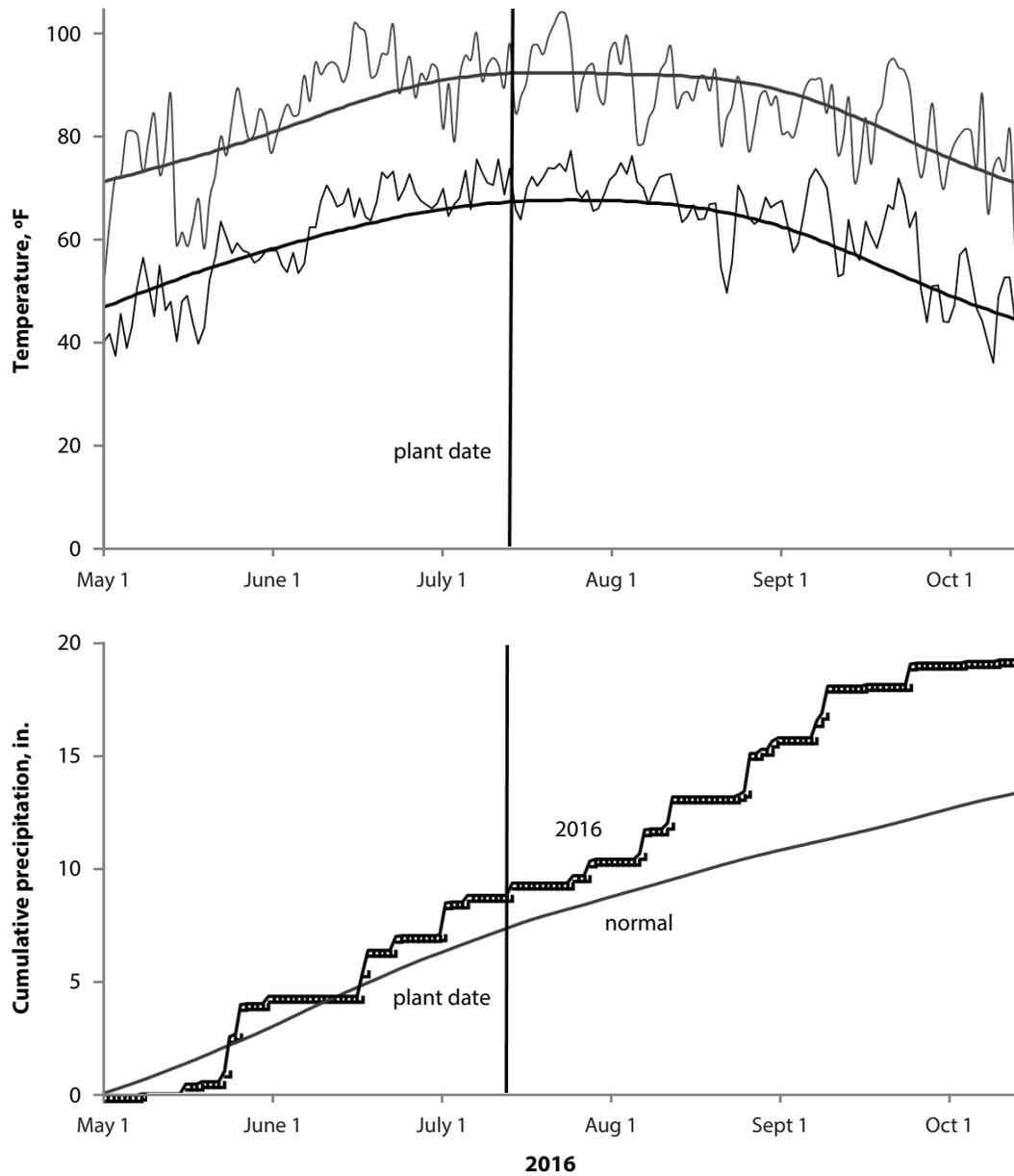


Figure 3. Precipitation and temperature during the growing season near Hutchinson, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.

CROPPING AND TILLAGE SYSTEMS

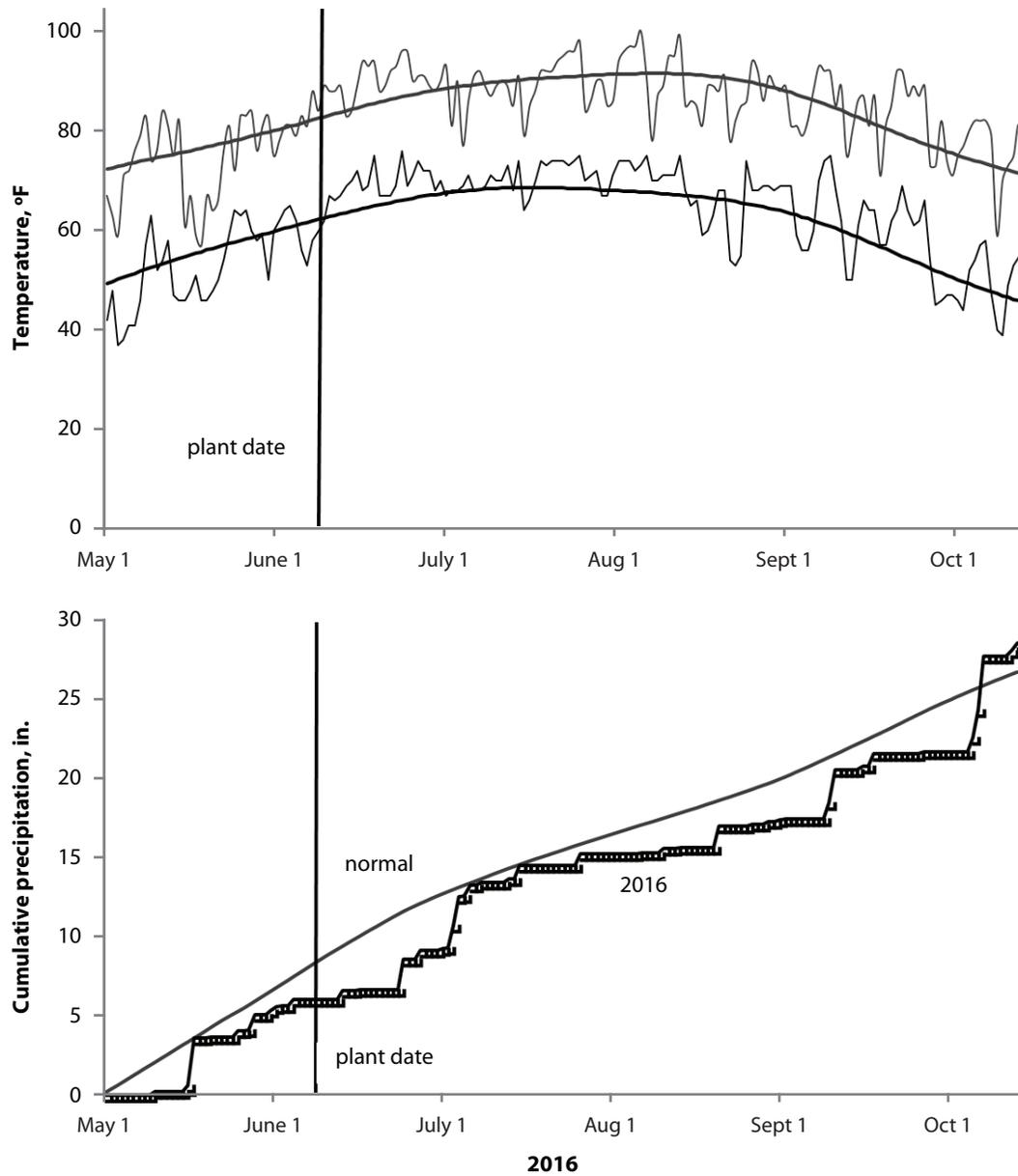


Figure 4. Precipitation and temperature during the growing season near Mound Valley, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.

CROPPING AND TILLAGE SYSTEMS

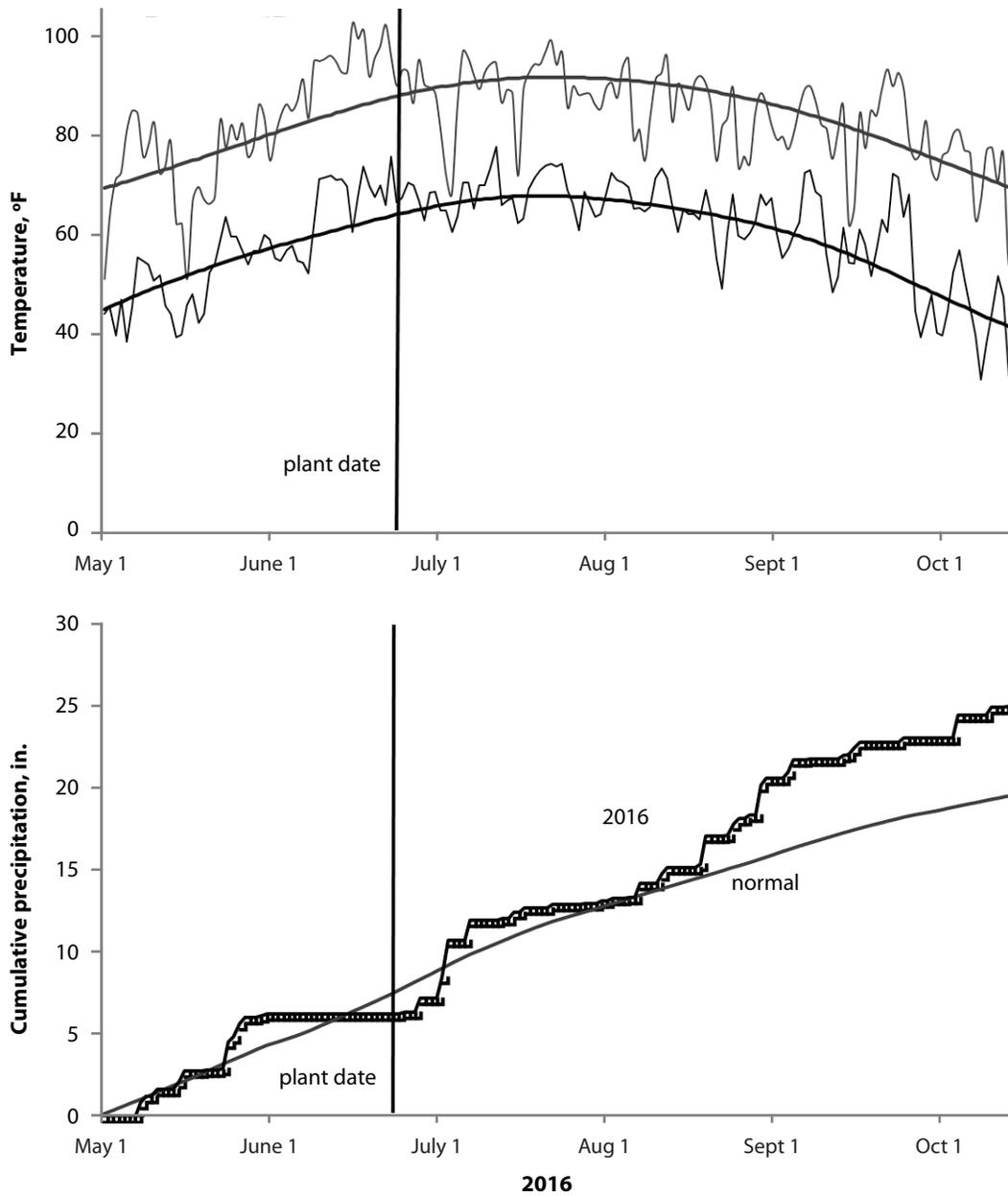


Figure 5. Precipitation and temperature during the growing season near Scandia, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.

Interaction of Seeding and Nitrogen Rate on Grain Sorghum Yield in Southwest Kansas

A.J. Foster, A. Schlegel, J. Holman, I. Ciampitti, C. Thompson, and D. Ruiz Diaz

Summary

This study compared drilled planted sorghum at four seeding rates to planted sorghum at three different nitrogen (N) fertility levels at two locations in southwest Kansas (Garden City and Tribune). At the Garden City location, no difference was observed in yield among the drilled seeded sorghum populations greater than 27,000 seeds/a compared to the standard planted sorghum (sorghum planted at 27,000 seeds/a with a planter at 30 in.-row spacing). At Tribune, there was no difference in yield between the drilled sorghum and the standard planted sorghum (sorghum planted at 40,000 seeds/a with a planter at 30 in.-row spacing) regardless of seeding rate. Nitrogen fertilizer did not interact with seeding rate or affect yield independently at either location. The use of normalized difference vegetation index (NDVI) to assess canopy coverage suggested that planted sorghum and drilled sorghum at population greater than 40,000 seeds/a may achieve canopy coverage at a faster rate. In general, nitrogen rate and seeding rates did not affect sorghum yield. However, we did observe that drilled planted sorghum was more at risk of irregular stand emergence and required a higher seeding rate to achieve canopy closure at a rate similar to that of planted sorghum.

Introduction

Drilled sorghum is normally done at super-high population at row spacing between 7.5 and 10 inches, compared to rows planted at spacing between 15 and 30 inches. Thompson (1983), growing super-thick sorghum at the Hays Research Station from 1974-1977, found that sorghum planted in narrow rows (12-18 in.) often produced higher yields than when planted in wide rows (24-40 in.). Norwood (1982) in Garden City repeated Thompson's work and also came to the conclusion that yield of high population narrow row sorghum could exceed that of low population wide row when subsoil moisture and precipitation were adequate. The conclusion from the work of Thompson and Norwood was that subsoil moisture and precipitation were big drivers for the high population, narrow-row sorghum to equal or exceed the yield of the low population wide row. Since then, most researchers have found yield response to plant population to be variable depending on environment. Overall, the general consensus is that under conditions of adequate moisture, yield of high population sorghum can continue to increase, but can decrease under dry conditions. Today moisture still remains the key for successful dryland sorghum production in southwest Kansas. Thus, the very familiar saying, "moisture and fertility are joined at the hip." Thompson's and Norwood's work did not evaluate narrow row at population under 25,000 seeds/a and at spacing below 10 in. We hypothesized that drilled sorghum at lower population could make better use of water resources and produce similar yields to drilled sorghum at higher population, and planted sorghum at the same population. Thus, the objective of this study is to evaluate drilled sorghum at different populations ranging from 20,000 to 80,000 seeds/a at row spacing of 10 in. or less at different nitrogen rates. Furthermore, most farmers in

southwest Kansas own both a drill and a planter. Thus, it is not just an agronomic issue, but it is also about getting better value from a single piece of equipment in an already economically challenging wheat-sorghum-fallow production system.

Experimental Procedures

Experiments with small plots were conducted under dryland conditions at two locations in western Kansas (Southwest Research-Center in Garden City and Tribune) to determine interaction of seeding rate and nitrogen rate under narrow row sorghum in southwest Kansas.

Planting Dates and Plot Layout

Sorghum variety Dekalb 3707 was planted at both locations on June 2, 2016, in Garden City and June 7, 2016, in Tribune.

A randomized complete block design with a 5×3 factorial treatment arrangement with four replications was used at both locations. At Garden City, the five factors included four drilled seeding rates (27,000 (lowest amount recommended with the air seeder no-tillage planter) and 40,000, 54,000, and 68,000 seeds/a) and sorghum planted at 27,000 seeds/a with a planter at 30-in. row spacing. At Tribune, the five factors included four drilled seeding rates (20,000, 40,000, 60,000, and 80,000 seeds/a) and sorghum planted at 40,000 seeds/a with a planter at 30 in.-row spacing. The three factors included three nitrogen rates: (0, 50, and 100 lb/a) at Tribune; (50, 75, and 100 lb/a) at Garden City.

At both locations, potassium (K) and phosphorus (P) were applied based on the soil test recommendations provided by the Kansas State University Soil and Plant Testing Laboratory. At Garden City, the drilled treatments were planted with a John Deere 1910 air seeder no-tillage drill and the planted with a John Deere 7300 planter. In Tribune, drilled treatments were planted with a John Deere 1590 no-tillage drill and the planted with a John Deere 1700 planter.

Herbicide management at Garden City was the application of glyphosate at 1.25 qt/a + Harness at 2.5 pt/a + Starane Ultra at 0.75 pt/a applied pre-plant on June 1, 2016. At Tribune, atrazine at 1 lb/a + Dicamba at 1 pt/a was applied early on March 10, 2016, followed by Degree Extra at 3 qt/a + Sharpen at 2 oz /a + glyphosate at 0.75 lb a.e./a applied pre-emergence on June 8, 2016.

Data Collection and Analysis

Reducing plant density in narrow row planted sorghum could result in large areas of exposed soil. This exposed soil is subjected to wind and water erosion and weed infestation during the growing season and after harvest. However, the sorghum plant has an extreme capability to compensate and utilize space by tillering. Normalized difference vegetation index (NDVI) measurements were collected during the growing season as a means of assessing exposed soil among the different plant population treatments. NDVI was measured using the GreenSeeker® hand-held device (NTech Industries Inc, Stillwater, OK). Measurement was collected from an approximately 80 ft² (2 ft GreenSeeker viewing area \times 40 ft plot length) area at Garden City and a 100 ft² (2 ft GreenSeeker viewing area \times 50 ft plot length) area in Tribune from each treatment plot.

The Garden City location was harvested using a 7.5-ft wide head plot combine and Tribune was harvested with a 5-ft wide head. Crop weights were adjusted to 13% moisture.

Data were analyzed using PROC GLM with SAS 9.4 (SAS Institute, Inc., Cary, NC) and a model statement appropriate for a factorial design. Treatment means were separated by Fisher's projected least significant difference test.

Results and Discussion

Garden City

The emergence of drilled sorghum was more irregular compared to the standard planted (Figure 1). Emergence of the drilled sorghum was over a 3-15 day period compared to 3-5 days of the planted sorghum. This may have contributed to the large variation in yield observed among the treatments (least significant difference (LSD) = 24 bu/a). The 2016 results found no difference in yield among the three nitrogen rates (Figure 2), and drilled sorghum populations greater than 40,000 seeds/a and the standard planted sorghum (Figure 3). Grain yield of the standard planted sorghum was 31 bu/a greater than the drilled sorghum at 27,000 seeds/a. These results are in agreement with our initial hypothesis that drilled sorghum at lower population would not result in a yield penalty.

Tribune

The 2016 results found no difference in grain yield among the N rates (Figure 4) and for drilled sorghum at different populations and the standard planted sorghum (Figure 5). Similar to Garden City, the results are in agreement with our hypothesis that narrow sorghum could be planted at lower seeding rates without a yield penalty.

Assessing Canopy Coverage/Canopy Closure

Normalized difference vegetation index (NDVI) measured during the growing season was used to monitor the rate of change in green area among the different treatments throughout the growing season. The rate of change in green area was used to reflect the rate of canopy coverage over the plot area. Figure 6 shows that planted sorghum at 27,000 reached maximum green coverage or canopy closure at a faster rate compared to the drilled sorghum at the different populations at Garden City. At Tribune, the planted sorghum reached maximum green coverage at a similar rate to the higher drilled rates of 80,000 and 60,000 (Figure 6). Normalized difference vegetative index measurements starting at 23-29 days after planting showed lower readings for the lower drilled seeding rates throughout the growing season (Table 1). These results indicate that narrow row planted at lower seeding rates (20,000 – 40,000 seeds/a) reached canopy closure at a much slower rate. Based on field observation, the slower rate of canopy closure of the drilled sorghum at Garden City could be attributed to non-uniform emergence that lasted over 10-15 days. This result indicates the importance of achieving a uniform emergence on the rate of canopy closure.

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- Thompson, C. 1983. Super-thick sorghum management. Kansas Agricultural Experiment Station Report of Progress, 437, 24.

Table 1. Normalized difference vegetation index (NDVI) measurements collected at different times after planting at five seeding rates across two locations in southwest Kansas

Seeding rate	Garden City				
	Days after planting				
	29	36	47	54	
seeds/a					
STAND_27 ¹	0.428	0.768	0.823	0.848	
67,500	0.392	0.631	0.793	0.839	
54,000	0.324	0.549	0.753	0.819	
40,500	0.288	0.424	0.650	0.792	
27,000	0.288	0.417	0.642	0.748	
LSD ³	0.077	0.110	0.100	0.063	
CV ⁴	26	15.6	6.4	3.6	
Seeding rate	Tribune				
	Days after planting				
	23	32	38	45	65
seeds/a					
STAND_40 ²	0.214	0.347	0.537	0.749	0.787
80,000	0.223	0.411	0.634	0.796	0.803
60,000	0.210	0.338	0.560	0.756	0.795
40,000	0.209	0.285	0.520	0.689	0.771
20,000	0.209	0.248	0.426	0.664	0.759
LSD	0.02	0.064	0.12	0.076	0.024
CV	6.3	15.9	12.04	7.16	2

¹Sorghum planted with a planter on 30 in.-row spacing at seeding rate of 27,000 seeds/a.

²Sorghum planted with a planter on 30 in.-row spacing at seeding rate of 40,000 seeds/a.

³LSD = least significant difference.

⁴CV = coefficient of variation.

SOIL FERTILITY



Figure 1. Emergence of drilled and planted sorghum. A) Sorghum planted using a no-tillage air seeder drill. B) Sorghum planted using a standard 30 in. planter.

SOIL FERTILITY

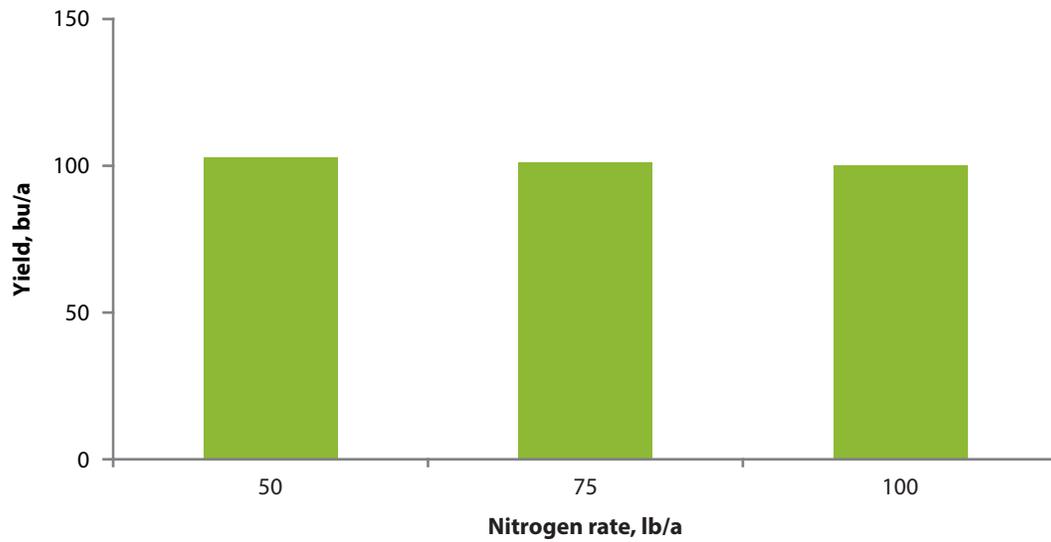


Figure 2. Grain sorghum yield affected by nitrogen rate under four drilled seeding rates and the standard planting rate in Garden City, KS (least significant difference = 6).

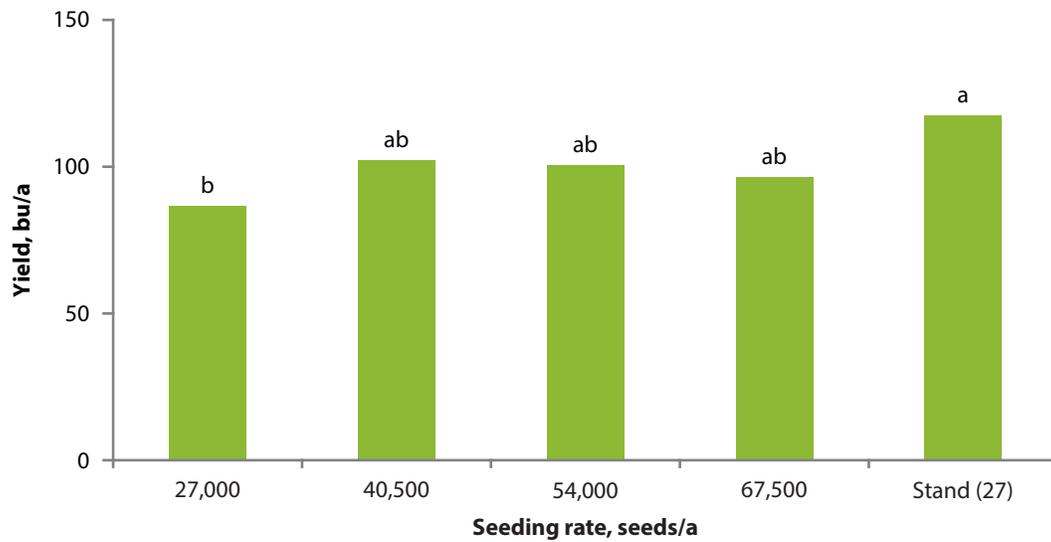


Figure 3. Grain sorghum yield affected by four drilled seeding rates and the standard planting rate at three different nitrogen rates in Garden City, KS.

^{ab}Means followed by same letter are not significantly different (least significant difference = 24).

SOIL FERTILITY

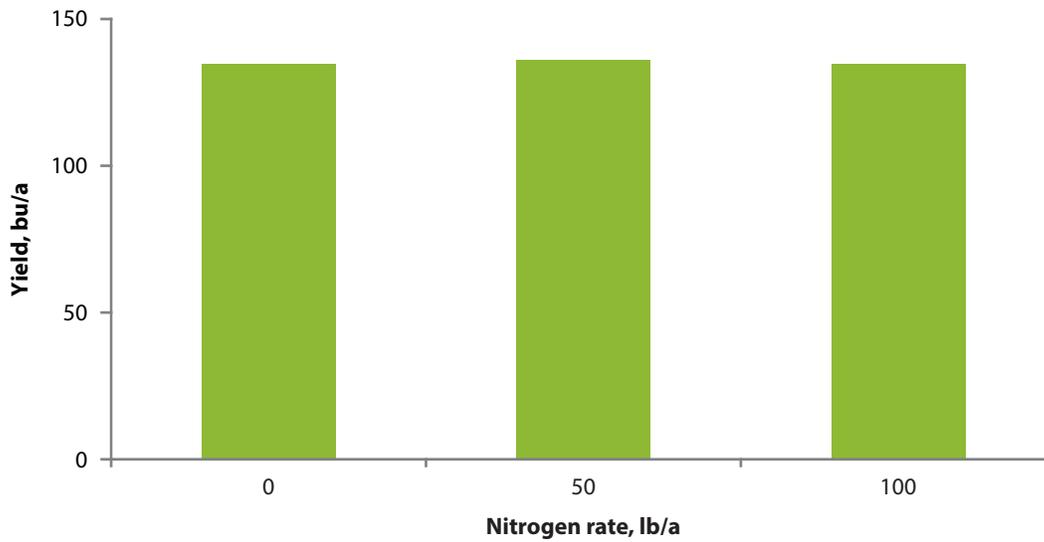


Figure 4. Grain sorghum yield affected by N rate under four drilled seeding rates and the standard planting rate in Tribune, KS (least significant difference = 4).

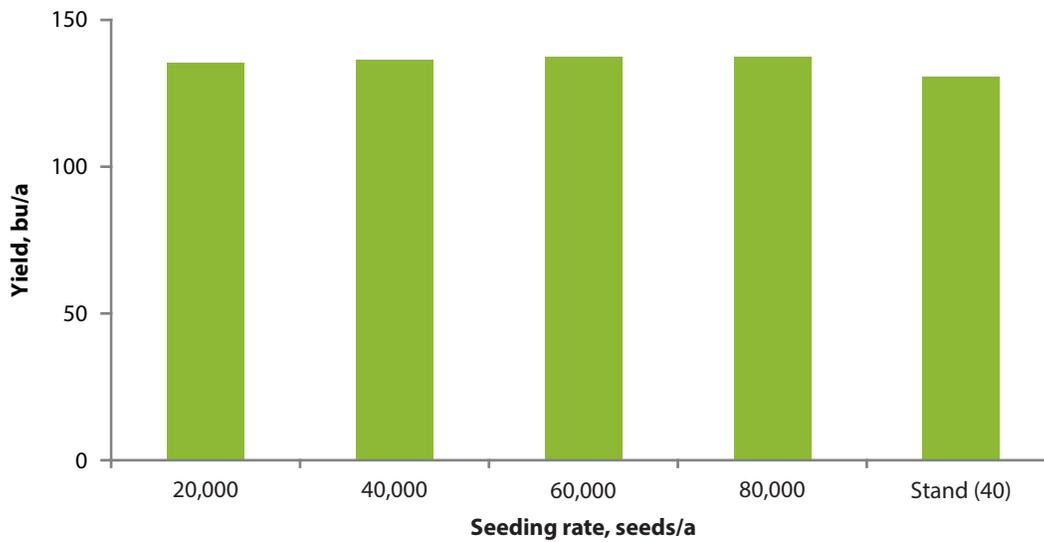


Figure 5. Grain sorghum yield affected by four drilled seeding rates and the standard planting rate averaged across three different N rates at Tribune, KS (least significant difference = 7).

SOIL FERTILITY

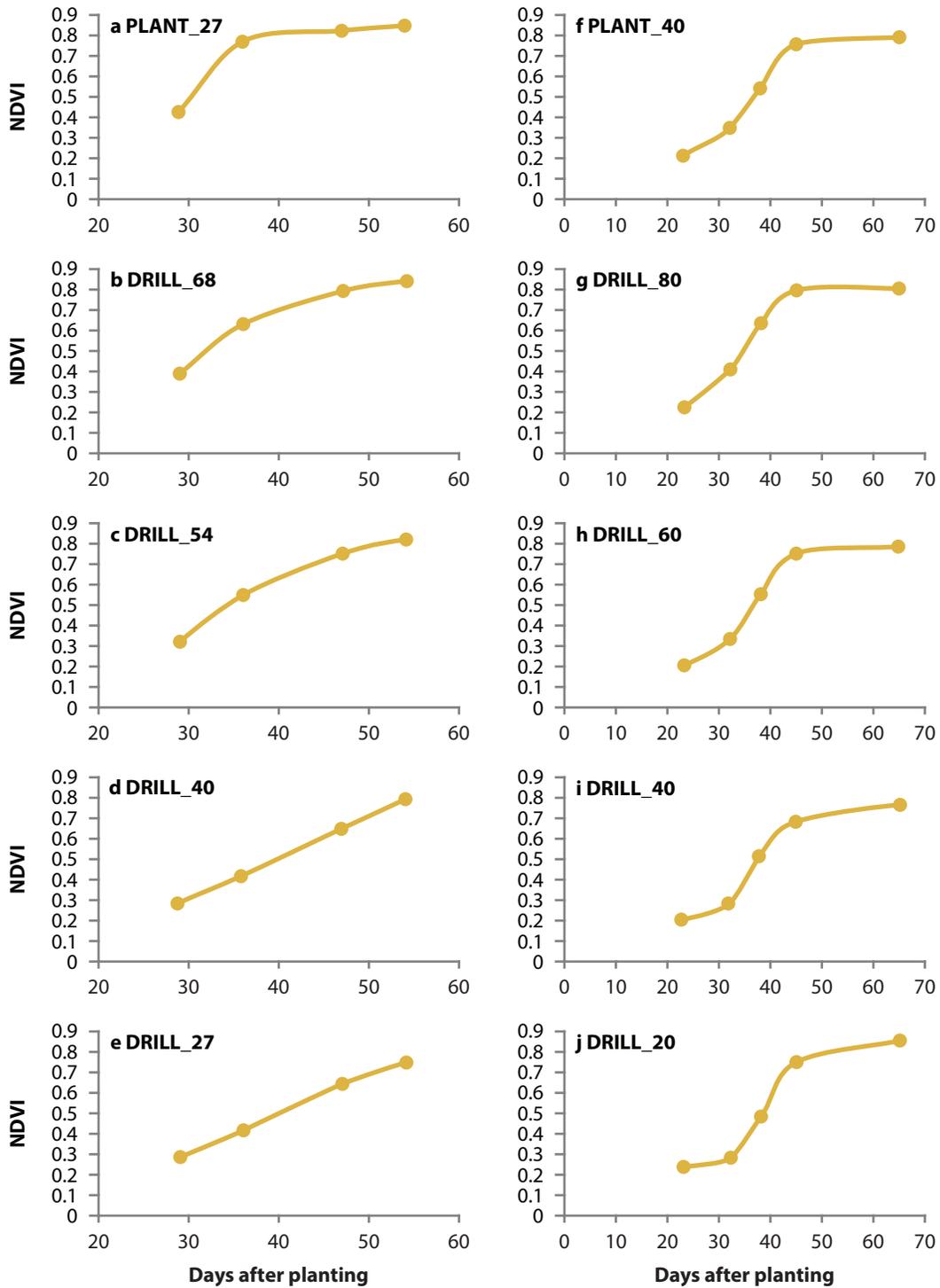


Figure 5. Normalized difference vegetation index and days after planting in relation to drilled vs. planted sorghum for both Garden City and Tribune locations used for determining the rate of canopy closure. Garden City: (a) planted sorghum at 27,000 seeds/a, (b) drilled at 67,500 seeds/a, (c) drilled at 54,000 seeds/a, (d) drilled at 40,500 seeds/a, and (e) drilled at 27,000 seeds/a. Tribune: (f) planted sorghum at 40,000 seeds/a, (g) drilled at 80,000 seeds/a, (h) drilled at 60,000 seeds/a, (i) drilled at 40,000 seeds/a, and (j) drilled at 20,000 seeds/a.

Exploring the Value of Plant Analysis to Enhance Water Use Efficiency in Southwest Kansas

A.J. Foster, I. Kisekka, and B. Golden

Summary

Nutrient deficiency is identified by use of visual symptoms. However, the application of the proposed deficient nutrient often does not result in the correction of the observed visual symptoms. This is because essential nutrients do not operate independently of each other or independently of the overall plant health and growing conditions. A study was initiated in 2016 at the Kansas State University Southwest Research-Extension Center Fannup Farm near Garden City, KS, to use both soil and plant analyses to identify toxicities or hidden deficiencies that could be limiting corn yield at various irrigation capacities. Soil samples prior to planting and plant samples at tasseling were collected from corn grown under five irrigation capacities and dryland conditions. Irrigation capacities were 0.25, 0.17, 0.13, 0.10, and 0.08 in./d. Relationships among plant nutrients and corn yield were developed to identify possible nutrients that could be limiting corn yield. Soil analysis showed soil pH of around 8 and organic matter of around 2%. In general, as expected, soil pH did increase with reduction in irrigation capacity. Sulfur (S) was the only nutrient found to be of concern within the soil analysis. Sulfur was also found to be of concern in the plant analysis. The S concentration was right at the lower limit of the sufficiency level. All other nutrients were within the required sufficiency level. However, manganese (Mn) (110 ppm) concentration was found to be higher than that of iron (Fe) (94 ppm). Whenever Mn concentration in a plant is higher than that of Fe regardless of concentration, it is an indication of Fe deficiency. Moreover, a significant relationship ($P = 0.05$) was observed for plant Fe concentration and corn grain yield at the 10% significance level. Likewise, an even stronger significant relationship ($P = 0.035$) was observed for Fe/Mn ratio and corn grain yield at the 5% significance level. These results suggest that Fe deficiency could be the hidden deficiency limiting corn yield.

Introduction

Irrigated corn production is an important part of the agricultural systems in southwest Kansas. Deep, well-drained soils coupled with abundant sunlight enables farmers to produce high yielding crops when using irrigation. However, good fertility and balanced nutrient inputs are critical to producing optimum yields that lead to profitability.

Soil testing has always been the cornerstone of any well-designed fertility program. However, plant analysis can provide a good evaluation of the micronutrient status. In fact, when developing a good fertility program that maximizes profitability, soil and plant analyses are recommended to be used together to obtain the best result, particularly to detect shortages in micronutrients. Plant analysis was used to discover that ions present in high concentration could depress the adsorption of other ions of like charge and influence optimum plant growth (Pierre and Bower, 1943).

Most soils in southwest Kansas have a high pH (7-8.5). The chemistry of high pH soils makes them susceptible to deficiencies of most micronutrients. Nutrient interactions affect the availability of other nutrients, which are predominantly micronutrients. For example, a high potassium (K) level, which is common to soils of southwest Kansas, could cause a reduction in both calcium (Ca) and magnesium (Mg) uptake (Barber, 1995; Mengel et al., 2001). Sulfur uptake can also be influenced by nitrates (Rehm and Caldwell, 1968). Sulfate levels can also depress molybdenum uptake by the roots (Olsen and Watanabe, 1979). Cations K, Mg, and Ca and the anion phosphate at high levels can reduce zinc uptake (Barber, 1995). High nitrate levels can also inhibit copper uptake (Kinsey and Walters, 1999). Clearly, the nutrient dynamics in a growing plant are very complex. Plant analysis provides a nutritional profile of the growing plant that can reveal a hidden need for specific nutrients or imbalanced plant nutrition. This hidden need is not often expressed in visible symptoms, but can often be the missing link limiting crop yield. Plant analysis is an important research tool to study the interaction among nutrients and to identify hidden deficiencies or toxicities.

Experimental Procedures

Treatments

This experiment was conducted under 5 irrigation capacities (0.25, 0.17, 0.13, 0.10, and 0.08 in./d) and dryland. Irrigation was triggered based on an evapotranspiration (ET) water budget limited by irrigation capacity. Soil water measurements were taken weekly using a neutron attenuation technique (CPN 503DR, CPN International, Concord, CA) at 12-in. increments up to 8 ft, to monitor the adequacy of the irrigation schedule.

Design

Treatments were replicated four times in a randomized complete block design. Individual plots were 45- × 90-ft.

Cultural Practice

Fertilizer application and weed control were based on Kansas State University's recommendations for high-yielding corn production.

Measurements

Soil nutrient analysis: Soil samples were collected from each plot pre-plant at a 0-6-inch depth and analyzed for nitrogen (N), phosphorus (P), K, Ca, Mg, Fe, zinc (Zn), Mn, and S.

Plant nutrient analysis: 15 of the uppermost, fully expanded leaves were collected at random from each plot at tasseling (VT) and analyzed to determine the levels of primary nutrients (N, P, and K), secondary nutrients (Ca, Mg, S, and chlorine), and for micronutrients (Zn, Cu, Fe, Mn, boron (B), molybdenum (Mo), and aluminum (Al)).

Plant health and N status: Sensor readings were collected within each plot using a GreenSeeker (Ntech Industries, Inc, Ukiah, CA) handheld at different growth stages and at the time of leaf sampling.

Grain yield: Yield was collected by hand harvesting two center rows of 10 feet each.

Data Analysis

Analysis of variance were conducted using the SAS 9.4 (SAS Institute Inc., Cary, NC) statistical software. Regression and correlation analyses were used to establish a relationship between sensor readings, nutrient content, and irrigation level. Plant analysis data was compared to published sufficiency ranges. Comparative economic analysis was conducted to determine the value of plant analysis to the producers.

Results and Discussion

Soil analysis revealed all nutrients with the exception of S to be sufficient for maximizing corn yield (Table 1). Plant analysis also showed all nutrients to be sufficient for optimal yield (Table 2). However, nutrient levels of S and Fe could impact yield. The concentration of S was a concern because some studies report sufficiency levels between 0.20 - 0.50%. Regression analysis reported a significant (P value = 0.05) relationship at the 10% significance level between plant Fe concentration and grain yield (Figure 1). The Fe and Mn ratio also showed a significant (P value = 0.035) relationship with grain yield at the 5% significance level (Figure 2). Iron deficiency is a severe problem in high pH (calcareous and/or alkaline) soils in western Kansas. This limitation is not easily overcome with Fe fertilizer, because it is not a problem of lack of Fe but rather of solubility. The ability of some plant species to extract Fe from high pH soils suggests that the cause of this problem must reside in the internal plant metabolism; the pH and redox reactions near the root. Earlier studies have reported that excessive Mn can cause chlorosis curable by treatment with Fe, and plants susceptible to lime-induced chlorosis common in high pH soils are also susceptible to Mn chlorosis (Chapman, 1931; McGeorge, 1923). Iron and Mn are intimately interdependent in their effects upon the plant chlorosis (Shive, 1941). Plants absorb Fe in the active ferrous state under the influence of strong reducing systems of the living cell (Hell and Stephan, 2003; Kobayashi and Nishizawa, 2012; Somers and Shive, 1942). However, if a counter reactant in the form of a strong oxidizing agent such as Mn is present in adequate concentration the active Fe may be oxidized to the ferric state, rendering the Fe biologically inactive, producing the pathological symptom of chlorosis (Somers and Shive, 1942). Therefore, both oxidizing and reducing ions of both Fe and Mn must be maintained within a plant. Researchers have recommended that the Fe/Mn in the plant tissue should be between 1 and 2.5 irrespective of concentration in the plant tissue (Shive, 1941; Somers and Shive, 1942; Twyman, 1951). In our study, Fe/Mn ratio was less than 1, indicating that Fe could be the hidden deficiency limiting yield (Table 3, figure 3). These results suggest that increasing the Fe concentration in the plant could maximize grain yield.

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SOIL FERTILITY

Table 1. Soil analysis for corn grown under five different irrigation capacities and dryland conditions in 2016 growing season at the Kansas State University Southwest Research-Extension Center Finnup Farm near Garden City, KS

Soil component	Irrigation capacity					Dryland
	0.25	0.17	0.13	0.1	0.08	
	----- inches per day -----					
Depth	0-6"	0-6"	0-6"	0-6"	0-6"	0-6"
pH	8.03	8.08	7.98	8.03	8.10	8.13
Cation exchange capacity	29	29	30	30	31	31
Organic matter (%)	2.0	2.1	2.1	2.1	2.2	2.0
Calcium (ppm)	4588	4629	4656	4911	5093	5232
Magnesium (ppm)	604	627	598	574	525	499
Sodium (ppm)	48	51	38	50	37	31
Potassium (ppm)	615	644	690	651	675	726
Nitrogen (ppm)	50	46	54	54	54	48
Phosphorus (ppm)	47	45	57	69	63	66
Sulfur (ppm)	18	21	13	27	16	12
Zinc (ppm)	3.2	2.8	3.1	4.0	2.9	2.8
Iron (ppm)	4.8	5.3	5.3	4.8	3.8	4.0
Manganese (ppm)	2.8	3.3	3.0	3.3	3.0	2.5
Copper (ppm)	1.2	1.2	1.2	1.5	1.2	1.3

Table 2. Plant analysis for corn grown under five different irrigation capacities and dryland conditions in 2016 growing season at the Kansas State University Southwest Research-Extension Center Finnup Farm near Garden City, KS

Plant component	Irrigation capacity					Dryland
	0.25	0.17	0.13	0.1	0.08	
	----- inches per day -----					
Calcium (%)	0.44	0.43	0.46	0.42	0.44	0.48
Magnesium (%)	0.17	0.16	0.17	0.16	0.16	0.17
Sodium (%)	0.01	0.01	0.01	0.01	0.01	0.01
Potassium (%)	2.53	2.56	2.52	2.58	2.53	2.54
Nitrogen (%)	3.23	3.33	3.31	3.25	3.38	3.25
Phosphorus (%)	0.30	0.30	0.31	0.29	0.29	0.30
Sulfur (%)	0.20	0.20	0.20	0.19	0.19	0.19
Zinc (ppm)	31.25	30.50	32.50	29.50	31.25	30.25
Iron (ppm)	96.00	96.75	92.75	93.75	93.00	89.50
Manganese (ppm)	105.00	105.75	115.50	105.50	115.50	113.25
Copper (ppm)	12.75	12.50	13.25	12.25	13.00	12.50
Boron (ppm)	24.75	25.00	26.00	23.75	24.25	24.50

SOIL FERTILITY

Table 3. Effect of irrigation capacity on five nutrient ratios in the soil and two plant nutrient ratios in 2016 growing season at the Kansas State University Southwest Research–Extension Center Finnup Farm near Garden City, KS

Irrigation capacity		Soil				Plant	
Inches per day	Ca/Mg	K/Mg	P/S	P/Zn	Fe/Mn	N/S	Fe/Mn
0.25	7.6	1.0	2.7	16.5	1.7	16	0.92
0.17	7.4	1.0	2.1	16.2	1.7	17	0.92
0.13	7.9	1.2	4.9	18.2	1.7	17	0.81
0.10	8.6	1.1	4.3	17.0	1.4	17	0.89
0.08	9.7	1.3	4.2	21.5	1.3	18	0.81
Dryland	10.5	1.5	6.2	23.9	1.7	17	0.79

In soil, calcium/magnesium (Ca/Mg) (7:1 for a high clay and 3:1 for a sandy soil) ratio determines gas exchange in the soil; potassium/magnesium (K/Mg) (1:1) affects Mg, K and P uptake; phosphorus/sulfur (P/S) (1:1) affects P uptake; P/Zn (10:1 Mehlich 3 extraction) affects P and /zinc (Zn) uptake; and Fe/Mn (2:1) affects plant resilience and ability to fight off pests and diseases. In the plant, N/S (15:1) affects protein synthesis; and Fe/Mn (between 1.5:1 and 2.5:1) affects Fe and manganese (Mn) availability in the plant; greater than 2.5 results in Mn deficiency and lower than 1 results in Fe deficiency.

SOIL FERTILITY

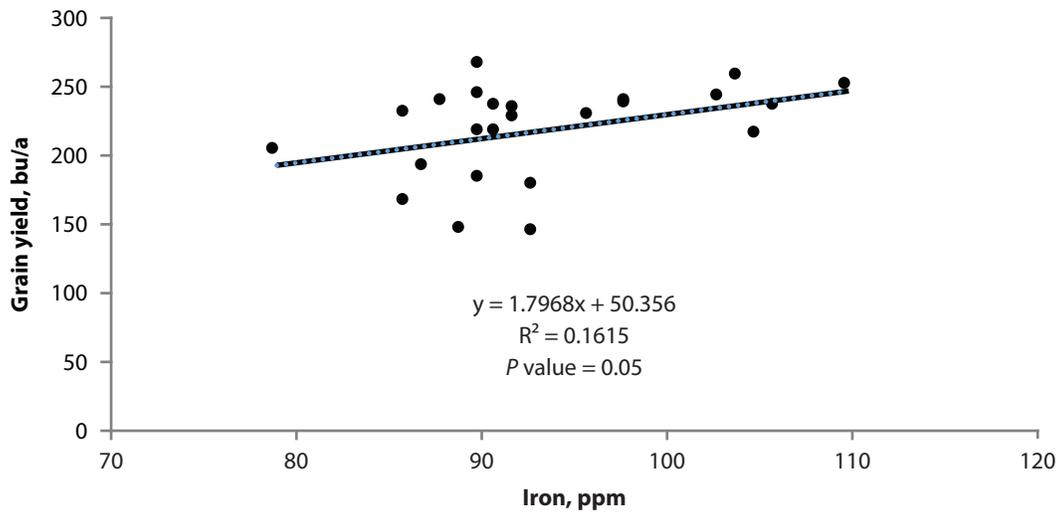


Figure 1. Relationship between grain yield and plant iron concentration for corn grown under five irrigation capacities (0.25, 0.17, 0.13, 0.10, and 0.08 in./d) and dryland at the Kansas State University Southwest Research–Extension Center Finnpup Farm near Garden City, KS.

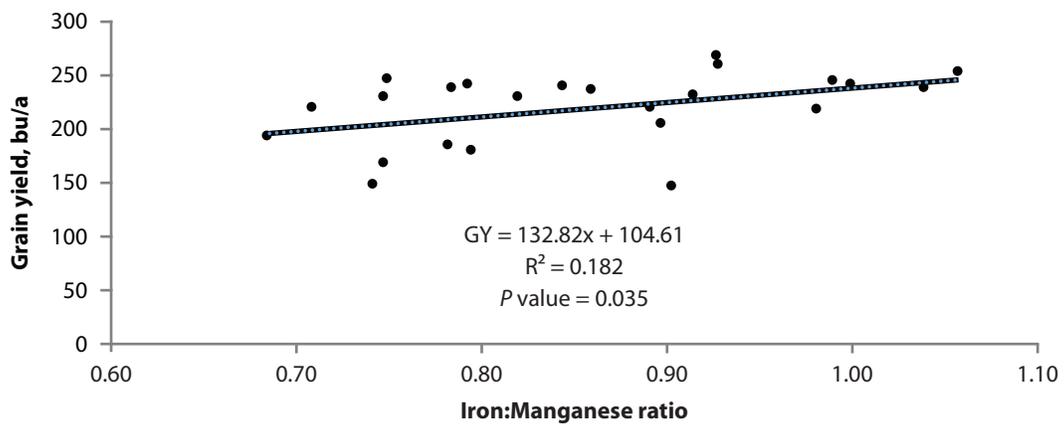


Figure 2. Relationship between grain yield and plant Fe/Mn ratio for corn grown under five irrigation capacities (0.25, 0.17, 0.13, 0.10, and 0.08 in./d) and dryland at the Kansas State University Southwest Research–Extension Center Finnpup Farm near Garden City, KS.

Irrigated Corn Response to Long-Term Nitrogen and Phosphorus Fertilization

A. Schlegel and D. Bond

Summary

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize the production of irrigated corn in western Kansas. In 2016, N applied alone increased yields by 85 bu/a, whereas P applied alone increased yields by only 12 bu/a. Nitrogen and P applied together increased yields up to 164 bu/a. This is 20 bu/a greater than the 10-year average, where N and P fertilization increased corn yields up to 144 bu/a. Application of 120 lb/a N (with the highest P rate) produced about 94% of maximum yield in 2016, which is similar to the 10-year average. Application of 80 instead of 40 lb P₂O₅/a increased average yields 6 bu/a. Average grain N content reached a maximum of 0.6 lb/bu, while grain P content reached a maximum of 0.15 lb/bu (0.34 lb P₂O₅/bu). At the highest N and P rate, apparent fertilizer nitrogen recovery (grain) (AFNR_g) was 44% and apparent fertilizer phosphorus recovery (grain) (AFPR_g) was 62%.

Introduction

This study was initiated in 1961 to determine responses of continuous corn and grain sorghum grown under flood irrigation to N, P, and potassium (K) fertilization. The study is conducted on a Ulysses silt loam soil with an inherently high K content. No yield benefit to corn from K fertilization was observed in 30 years, and soil K levels remained high, so the K treatment was discontinued in 1992 and replaced with a higher P rate.

Experimental Procedures

This field study is conducted at the Tribune unit of the Kansas State University Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a without P and K; with 40 lb/a P₂O₅ and zero K; and with 40 lb/a P₂O₅ and 40 lb/a K₂O. The treatments were changed in 1992; the K variable was replaced by a higher rate of P (80 lb/a P₂O₅). All fertilizers were broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids [Pioneer 33B54 (2007), Pioneer 34B99 (2008), DeKalb 61-69 (2009), Pioneer 1173H (2010), Pioneer 1151XR (2011), Pioneer 0832 (2012-2013), Pioneer 1186AM (2014), Pioneer 35F48 AM1 (2015), and Pioneer 1197 (2016)] were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2008 and 2010 crops. The corn was irrigated to minimize water stress. Sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 15.5% moisture. Grain samples were collected at harvest, dried, ground and analyzed for N and P concentrations. Grain N and P content (lb/bu) and removal (lb/a) were calculated. Apparent fertilizer N recovery in the grain (AFNR_g) was calculated as N uptake in treatments receiving N fertilizer minus N uptake in the unfertilized control divided by N rate. The same approach was used to calculate apparent fertilizer P recovery in the grain (AFPR_g).

Results and Discussion

Corn yields in 2016 were 10% greater than the 10-year average (Table 1). Nitrogen alone increased yields 85 bu/a, whereas P alone increased yields only 12 bu/a. However, N and P applied together increased corn yields up to 164 bu/a. Maximum yield was obtained with 160 lb/a N with 80 lb/a P_2O_5 . Corn yields in 2016 (averaged across all N rates) were 6 bu/a greater with 80 than with 40 lb/a P_2O_5 .

The 10-year average grain N concentration (%) increased with N rates but tended to decrease when P was also applied, presumably because of higher grain yields diluting N content (Table 2). Grain N content reached a maximum of 0.6 lb/bu. Maximum N removal (lb/a) was greatest at the highest yield levels, which were attained with 200 lb N and 80 lb P_2O_5 /a. At the highest N and P rate, $AFNR_g$ was 44% and $AFPR_g$ was 62%. Similar to N, average P concentration increased with increased P rates but decreased with higher N rates. Grain P content (lb/bu) of about 0.15 lb P/bu (0.34 lb P_2O_5 /bu) was greater at the highest P rate with low N rates. Grain P removal averaged 30 lb P/a at the highest yields.

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2007-2016

Fertilizer		Yield										
Nitrogen	P ₂ O ₅	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
----- lb/a -----		----- bu/a -----										
0	0	49	36	85	20	92	86	70	86	92	74	69
0	40	50	57	110	21	111	85	80	95	103	78	79
0	80	51	52	106	28	105	94	91	98	104	86	81
40	0	77	62	108	23	114	109	97	106	113	105	91
40	40	112	105	148	67	195	138	125	153	164	145	135
40	80	116	104	159	61	194	135	126	149	162	135	134
80	0	107	78	123	34	136	128	112	117	131	118	108
80	40	163	129	179	85	212	197	170	187	195	196	171
80	80	167	139	181	90	220	194	149	179	193	193	171
120	0	106	65	117	28	119	134	114	115	124	109	103
120	40	194	136	202	90	222	213	204	213	212	212	190
120	80	213	151	215	105	225	211	194	216	216	223	197
160	0	132	84	139	49	157	158	122	128	144	142	125
160	40	220	150	210	95	229	227	199	211	215	226	198
160	80	227	146	223	95	226	239	217	233	216	238	206
200	0	159	99	155	65	179	170	139	144	162	159	143
200	40	224	152	207	97	218	225	198	204	214	216	196
200	80	232	157	236	104	231	260	220	238	221	235	213

continued

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2007-2016

Fertilizer		Yield										
Nitrogen	P ₂ O ₅	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
----- lb/a -----		----- bu/a -----										
Analysis of variance (ANOVA) (P > F)												
Nitrogen		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Nitrogen × Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Means ¹												
Nitrogen, lb/a												
0		50f	48e	100e	23e	103d	88f	80e	93e	100e	79e	76e
40		102e	91d	138d	50d	167c	127e	116d	136d	146d	129d	120d
80		146d	115c	161c	70c	189b	173d	143c	161c	173c	169c	150c
120		171c	118c	178b	74bc	189b	186c	171b	181b	184b	182b	163b
160		193b	127b	191a	80ab	204a	208b	179ab	190ab	192ab	202a	177a
200		205a	136a	199a	89a	209a	218a	186a	196a	199a	203a	184a
Least significant difference _(0.05)		11	9	12	9	13	10	10	10	9	10	8
P ₂ O ₅ , lb/a												
0		105b	71b	121c	36b	133b	131c	109b	116c	128b	118b	107c
40		160a	122a	176b	76a	198a	181b	163a	177b	184a	179a	162b
80		168a	125a	187a	81a	200a	189a	166a	186a	185a	185a	167a
Least significant difference _(0.05)		8	6	9	7	9	7	7	7	6	7	5

*Note: Hail events on 7/23/10 and 5/28/15

¹ Means within a column with the same letter are not statistically different at $P = 0.05$.

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2007-2016

Fertilizer		Grain				Grain removal		*AFNR _g	*AFPR _g
Nitrogen	P ₂ O ₅	N	P	N	P	N	P		
lb/a		%		lb/bu		lb/a		%	
0	0	0.99	0.230	0.47	0.109	31	7	---	---
0	40	0.95	0.312	0.45	0.147	35	12	---	24
0	80	0.96	0.321	0.45	0.152	36	12	---	14
40	0	1.15	0.182	0.55	0.086	49	8	45	---
40	40	0.97	0.301	0.46	0.143	61	19	75	67
40	80	0.98	0.323	0.46	0.153	61	21	75	37
80	0	1.26	0.177	0.60	0.084	64	9	40	---
80	40	1.05	0.257	0.50	0.122	84	21	66	74
80	80	1.03	0.310	0.49	0.147	82	25	63	49
120	0	1.25	0.170	0.59	0.081	61	8	24	---
120	40	1.14	0.226	0.54	0.107	102	20	58	71
120	80	1.10	0.297	0.52	0.140	102	28	59	57
160	0	1.25	0.176	0.59	0.083	73	10	26	---
160	40	1.18	0.242	0.56	0.114	110	22	49	84
160	80	1.17	0.281	0.56	0.133	114	27	51	55
200	0	1.24	0.186	0.59	0.088	83	12	26	---
200	40	1.20	0.239	0.57	0.113	110	22	39	82
200	80	1.19	0.295	0.56	0.140	119	30	44	62

continued

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2007-2016

Fertilizer		Grain				Grain removal		*AFNR _g	*AFPR _g
Nitrogen	P ₂ O ₅	N	P	N	P	N	P		
lb/a		%		lb/bu		lb/a		%	
Analysis of variance (ANOVA) (P > F)									
Nitrogen		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	---	0.001
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	---	0.001
Phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear		0.001	0.001	0.001	0.001	0.001	0.001	0.001	---
Quadratic		0.001	0.001	0.001	0.001	0.001	0.001	0.001	---
Nitrogen × phosphorus		0.001	0.001	0.001	0.001	0.001	0.001	0.036	0.126
Means ¹									
Nitrogen, lb/a									
0		0.97e	0.288a	0.46e	0.136a	34f	10e	---	19d
40		1.04d	0.269b	0.49d	0.127b	57e	16d	65a	52c
80		1.11c	0.248c	0.53c	0.117c	77d	18c	56b	62b
120		1.16b	0.231d	0.55b	0.109d	88c	19c	47c	64ab
160		1.20a	0.233d	0.57a	0.110d	99b	20b	42d	70ab
200		1.21a	0.240cd	0.57a	0.114cd	104a	21a	36e	72a
Least significant difference _(0.05)		0.02	0.011	0.01	0.005	4	1	5	8
P ₂ O ₅ , lb/a									
0		1.19a	0.187c	0.56a	0.088c	60b	9c	32b	---
40		1.08b	0.263b	0.51b	0.124b	84a	19b	57a	67a
80		1.07b	0.304a	0.51b	0.144a	86a	24a	58a	46b
Least significant difference _(0.05)		0.01	0.008	0.01	0.004	3	1	4	5

*AFNR_g and AFPR_g = Apparent Fertilizer N Recovery (grain) and Apparent Fertilizer P Recovery (grain).¹ Means within a column with the same letter are not statistically different at P = 0.05.

Irrigated Grain Sorghum Response to Long-Term Nitrogen and Phosphorus Fertilization

A. Schlegel and D. Bond

Summary

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated grain sorghum in western Kansas. In 2016, N applied alone increased yields 71 bu/a, whereas N and P applied together increased yields up to 93 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 77 bu/a. Application of 80 lb/a N (with P) was sufficient to produce 89% of maximum yield in 2016, which is slightly less than the 10-yr average. Application of potassium (K) has had no effect on sorghum yield throughout the study period. Average grain N content reached a maximum of ~0.7 lb/bu while grain P content reached a maximum of 0.15 lb/bu (0.34 lb P₂O₅/bu) and grain K content reached a maximum of 0.19 lb/bu (0.23 lb K₂O/bu). At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 33% for N, 69% for P, and 40% for K.

Introduction

This study was initiated in 1961 to determine responses of continuous grain sorghum grown under flood irrigation to N, P, and K fertilization. The study is conducted on a Ulysses silt loam soil with an inherently high K content. The irrigation system was changed from flood to sprinkler in 2001.

Experimental Procedures

This field study is conducted at the Tribune unit of the Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a N without P and K; with 40 lb/a P₂O₅ and zero K; and with 40 lb/a P₂O₅ and 40 lb/a K₂O. All fertilizers are broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. Sorghum (Pioneer 8505 in 2007, Pioneer 85G46 in 2008-2011, Pioneer 84G62 in 2012-2014, Pioneer 86G32 in 2015, and Pioneer 84G62 in 2016) was planted in late May or early June. Irrigation is used to minimize water stress. Sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 12.5% moisture. Grain samples were collected at harvest, dried, ground and analyzed for N, P, and K concentrations. Grain N, P, and K content (lb/bu) and removal (lb/a) were calculated. Apparent fertilizer N recovery in the grain (AFNR_g) was calculated as N uptake in treatments receiving N fertilizer minus N uptake in the unfertilized control divided by N rate. The same approach was used to calculate apparent fertilizer P recovery in the grain (AFPR_g) and apparent fertilizer K recovery (AFKR_g).

Results and Discussion

Grain sorghum yields in 2016 were 10% greater than the 10-year average (Table 1). Nitrogen alone increased yields 71 bu/a while P alone increased yields 11 bu/a. How-

SOIL FERTILITY

ever, N and P applied together increased yields up to 93 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 77 bu/a. In 2016, 40 lb/a N (with P) produced about 82% of maximum yield, which is slightly less than the 10-year average of 84%. The 10-year average for 80 lb/a N (with P) and 120 lb/a N (with P) was 93 and 96% of maximum yield, respectively. Sorghum yields were not affected by K fertilization, which has been the case throughout the study period.

The 10-year average grain N concentration (%) increased with N rates but tended to decrease when P was also applied, presumably because of higher grain yields diluting N content (Table 2). Grain N content reached a maximum of ~0.7 lb/bu. Maximum N removal (lb/a) was obtained with 160 lb N/a or greater with P. Similar to N, average P concentration increased with P application but decreased with higher N rates. Grain P content (lb/bu) of ~0.15 lb P/bu (0.34 lb P₂O₅/bu) was similar for all N rates when P was applied. Grain P removal was similar for all N rates of 40 lb/a or greater, with P removal ranging from 19 to 23 lb/a. Average K concentration (%) and content (lb/bu) tended to decrease with increased N rates. Similar to P, K removal was similar for all N rates of 40 lb/a or greater plus K, ranging from 23 to 27 lb/a. At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 33% for N, 69% for P, and 40% for K.

Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2007-2016

Fertilizer			Grain sorghum yield										
Nitrogen	P ₂ O ₅	K ₂ O	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
lb/a			bu/a										
0	0	0	80	66	64	51	75	78	62	90	89	80	74
0	40	0	97	60	70	51	83	90	77	94	102	91	82
0	40	40	94	65	76	55	88	93	72	96	97	91	83
40	0	0	123	92	84	66	106	115	94	115	122	106	102
40	40	0	146	111	118	77	121	140	114	144	160	142	127
40	40	40	145	105	109	73	125	132	110	142	155	137	123
80	0	0	138	114	115	73	117	132	102	120	133	120	116
80	40	0	159	128	136	86	140	163	136	151	173	154	143
80	40	40	166	126	108	84	138	161	133	164	178	160	142
120	0	0	138	106	113	70	116	130	100	116	127	108	112
120	40	0	164	131	130	88	145	172	137	162	177	164	147
120	40	40	165	136	136	90	147	175	142	170	178	170	151
160	0	0	146	105	108	74	124	149	117	139	150	135	125
160	40	0	170	138	128	92	152	178	146	171	181	173	153
160	40	40	167	133	140	88	151	174	143	176	179	161	151
200	0	0	154	120	110	78	128	147	119	139	155	151	130
200	40	0	168	137	139	84	141	171	136	165	177	167	149
200	40	40	170	135	129	87	152	175	138	170	179	170	151

continued

Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2007-2016

Fertilizer			Grain sorghum yield										
Nitrogen	P ₂ O ₅	K ₂ O	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Mean
----- lb/a -----			----- bu/a -----										
Analysis of variance (ANOVA) (P > F)													
Nitrogen			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P-K			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zero P vs. P			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
P vs. P-K			0.992	0.745	0.324	0.892	0.278	0.826	0.644	0.117	0.806	0.943	0.974
N × P-K			0.965	0.005	0.053	0.229	0.542	0.186	0.079	0.012	0.002	0.001	0.012
Means ¹													
Nitrogen, lb/a													
0			91d	64d	70c	52c	82d	87d	70d	94e	96d	87d	79d
40			138c	103c	104b	72b	117c	129c	106c	134d	146c	129c	118c
80			155b	123b	120a	81a	132b	152b	124b	145c	161b	145b	134b
120			156ab	124ab	126a	82a	136ab	159ab	126b	149bc	161b	147b	137b
160			161ab	125ab	125a	84a	142a	167a	135a	162a	170a	156a	143a
200			164a	131a	126a	83a	141a	165a	131ab	158ab	170a	163a	143a
Least significant difference _(0.05)			9	7	11	5	8	9	8	9	8	8	6
P ₂ O ₅ -K ₂ O, lb/a													
0 - 0			130b	101b	99b	68b	111b	125b	99b	120b	129b	117b	110b
40 - 0			151a	117a	120a	80a	130a	152a	124a	148a	162a	149a	133a
40 - 40			151a	117a	116a	79a	133a	152a	123a	153a	161a	148a	133a
Least significant difference _(0.05)			6	5	7	4	6	6	5	6	5	6	4

¹ Means within a column with the same letter are not statistically different at $P = 0.05$.

Table 2. Nitrogen, phosphorus, and potassium fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2007-2016

Fertilizer			Grain						Grain removal			*AFNR _g	*AFPR _g	*AFKR _g
N	P ₂ O ₅	K ₂ O	N	P	K	N	P	K	N	P	K			
lb/a			%			lb/bu			lb/acre			%		
0	0	0	1.04	0.267	0.370	0.51	0.131	0.181	37	9	13	---	---	---
0	40	0	1.02	0.314	0.389	0.50	0.154	0.191	41	13	16	---	18	---
0	40	40	1.02	0.312	0.386	0.50	0.153	0.189	41	13	16	---	18	7
40	0	0	1.14	0.239	0.344	0.56	0.117	0.169	57	12	17	49	---	---
40	40	0	1.11	0.318	0.377	0.54	0.156	0.185	69	20	24	79	59	---
40	40	40	1.11	0.311	0.373	0.54	0.152	0.183	67	19	23	73	53	28
80	0	0	1.35	0.226	0.339	0.66	0.111	0.166	76	13	19	49	---	---
80	40	0	1.23	0.299	0.360	0.60	0.146	0.176	85	21	25	60	65	---
80	40	40	1.20	0.311	0.367	0.59	0.153	0.180	83	22	25	57	69	37
120	0	0	1.40	0.213	0.335	0.69	0.104	0.164	77	12	18	33	---	---
120	40	0	1.33	0.287	0.354	0.65	0.141	0.174	95	21	26	48	63	---
120	40	40	1.33	0.309	0.360	0.65	0.151	0.176	98	23	27	50	76	40
160	0	0	1.43	0.233	0.345	0.70	0.114	0.169	87	14	21	31	---	---
160	40	0	1.39	0.309	0.362	0.68	0.151	0.177	104	23	27	42	78	---
160	40	40	1.36	0.288	0.355	0.66	0.141	0.174	100	21	26	39	67	39
200	0	0	1.43	0.239	0.348	0.70	0.117	0.171	91	15	22	27	---	---
200	40	0	1.39	0.288	0.361	0.68	0.141	0.177	101	21	26	32	66	---
200	40	40	1.40	0.294	0.361	0.69	0.144	0.177	103	22	27	33	69	40

continued

Table 2. Nitrogen, phosphorus, and potassium fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2007-2016

Fertilizer			Grain						Grain removal			*AFNR _g	*AFPR _g	*AFKR _g
N	P ₂ O ₅	K ₂ O	N	P	K	N	P	K	N	P	K			
----- lb/a -----			----- % -----			----- lb/bu -----			----- lb/acre -----			----- % -----		
Analysis of variance (ANOVA) (P > F)														
Nitrogen			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Linear			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Quadratic			0.001	0.014	0.001	0.001	0.014	0.001	0.001	0.001	0.001	0.054	0.001	0.001
P-K			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.790	---
Zero P vs. P			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	---	---	---
P vs. P-K			0.435	0.707	0.963	0.435	0.707	0.963	0.672	0.822	0.991	---	---	---
N × P-K			0.407	0.014	0.083	0.407	0.014	0.083	0.101	0.001	0.007	0.001	---	---
Means ¹														
Nitrogen, lb/a														
0			1.03e	0.298a	0.382a	0.50e	0.146a	0.187a	40e	12c	15d	---	18c	7c
40			1.12d	0.289ab	0.365b	0.55d	0.142ab	0.179b	64d	17b	21c	67a	56b	28b
80			1.26c	0.279bc	0.355cd	0.62c	0.137bc	0.174cd	82c	18a	23b	55b	67a	37a
120			1.35b	0.269c	0.350d	0.66b	0.132c	0.171d	90b	18a	24b	44c	69a	40a
160			1.39ab	0.277bc	0.354cd	0.68ab	0.136bc	0.174cd	97a	19a	25a	37d	72a	39a
200			1.41a	0.274c	0.357c	0.69a	0.134c	0.175c	98a	19a	25a	30e	67a	40a
Least significant difference _(0.05)			0.04	0.012	0.006	0.02	0.006	0.003	4	1	1	6	8	4
P ₂ O ₅ -K ₂ O, lb/a														
0 - 0			1.30a	0.236b	0.347b	0.64a	0.116b	0.170b	71b	13b	19b	38b	---	---
40 - 0			1.25b	0.303a	0.367a	0.61b	0.148a	0.180a	82a	20a	24a	52a	58	---
40 - 40			1.24b	0.304a	0.367a	0.61b	0.149a	0.180a	82a	20a	24a	51a	59	---
Least significant difference _(0.05)			0.03	0.009	0.004	0.01	0.004	0.002	3	1	1	4	5	---

*AFNR_g, AFPR_g, and AFKR_g = apparent fertilizer N recovery (grain), apparent fertilizer P recovery (grain), and apparent fertilizer K recovery (grain).

¹ Means within a column with the same letter are not statistically different at P = 0.05.

Balance Pro, Atrazine, Autumn Super, Corvus, Sencor, Authority, and Banvel for Preemergence Kochia Control in Fallow

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016 comparing kochia control of several herbicide treatments and their time of application in fallow. Spring applications of five tank mixes containing the active ingredient isoxaflutole provided greater than 92% control of kochia. Fall applications of similar tank mixes provided from 78 to 84% control. Tank mixes of atrazine and dicamba applied in the spring provided only 89% control.

Introduction

It has become common for growers to apply Banvel (dicamba) for effective preemergence control of kochia in early spring. Due to time constraints, growers often would like to apply these treatments in the fall or early winter. Although dicamba resistance in kochia is very rare, it has been reported. Balance Pro (isoxaflutole), atrazine, Autumn Super (iodosulfuron + thien carbazon), Corvus (isoxaflutole + thien carbazon), Sencor (metribuzin) and Authority (sulfentrazone) have all been shown to have activity for kochia control. Therefore, it was the objective of this study to explore tank mix combinations and timing of these compounds with and without dicamba for kochia control.

Experimental Procedures

An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to examine the efficacy of fall and spring preemergence herbicides in fallow. Fall applications were applied December 3, 2015, and spring treatments were applied March 3, 2016. All herbicides were applied using a tractor-mounted, CO₂-pressurized plot sprayer, delivering 20 gallons per acre (GPA) at 30 psi and 4.1 mph. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and a cation exchange capacity of 18.4. Plots were 10- by 35-feet. The experimental design was a randomized complete block and treatments were replicated four times. Visual kochia control was determined on April 6, May 26, and July 28, 2016, which was 5, 12, and 21 weeks after spring applications (WAST), respectively.

Results and Discussion

A spring application of tank mixes containing the active ingredients isoxaflutole, atrazine, or dicamba provided greater than 92% control of kochia at 12 WAST. Fall applications of similar tank mixes provided 78 to 84% control. Previous work has also shown a reduced control with winter application (Proc. North Central Weed Sci. Soc. 70:49-50). However, these studies did not show as severe a penalty for fall application due to different patterns of fall and winter precipitation. Tank mixes of atrazine and dicamba provided only 89% control. By 21 WAST, no treatment provided more than 65% kochia control.

Dicamba rates used in this study are only 75% of the most effective rate often used in fallow. This was done to maximize expression of the other tank mix partners evaluated. Further, this trial was conducted in an area with exceptional naturally occurring kochia seed load. In fields with modest infestations of kochia or if the rate of dicamba is increased to 16 oz, most of these tank mixes should provide good control. With the increasing threat of dicamba resistance, it should always be applied with a tank mix partner of a different mode of action. Clearly several of these products should enhance control over dicamba alone and help delay the onset of dicamba-resistant kochia.

Table 1. Fallow kochia control with Balance Pro, Atrazine, Autumn Super, Corvus, and Banvel

Herbicide ^a	Rate oz/a	Timing	Kochia		
			5 WAST ^b	12 WAST	21 WAST
			----- % control -----		
Balance Pro	2	Fall	100	84	40
Atrazine	32	Fall			
Balance Pro	2	Fall	100	86	43
Atrazine	32	Fall			
Corvus	0.5	Fall			
Corvus	4	Fall	100	86	38
Atrazine	32	Fall			
Authority MTZ	12	Fall	99	78	30
Atrazine	32	Fall	100	80	35
Atrazine	32	Fall	100	87	43
Balance Pro	2	Spring			
Sencor	8	Spring			
MSO	1%	Spring			
Atrazine	32	Fall	99	89	38
Corvus	3.5	Spring			
Sencor	8	Spring			
MSO	1%	Spring			
Balance Pro	2	Spring	100	90	50
Atrazine	32	Spring			
MSO	1%	Spring			
Balance Pro	2	Spring	99	93	48
Atrazine	32	Spring			
Banvel	12	Spring			
MSO	1%	Spring			
Balance Pro	2	Spring	100	93	50
Atrazine	32	Spring			
Autumn Super	0.5	Spring			
MSO	1%	Spring			

continued

Table 1. Fallow kochia control with Balance Pro, Atrazine, Autumn Super, Corvus, and Banvel

Herbicide ^a	Rate oz/a	Timing	Kochia		
			5 WAST ^b	12 WAST	21 WAST
			----- % control -----		
Balance Pro	2	Spring	99	95	65
Atrazine	32	Spring			
Autumn Super	0.5	Spring			
Banvel	12	Spring			
MSO	1%	Spring			
Corvus	3.5	Spring	99	95	53
Atrazine	32	Spring			
MSO	1%	Spring			
Corvus	4	Spring	100	97	63
Atrazine	32	Spring			
Banvel	12	Spring			
MSO	1%	Spring			
Atrazine	32	Spring	99	89	50
Banvel	12	Spring			
MSO	1%	Spring			
Authority MTZ	10	Spring	99	89	25
Untreated	---	---	0	0	0
Least significant difference (0.05)			2	4	13

^a MSO is methylated seed oil.^b WAST is weeks after spring application.

Atrazine, Clarity, Verdict, and Armezon Pro Application Timings for Weed Control in Fallow

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016, comparing the weed control of several herbicide treatments and their time of application in fallow. A single application of Clarity (dicamba) and atrazine applied on March 3, 2016, did not provide more than 93% control of kochia, Russian thistle, and Palmer amaranth on June 9. All other treatments provided 95% or greater control at the evaluation conducted June 9. Three applications were needed to provide 90% or greater control of all three species through July 6.

Introduction

With the advent of kochia and Palmer amaranth that is resistant to glyphosate, there is an urgent need to explore non-glyphosate options for control of these weeds. Atrazine, Clarity, Verdict (saflufenacil + dimethenamid), and Armezon Pro (topramezone + dimethenamid) have been shown to have activity on both kochia and Palmer amaranth. It is not known what rates and what times of application might provide season-long control of these species. Therefore, it was the objective of this research to explore timings and rates of various combinations of these products for control of kochia and Palmer amaranth.

Experimental Procedures

An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to examine the efficacy of single and sequential herbicide treatments in fallow. Application, environmental, and weed information are given in Table 1. All herbicides were applied using a compressed-CO₂ backpack sprayer, delivering 20 GPA at 3.0 mph and 27 psi. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Plots were 10- by 35-feet, arranged in a randomized complete block design with four replications. Control of kochia, Palmer amaranth, and Russian thistle were visually determined on June 9 and July 6, 2016, which were 15 and 42 days after the May 25 application, respectively.

Results and Discussion

A single application of Clarity and atrazine applied on March 3, 2016, did not provide more than 93% control of kochia, Russian thistle, and Palmer amaranth on June 9. All other treatments provided 95% or greater control at the evaluation conducted June 9. Three applications were needed to provide 90% or greater control of all three species through July 6. Previous unpublished work by the BASF Corporation had suggested that Armezon Pro might be an effective tool in the fallow period prior to planting sorghum. However, at the completion of this study, and based on other data, they have concluded that subsequent sorghum injury might be too severe to allow its use in this

crop. Consequently, although initial results in this and other studies looked promising, it is unlikely that Armezon Pro will be labeled for this use. However, Armezon Pro has excellent crop safety in corn, and these tank mixes would provide an excellent strategy for dealing with both kochia and Palmer amaranth in that crop.

Table 1. Application information

Application date	March 3, 2016	April 22, 2016	May 11, 2016	May 25, 2016
Air temperature (°F)	64	62	50	57
Relative humidity (%)	14	54	64	81
Soil temperature (°F)	47	47	60	64
Wind speed (mph)	5	1	5	5
Wind direction	West-northwest	South	North-northwest	West-northwest
Soil moisture	Dry	Good	Fair	Fair
Kochia				
Height (in.)	0.25	0.25	2	3
Density (plants/m ²)	100	75	3	1
Palmer amaranth				
Height (in.)	---	---	2	2
Density (plants/m ²)	0	0	1	1
Russian thistle				
Height (in.)	---	---	---	---
Density (plants/m ²)	0	0	0	0

Table 2. Fallow weed control with Clarity, atrazine, Verdict, and Armezon Pro application timings

Herbicide ^a	Rate	Application date	June 9, 2016			July 6, 2016		
			Kochia	Russian thistle	Palmer amaranth	Kochia	Russian thistle	Palmer amaranth
			----- % control -----					
Clarity	16	March 3	93	88	73	80	88	13
Atrazine	24	March 3						
Glyphosate	22	March 3						
MSO	1%	March 3						
AMS	2%	March 3						
Clarity	16	March 3	99	99	95	99	98	61
Atrazine	24	March 3						
Glyphosate	22	March 3						
MSO	1%	March 3						
AMS	2%	March 3						
Verdict	10	April 21						
Atrazine	16	April 21						
Glyphosate	22	April 21						
MSO	1%	April 21						
AMS	2%	April 21						
Clarity	16	March 3	100	100	100	100	100	90
Atrazine	24	March 3						
Glyphosate	22	March 3						
MSO	1%	March 3						
AMS	2%	March 3						
Verdict	10	April 21						
Atrazine	16	April 21						
Glyphosate	22	April 21						
MSO	1%	April 21						
AMS	2%	April 21						
Armezon Pro	16	May 25						
Atrazine	16	May 25						
Glyphosate	22	May 25						
COC	1%	May 25						
AMS	2%	May 25						
Clarity	16	March 3	100	100	100	98	100	74
Atrazine	24	March 3						
Glyphosate	22	March 3						
MSO	1%	March 3						
AMS	2%	March 3						
Armezon Pro	20	May 12						
Atrazine	16	May 12						
Glyphosate	22	May 12						
COC	1%	May 12						
AMS	2%	May 12						
Untreated	---	---	0	0	0	0	0	0
Least significant difference (0.05)			2	3	4	4	4	20

^a AMS is ammonium sulfate, COC is crop oil concentrate, and MSO is methylated seed oil.

Preemergence and Post-Harvest Kochia Control in Wheat

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016, comparing the weed control of several herbicide treatments applied preemergence and post-harvest for kochia control in wheat. Clarity (dicamba) with any premix partner applied preemergence provided less than 30% kochia control at evaluations conducted on July 25 and August 12, 2016. The addition of glyphosate plus Distinct (dicamba + diflufenzopyr) postemergence increased control 45 to 66% compared to preemergence treatments alone on July 25 and August 12. However, all treatments receiving a postemergence application controlled kochia similarly on August 12.

Introduction

A scheduled approach of herbicides before and after wheat harvest is needed for effective season-long weed control. Clarity, Distinct, Prowl H₂O (pendimethalin), Rave (dicamba + triasulfuron), and Zidua (pyroxasulfone) have all shown activity on the normal weed spectrum seen in this region. The various combinations and timings of application to achieve effective weed control with these herbicides are not known. Therefore, it was the objective of this study to explore various combinations and timings of these compounds for season-long weed control.

Experimental Procedures

An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to examine the efficacy of preemergence and/or post-harvest dicamba tank mixtures in winter wheat. Herbicides were applied March 3, 2016 (preemergence to kochia), and July 11, 2016 (postemergence following wheat harvest). Treatments were applied using a CO₂-compressed, tractor-mounted or backpack sprayer, delivering 20 GPA at 3.0 mph and 27 or 30 psi. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Plot size was 10- by 40-feet and arranged in a split-plot design replicated four times, with preemergence herbicide as the main plot and post-harvest herbicides as the subplots. Wheat was removed from the experiment June 20, 2016, but no yield data were collected. Kochia control was evaluated visually on March 4, July 11, July 25, and August 12, 2016. These dates were 29 and 130 days after the preemergence treatments and 14 and 32 days after the post-harvest treatments, respectively.

Results and Discussion

Clarity with any premix partner applied preemergence provided less than 30% kochia control at the evaluations conducted on July 25 and August 12, 2016. The addition of glyphosate plus Distinct postemergence increased control 45 to 66% compared to preemergence treatments alone on July 25 and August 12. However, all treatments receiving a postemergence application controlled kochia similarly on August 12. No set of treatments provided season-long control of kochia. The study area was allowed to natu-

rally reseed for two years prior to conducting this trial. Therefore, weed pressure was far more than what might be normally found in a producer's field. Although 85% control is not acceptable, it is often enough to thin the weeds, allowing a postemergence application of paraquat with atrazine or metribuzin to be successful, which would otherwise have been ineffective due to poor spray coverage.

Table 1. Preemergence and post-harvest kochia control in wheat

Herbicide ^a	Rate oz/a	Timing	Kochia			
			March 4	July 11	July 25	August 12
			----- % control -----			
Glyphosate	32	POST-Harvest	---	---	60	85
Distinct	6	POST-Harvest				
COC	1%	POST-Harvest				
AMS	2%	POST-Harvest				
Clarity	4	Preemergence	80	25	25	20
MCPA ester	8	Preemergence				
Zidua	2	Preemergence				
NIS	0.125%	Preemergence				
Clarity	4	Preemergence	80	25	70	86
MCPA ester	8	Preemergence				
Zidua	2	Preemergence				
NIS	0.125%	Preemergence				
Glyphosate	32	POST-Harvest				
Distinct	6	POST-Harvest				
COC	1%	POST-Harvest				
AMS	2%	POST-Harvest				
Clarity	4	Preemergence	83	33	20	20
MCPA ester	8	Preemergence				
Prowl H ₂ O	32	Preemergence				
NIS	0.125%	Preemergence				
Clarity	4	Preemergence	83	33	70	85
MCPA ester	8	Preemergence				
Prowl H ₂ O	32	Preemergence				
NIS	0.125%	Preemergence				
Glyphosate	32	POST-Harvest				
Distinct	6	POST-Harvest				
COC	1%	POST-Harvest				
AMS	2%	POST-Harvest				
Clarity	4	Preemergence	84	30	28	28
MCPA ester	8	Preemergence				
Prowl H ₂ O	32	Preemergence				
Zidua	2	Preemergence				
NIS	0.125%	Preemergence				

continued

Table 1. Preemergence and post-harvest kochia control in wheat

Herbicide ^a	Rate	Timing	Kochia			
			March 4	July 11	July 25	August 12
	oz/a		----- % control -----			
Clarity	4	Preemergence	84	30	73	85
MCPA ester	8	Preemergence				
Prowl H ₂ O	32	Preemergence				
Zidua	2	Preemergence				
NIS	0.125%	Preemergence				
Glyphosate +	32	POST-Harvest				
Distinct	6	POST-Harvest				
COC	1%	POST-Harvest				
AMS	2%	POST-Harvest				
Rave	4	Preemergence	73	28	23	23
NIS	0.125%	Preemergence				
Rave	4	Preemergence	73	28	68	84
NIS	0.125%	Preemergence				
Glyphosate	32	POST-Harvest				
Distinct	6	POST-Harvest				
COC	1%	POST-Harvest				
AMS	2%	POST-Harvest				
Untreated	---	---	0	0	0	0
Least significant difference (0.05)			4	8	4	4

^a AMS is ammonium sulfate, COC is crop oil concentrate, and NIS is nonionic surfactant.

Winter and Early Spring Herbicides for Kochia Control in Fallow

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in fall of 2015 and spring of 2016 comparing the weed control of several herbicide treatments and their time of application for kochia control in fallow. All herbicide treatments applied in December 2015 provided 99 or 100% kochia control in early spring. However, control declined to less than 60% with these treatments by June 8, 2016. Spring-applied herbicides were generally more efficacious than winter-applied herbicides on June 8, with the best control from treatments of Clarity (dicamba) plus atrazine with or without Zidua (pyroxasulfone) (88 to 89%).

Introduction

Atrazine, Clarity, Corvus (isoxaflutole + thienencarbazon), OpTill (saflufenacil + imazethapyr), Sharpen (saflufenacil), and Zidua have all been shown to effect kochia control. However, information is needed on how to combine these products in tank mixes and when to apply them. Therefore, it was the objective of this research to explore various combinations and timings of application of these products for kochia control.

Experimental Procedures

An experiment at the Kansas State University Southwest Research-Extension Center near Garden City, KS, examined the efficacy of winter and early spring herbicide applications for kochia control in fallow. Herbicides were applied December 3, 2015, and March 14, 2016. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Plots were 10- by 35-feet and arranged in a randomized complete block replicated four times. A tractor-mounted, compressed-CO₂ sprayer delivering 20 GPA at 3.0 mph and 30 psi was used to apply all herbicides. Kochia plants in the spring averaged less than 0.5-inch tall and 100 plants/10 ft² on March 14. Visual weed control was determined on March 7, April 1, and June 8, 2016, which was 95 days after winter applications and 18 and 86 days after spring applications, respectively.

Results and Discussion

All herbicide treatments applied in December 2015 provided 99 or 100% kochia control on March 7 and April 1, 2016. However, control declined to less than 60% with these treatments by June 8. Spring-applied herbicides were generally more effective than winter-applied herbicides on June 8, with the best control from treatments of Clarity plus atrazine with or without Zidua (88 to 89%). Previous work has also shown a reduced control with winter application (Proc. North Central Weed Sci. Soc. 70:49-50). However, these studies did not show as severe a penalty for winter application due to different patterns of fall and winter precipitation. Although the weed control shown here in June is not commercially acceptable, it was likely good enough to allow a later application with paraquat combined with atrazine or metribuzin to maintain adequate control further into the season.

Reference

Currie, R.S., P.W. Geier, C.R. Thompson. Comparisons of winter versus early spring preemergence herbicide applications for kochia control in fallow. Proc. North Central Weed Sci. Soc. 70:49-50

Table 1. Winter and spring herbicide applications for kochia control

Herbicide	Rate oz/a	Timing	Kochia		
			March 7	April 1	June 8
			----- % control -----		
Clarity	16	Winter	100	100	53
Atrazine	24	Winter			
Sharpen	2	Winter	99	99	45
Atrazine	24	Winter			
Sharpen	2	Winter	100	100	53
Atrazine	24	Winter			
Clarity	8	Winter			
Zidua	2.5	Winter	100	100	55
Atrazine	24	Winter			
Clarity	8	Winter			
OpTill	2	Winter	100	100	59
Zidua	2	Winter			
Clarity	8	Winter			
Corvus	3.3	Winter	100	100	53
Atrazine	24	Winter			
Clarity	8	Winter			
Clarity	16	Spring	---	65	88
Atrazine	24	Spring			
Sharpen	2	Spring	---	70	74
Atrazine	24	Spring			
Sharpen	2	Spring	---	70	73
Atrazine	24	Spring			
Clarity	8	Spring			
Zidua	2.5	Spring	---	63	89
Atrazine	24	Spring			
Clarity	8	Spring			
OpTill	2	Spring	---	60	58
Zidua	2	Spring			
Clarity	8	Spring			
Corvus	3.3	Spring	---	75	64
Atrazine	24	Spring			
Clarity	8	Spring			
Untreated	---	---	0	0	0
Least significant difference (0.05)			2	6	7

Clarity, Laudis, Diflexx Duo, Atrazine, and Glyphosate for Efficacy in Corn

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016 comparing the weed control of several herbicide treatments in irrigated corn. Control of quinoa, Russian thistle, and kochia was excellent with all herbicide treatments, and late-season control of common sunflower was 100% with all treatments except for those applied preemergence alone. Most treatments controlled green foxtail 95% or more, except Corvus (isoxaflutole + thiencazuron) plus atrazine preemergence, or the early postemergence (EPOST) treatments containing Liberty 280 (glufosinate). Liberty 280 severely injured the non-Liberty Link corn in this trial, but all other herbicide-treated corn yielded 21 to 45 bu/a more grain than untreated corn.

Introduction

Various commercial herbicides containing isoxaflutole (Balance Flexx, Corvus), thiencazuron (Capreno, Corvus), tembotrione (Diflexx Duo, Laudis), and dicamba (Clarity, Diflexx Duo) have shown good results in providing weed control with either preemergence or postemergence applications. The objective of this study was to evaluate these products along with atrazine, glyphosate, Liberty 280, and Halex GT (metolachlor + glyphosate + mesotrione) in a single or sequential program for efficacy in corn.

Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated the efficacy of preemergence (PRE), early postemergence (EPOST), and sequential (preemergence followed by postemergence) herbicides in corn. All herbicide treatments were applied using a compressed-CO₂ backpack sprayer, delivering 20 GPA at 3.0 mph and 27 psi. Application dates and environmental conditions are given in Table 1. Soil was a Ulysses silt loam with pH 8.0, 1.4% organic matter and cation exchange capacity of 18.4. Plot size was 10- by 35-feet. The experiment was a randomized complete block with each treatment replicated four times. Visual weed control was determined on June 3 and July 7, 2016, which was 9 days after early postemergence and 31 days after the postemergence treatments, respectively. Corn yields were determined September 26, 2016, by mechanically harvesting the center two rows of each plot and adjusting grain moisture to 15.5%.

Results and Discussion

Control of quinoa and Russian thistle was 100% regardless of herbicide treatment or evaluation date (data not shown). Kochia control was 95% or more on June 3 regardless of herbicide treatment and 100% by July 7. Common sunflower control was 100% with all EPOST and sequential treatments on July 7, whereas green foxtail control was 95% or more on July 7, except with Corvus plus atrazine preemergence or the EPOST treatments containing Liberty 280. No visible corn injury was observed with any treatment except those containing Liberty 280. The intent of this study was to plant a corn variety

resistant to glufosinate. However, a glufosinate-susceptible variety was mistakenly planted. Therefore, Liberty-containing treatments caused 68 to 70 and 88 to 91% corn injury June 3 and July 7, respectively (data not shown). The high degree of corn injury with the Liberty treatments severely limited corn yield. All other herbicide-treated corn yielded 21 to 45 bu/a more grain than untreated corn.

Table 1. Application information

Application timing	Preemergence	Early postemergence	Postemergence
Application date	April 28, 2016	May 25, 2016	June 6, 2016
Air temperature (°F)	42	64	75
Relative humidity (%)	62	77	40
Soil temperature (°F)	53	65	69
Wind speed (mph)	5 to 8	4 to 6	5 to 7
Wind direction	North	West-northwest	South
Soil moisture	Good	Good	Good

Table 2. Clarity, Laudis, Diflexx Duo, atrazine, and glyphosate in corn

Treatment ^a	Rate	Timing ^b	Kochia		Common sunflower		Green foxtail		Grain yield bu/a
			June 3	July 7	June 3	July 7	June 3	July 7	
	per a		----- % control -----						
Balance Flexx	4 oz	PRE	100	100	86	86	100	99	232
Harness Xtra 6.0	2.4 qt	PRE							
Corvus	5.6 oz	PRE	100	100	90	85	91	86	226
Atrazine	32 oz	PRE							
Balance Flexx	3 oz	PRE	100	100	78	100	90	99	234
Atrazine	32 oz	PRE							
Glyphosate	32 oz	POST							
Capreno	3 oz	POST							
Atrazine	16 oz	POST							
Clarity	8 oz	POST							
Superb HC	0.5%	POST							
AMS	2 lb	POST							
Corvus	3.3 oz	PRE	100	100	94	100	89	100	221
Atrazine	32 oz	PRE							
Glyphosate	32 oz	POST							
Laudis	3 oz	POST							
Atrazine	16 oz	POST							
Clarity	8 oz	POST							
Destiny HC	1%	POST							
AMS	2 lb	POST							

continued

Table 2. Clarity, Laudis, Diflexx Duo, atrazine, and glyphosate in corn

Treatment ^a	Rate	Timing ^b	Kochia		Common sunflower		Green foxtail		Grain yield
			June 3	July 7	June 3	July 7	June 3	July 7	
	per a		----- % control -----						bu/a
Corvus	3.3 oz	PRE	100	100	89	100	91	100	231
Atrazine	32 oz	PRE							
Glyphosate	32 oz	POST							
Diflexx Duo	24 oz	POST							
Atrazine	16 oz	POST							
Destiny HC	1%	POST							
AMS	2 lb	POST							
Halex GT	3.6 pt	EPOST	95	100	100	100	100	95	230
Diflexx	8 oz	EPOST							
NIS	0.25%	EPOST							
AMS	3 lb	EPOST							
Liberty 280	29 oz	EPOST	96	100	100	100	98	65	53
Diflexx Duo	24 oz	EPOST							
Atrazine	32 oz	EPOST							
AMS	3 lb	EPOST							
Liberty 280	29 oz	EPOST	100	100	100	100	97	75	17
Capreno	3 oz	EPOST							
Atrazine	32 oz	EPOST							
AMS	3 lb	EPOST							
Glyphosate	32 oz	EPOST	99	100	100	100	100	95	245
Capreno	3 oz	EPOST							
Atrazine	32 oz	EPOST							
Clarity	8 oz	EPOST							
Superb HC	0.5%	EPOST							
AMS	2 lb	EPOST							
Untreated	---	---	0	0	0	0	0	0	200
LSD (0.05)			3	NS	9	6	5	5	13.1

^a AMS is ammonium sulfate, and NIS is nonionic surfactant.

^b PRE is preemergence, POST is postemergence, and EPOST is early postemergence.

LSD = Least significant difference.

Resicore and Glyphosate Application Timings in Corn

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016, comparing the weed control of several herbicide treatments in irrigated corn. All treatments provided excellent, season-long control of kochia, Russian thistle, Palmer amaranth and green foxtail. Herbicide-treated corn yielded 219 to 235 bu/a, which was 86 to 102 bu/a more than nontreated corn; however, no differences in yield occurred among herbicide treatments.

Introduction

Hornet WDG (flumetsulam + clopyralid), Keystone NXT (acetochlor + atrazine), Resicore (acetochlor + clopyralid + mesotrione), and SureStart II (acetochlor + clopyralid + flumetsulam) have been shown to provide broad spectrum weed control in corn. Therefore, it was the objective of this study to measure their level of control under local irrigated conditions.

Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated the efficacy of preplant or preemergence followed by postemergence applications in corn. All herbicides were applied using a compressed CO₂ backpack sprayer, delivering 20 GPA at 3.0 mph and 27 psi. Application dates, timings, and environmental conditions are shown in Table 1. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Plots were 10- by 35-feet and arranged in a randomized complete block with four replications. Visual estimates of weed control were taken on May 26 and July 7, 2016. Corn yields were determined September 26, 2016, by mechanically harvesting the two center rows of each plot and adjusting weights to 15.5% moisture.

Results and Discussion

Kochia, Russian thistle, and green foxtail control was 98% or more regardless of herbicide treatment on May 26. Kochia control remained at 98% or more on July 7, while all herbicides provided complete Russian thistle and green foxtail control at the later rating date. Palmer amaranth control was 100% regardless of treatment or evaluation date (data not shown). Herbicide-treated corn yielded 219 to 235 bu/a, which was 86 to 102 bu/a more than nontreated corn; however, no differences in yield occurred among herbicide treatments (data not shown).

Table 1. Application information

Application timing	19 days preplant	Preemergence	Postemergence
Application date	April 7, 2016	April 26, 2016	June 6, 2016
Air temperature (°F)	49	81	75
Relative humidity (%)	47	10	83
Soil temperature (°F)	47	68	70
Wind speed (mph)	7 to 10	4 to 6	5 to 7
Wind direction	North	South-southeast	South
Soil moisture	Fair	Good	Excellent

Table 2. Resicore and glyphosate timings in corn

Treatment ^a	Rate	Timing ^b	Kochia		Russian thistle		Green foxtail	
			May 26	July 7	May 26	July 7	May 26	July 7
	per A		----- % control -----					
Resicore	2.5 qt	19 DPP	100	100	98	100	99	100
Atrazine	1 qt	19 DPP						
Glyphosate	1 qt	19 DPP						
2,4-D ester	16 oz	19 DPP						
AMS	2.5%	19 DPP						
Glyphosate	1 qt	POST						
AMS	2.5%	POST						
Keystone	2 qt	PRE	99	100	100	100	100	100
NXT	4 oz	PRE						
Hornet WDG	1 qt	PRE						
Glyphosate	2.5%	PRE						
AMS	1 qt	POST						
Glyphosate	2.5%	POST						
AMS								
SureStart II	2.5 qt	PRE	99	98	100	100	99	100
Atrazine	1 qt	PRE						
Glyphosate	1 qt	PRE						
AMS	2.5%	PRE						
Glyphosate	1 qt	POST						
AMS	2.5%	POST						
Resicore	2.5 qt	PRE	100	100	100	100	100	100
Atrazine	1 qt	PRE						
Glyphosate	1 qt	PRE						
AMS	2.5%	PRE						
Glyphosate	1 qt	POST						
AMS	2.5%	POST						
Resicore	1.25 qt	PRE	100	100	100	100	98	100
Atrazine	1 qt	PRE						
Glyphosate	1 qt	PRE						
AMS	2.5%	PRE						
Resicore	1.25 qt	POST						
Atrazine	0.5 qt	POST						
Glyphosate	1 qt	POST						
AMS	2.5%	POST						
Untreated	----	---	0	0	0	0	0	0
Least standard deviation (0.05)			2	2	2	NS	3	NS

^a AMS is ammonium sulfate.^b 19 DPP is 19 days preplant, PRE is preemergence and POST is postemergence when corn was 20 to 24 inches tall.

Rates of Armezon Pro for Postemergence Weed Control in Fallow

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016, comparing the weed control of several tank mixes of Armezon in fallow. Control of kochia and Russian thistle generally increased as Armezon Pro (topramezone + dimethenamid) rates increased from 14 to 20 oz/a. Although these herbicides injured the weeds present, smaller weeds will need to be targeted for effective control. The population of kochia was too thick and the size of the weeds was too large to allow enough coverage for this product to work under the conditions of this trial. The level of tissue damage suggests that further testing is needed with smaller weeds in a thinner population.

Introduction

Field observations have suggested that Armezon Pro might provide excellent burndown and residual control in fallow. It is not known when to apply Armezon Pro, what weeds it will control, and the duration of its residual control. Therefore, it was the objective of this study to establish a dose response relationship for Armezon Pro with a naturally occurring population of kochia and Russian thistle.

Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated the efficacy of Armezon Pro rates for postemergence weed control in fallow. All treatments were applied May 16, 2016, when kochia averaged 10 inches tall and 10 plants/square foot and Russian thistle averaged 4 inches in height and 1 plant per square foot. Herbicides were applied using a compressed-CO₂ backpack sprayer calibrated to deliver 20 GPA at 3.0 mph and 27 psi. Plots were 10- by 35-feet, and arranged in a randomized complete block with four replications. Soil was a Ulysses silt loam with pH of 8.0, organic matter of 1.4%, and cation exchange capacity of 18.4. Visual weed control was determined on May 23, June 1, and June 14, 2016, which was 7, 16, and 29 days after treatment (DAT).

Results and Discussion

At 7 and 16 DAT, control of kochia and Russian thistle generally increased as Armezon Pro rates increased from 14 to 20 oz/a. By 29 DAT, no differences occurred between herbicide rates. Although these herbicides injured the weeds present, smaller weeds will need to be targeted for effective control. Although field observations at other locations suggested that this product could work, the kochia was clearly too large and the population was too dense to allow adequate coverage of the kochia and Russian thistle tissue. Based on the observed burning of the tissue, this study should be repeated on smaller weeds at lower populations to allow complete coverage of the tissue.

Table 1. Armezon Pro rates for fallow weed control

Treatment ^a	Rate	Timing	7 days after treatment		16 days after treatment		29 days after treatment	
			Kochia	Russian thistle	Kochia	Russian thistle	Kochia	Russian thistle
			----- % control -----					
Armezon Pro	14	POST	27	20	66	73	73	85
Atrazine	16	POST						
COC	1%	POST						
AMS	2%	POST						
Armezon Pro	16	POST	28	18	63	78	70	83
Atrazine	16	POST						
COC	1%	POST						
AMS	2%	POST						
Armezon Pro	18	POST	30	20	68	80	76	86
Atrazine	16	POST						
COC	1%	POST						
AMS	2%	POST						
Armezon Pro	20	POST	35	28	70	80	76	85
Atrazine	16	POST						
COC	1%	POST						
AMS	2%	POST						
Untreated	---	---	0	0	0	0	0	0
Least significant difference (0.05)			5	5	7	4	7	6

^a COC is crop oil concentrate, and AMS is ammonium sulfate.

Single and Sequential Applications of Anthem Maxx, Solstice, Acuron, Balance Flexx, Corvus, Halex GT, Verdict, Sharpen, Glyphosate, and Atrazine in Irrigated Corn

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016, comparing the weed control of several herbicide treatments and their sequential application for weed control in irrigated corn. Quinoa and common sunflower control was excellent. All sequential herbicide treatments provided excellent control of kochia, velvetleaf, Palmer amaranth, and green foxtail. Single applications at the V4 stage, although still good, showed a reduced level of Palmer amaranth and green foxtail control compared to sequential treatments.

Introduction

Acuron (metolachlor + atrazine + mesotrione + bicyclopyrone), Anthem Maxx (pyroxasulfone + fluthiacet), Balance Flexx (isoxaflutole), Corvus (isoxaflutole + thiencazabone), Halex GT (metolachlor + glyphosate + mesotrione), Sharpen (saflufenacil), Solstice (fluthiacet + mesotrione), and Verdict (saflufenacil + dimethenamid) have all been shown to provide excellent broad spectrum weed control in irrigated corn. Head-to-head comparisons of these tank mixes with local weed populations are needed. Therefore, it was the objective of this trial to compare the weed control of these products under statistically replicated conditions.

Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated the efficacy of single and sequential herbicide applications in corn. The entire plot area was over-seeded with foxtail, crabgrass, and Palmer amaranth, as well as the domestically cultivated sorghum 'Rox orange,' quinoa, and sunflowers. These serve as proxies for their wild relatives, shattercane, lambsquarters, and wild sunflowers, respectively. Treatments were applied preemergence followed by early postemergence (V4) or postemergence (V8) or as early postemergence (V4) alone. All herbicides were applied using a tractor-mounted, compressed-CO₂ sprayer, delivering 20 GPA at 3.0 mph and 30 psi. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Plots were 10 by 35 feet and arranged in a randomized complete block design with four replications. Visual weed control was determined July 13, 2016, which was 27 days after the V8 applications (DAPO). Grain yields were determined September 20, 2016, by mechanically harvesting the center two rows of each plot and adjusting the weights to 15.5% moisture.

Results and Discussion

Quinoa and common sunflower control was 100% regardless of treatment at 27 DAPO (data not shown). All herbicides provided excellent control of kochia, velvetleaf, Palmer amaranth, and green foxtail when applied as sequential treatments. Single applications at the V4 stage, although still good, did not control Palmer amaranth and green foxtail as well as the sequential treatments. Herbicide-treated corn yielded 179 to 197 bu/a but did not differ between treatments. Untreated corn yielded 188 bu/a (data not shown).

Table 1. Application information

Application timing	Preemergence	V4 corn	V8 corn
Application date	May 6, 2016	June 2, 2016	June 16, 2016
Air temperature (°F)	60	76	79
Relative humidity (%)	55	47	46
Soil temperature (°F)	57	64	72
Wind speed (mph)	8 to 10	4 to 6	7 to 10
Wind direction	South	South	South
Soil moisture	Good	Good	Good

Table 2. Anthem Maxx, Solstice, and atrazine in corn

Treatment ^a	Rate	Timing ^b	Kochia	Velvetleaf	Palmer amaranth	Green foxtail
			27 DAPO ^c	27 DAPO	27 DAPO	27 DAPO
	per a		----- % control -----			
Anthem Maxx	4 oz	PRE	100	100	100	96
Solstice	2.5 oz	V4				
Atrazine	32 oz	V4				
Glyphosate	32 oz	V4				
COC	0.5%	V4				
AMS	1%	V4				
Anthem Maxx	4 oz	PRE	100	100	98	98
Atrazine	32 oz	PRE				
Solstice	2.5 oz	V4				
Atrazine	16 oz	V4				
Glyphosate	32 oz	V4				
COC	0.5%	V4				
AMS	1%	V4				
Anthem Maxx	4 oz	PRE	100	99	100	100
Atrazine	32 oz	PRE				
Balance Flexx	2 oz	PRE				
Glyphosate	32 oz	V4				
AMS	1%	V4				

continued

Table 2. Anthem Maxx, Solstice, and atrazine in corn

Treatment ^a	Rate	Timing ^b	Kochia	Velvetleaf	Palmer amaranth	Green foxtail
			27 DAPO ^c	27 DAPO	27 DAPO	27 DAPO
	per a		----- % control -----			
Verdict	16 oz	PRE	93	98	99	100
Glyphosate	32 oz	V8				
AMS	1%	V8				
Anthem Maxx	4 oz	PRE	98	98	100	100
Sharpen	2 oz	PRE				
Glyphosate	32 oz	V8				
AMS	1%	V8				
Anthem Maxx	4 oz	PRE	100	100	100	100
Balance Flexx	3 oz	PRE				
Glyphosate	32 oz	V8				
AMS	1%	V8				
Halex GT	3.6 pt	V4	98	100	93	95
NIS	0.25%	V4				
AMS	1%	V4				
Solstice	3.2 oz	V4	100	100	89	88
Atrazine	32 oz	V4				
Glyphosate	32 oz	V4				
COC	0.5%	V4				
AMS	1%	V4				
Solstice	2.5 oz	V4	98	100	83	85
Anthem Maxx	2 oz	V4				
Glyphosate	32 oz	V4				
COC	0.5%	V4				
Solstice	2.5 oz	V4	100	100	91	91
Anthem Maxx	2 oz	V4				
Atrazine	16 oz	V4				
Glyphosate COC	32 oz	V4				
	0.5%	V4				
Anthem Maxx	4 oz	PRE	100	100	100	100
Atrazine	32 oz	PRE				
Glyphosate	32 oz	V8				
AMS	1%	V8				
Acuron	2.5 qt	PRE	100	100	100	100
Glyphosate	32 oz	V8				
AMS	1%	V8				
Corvus	5.6 oz	PRE	100	100	100	100
Atrazine	32 oz	PRE				
Glyphosate	32 oz	V8				
AMS	1%	V8				
Untreated	---	---	0	0	0	0
Least significant difference (0.05)			4	3	5	4

^a AMS is ammonium sulfate, COC is crop oil concentrate, and NIS is nonionic surfactant.

^b PRE is preemergence, V4 is corn with 4 visible leaf collars, and V8 is corn with 8 visible leaf collars.

^c DAPO is days after V8 applications.

Armezon Pro, Status, Verdict, Glyphosate, Zidua, and Atrazine for Sequential Weed Control in Glyphosate-Resistant Corn

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016, comparing the weed control of several herbicide treatments applied sequentially in irrigated corn. Kochia control was 95% or more with all treatments at 1 day after late postemergence application (1 DALP) and 100% regardless of treatment at 63 days after late postemergence application (63 DALP). Palmer amaranth and green foxtail control was 98 to 100% and 83 to 93%, respectively, with all preemergence treatments at 1 DALP. A second late postemergence application was needed to achieve 100% control of Palmer amaranth and green foxtail 63 DALP. The single early postemergence treatment controlled Palmer amaranth and green foxtail 90 and 91% at 63 DALP.

Introduction

Armezon Pro (topramezone + dimethenamid), Status (dicamba + diflufenzopyr), Verdict (saflufenacil + dimethenamid), and Zidua (pyroxasulfone) have all been shown to provide excellent weed control in corn. The impact of exact timings of multiple applications of these products under local conditions is not clearly understood. Therefore, it was the objective of this study to measure various tank mix combinations of these products and various times of application.

Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated sequential preemergence followed by postemergence herbicide applications for weed control in corn. The entire plot area was over-seeded with foxtail, crabgrass, and Palmer amaranth, as well as the domestically cultivated sorghum 'Rox orange', quinoa, and sunflowers. These serve as proxies for their wild relatives, shattercane, lambsquarters, and wild sunflowers, respectively. A single early postemergence (EP) treatment was included for comparison purposes and was applied when the corn had two visible leaf collars (V2). The late postemergence treatments (LP) were applied when corn had five visible leaf collars (V5). Application dates and environmental conditions are shown in Table 1. All herbicides were applied using a tractor-mounted or backpack sprayer, delivering 19.5 or 20 GPA at 3.0 mph and 30 or 27 psi. Plot sizes were 10- by 35-feet and were arranged in a randomized complete block design with four replications. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Visual weed control was determined June 17 and August 18, 2016, which was 1 and 63 days after the late postemergence applications. Yields were determined on September 26, 2016, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 15.5% moisture.

Results and Discussion

Quinoa and common sunflower control was 98 to 100% regardless of treatment or evaluation date (data not shown). Kochia control was 95% or more with all treatments at 1 DALP, and 100% regardless of treatment at 63 DALP. Palmer amaranth and green foxtail control was 93 to 100% and 83 to 93%, respectively, with all treatments at 1 DALP. However, complete control of Palmer amaranth and green foxtail occurred with all sequential treatments at 63 DALP. The single early postemergence treatment controlled Palmer amaranth and green foxtail 90 and 91% at 63 DALP. Herbicide-treated corn yielded 180 to 193 bu/a but did not differ between treatments and did not differ from the yield of the untreated control (data not shown).

Table 1. Application information

Application timing	Preemergence	Early postemergence	Postemergence
Application date	May 13, 2016	June 1, 2016	June 16, 2016
Air temperature (°F)	80	66	75
Relative humidity (%)	36	61	52
Soil temperature (°F)	63	61	73
Wind speed (mph)	6 to 9	2 to 4	6 to 8
Wind direction	West-southwest	West	South
Soil moisture	Good	Excellent	Good

Table 2. Armezon Pro, Status, Verdict, and atrazine in corn

Treatment ^a	Rate	Timing ^b	Kochia		Palmer amaranth		Green foxtail	
			1 DALP ^c	63 DALP	1 DALP	63 DALP	1 DALP	63 DALP
	oz/a		----- % control -----					
Verdict	10	PRE	100	100	98	100	88	100
Atrazine	16	PRE						
Status	5	LP						
Atrazine	16	LP						
Glyphosate	32	LP						
MSO	1%	LP						
AMS	2%	LP						
Verdict	10	PRE	100	100	100	100	83	100
Atrazine	16	PRE						
Armezon Pro	16	LP						
Atrazine	16	LP						
Glyphosate	32	LP						
COC	1%	LP						
AMS	2%	LP						
Verdict	7.5	PRE	95	100	96	100	84	100
Atrazine	16	PRE						
Armezon Pro	20	LP						
Atrazine	16	LP						
Glyphosate	32	LP						
COC	1%	LP						
AMS	2%	LP						
Zidua	3.3	PRE	100	100	98	100	93	100
Sharpen	2	PRE						
Atrazine	16	PRE						
Armezon Pro	20	LP						
Atrazine	16	LP						
Glyphosate	32	LP						
COC	1%	LP						
AMS	2%	LP						
Armezon Pro	20	EP	98	100	93	90	91	91
Atrazine	16	EP						
Glyphosate	32	EP						
COC	1%	EP						
AMS	2%	EP						
Untreated	---		0	0	0	0	0	0
Least significant difference (0.05)			4	NS	6	3	5	3

^a AMS is ammonium sulfate, COC is crop oil concentrate, and MSO is methylated seed oil.

^b PRE is preemergence, EP is early postemergence to corn with 2 visible leaf collars, and LP is late postemergence to corn with 5 visible leaf collars.

^c DALP is days after late post emergence applications.

Kochiavore at Three Rates with Several Adjuvants for Postemergence Fallow Weed Control

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016, comparing the weed control Kochiavore with several additives for kochia control in fallow. The control of kochia, Russian thistle, and flixweed increased as Kochiavore rate increased when applied without adjuvant. There were no noticeable differences in the effect of adjuvant systems on Kochiavore performance. Russian thistle and flixweed control was excellent regardless of herbicide rate or adjuvant. Kochia control was generally best when Kochiavore was applied at 2.5 pt/a.

Introduction

Kochiavore is a proprietary package mix of 2,4-D, bromoxynil, and fluroxypyr marketed by Winfield Solutions LLC for kochia control. Banvel (dicamba) and Vida (pyraflufen) tank mixes have also shown promise for postemergence kochia control. Therefore, it was the objective of this study to compare these products with various adjuvant systems for fallow weed control.

Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated Kochiavore herbicide at three rates and with various adjuvants for weed control in fallow. All treatments were applied on May 10, 2016, when kochia averaged 5 inches tall and 10 plants per square foot, Russian thistle was 3 inches tall and 3 plants/10 ft², and flixweed was 15 inches tall and 1 plant per square foot. Herbicides were applied using a tractor-mounted, compressed-CO₂ sprayer, delivering 20 GPA at 3.0 mph and 30 psi. Plots were 10- by 35-feet, and treatments were arranged in a randomized complete block with four replications. Visual weed control was determined on May 24 and June 6, 2016, 14 and 27 days after herbicide treatment (DAT), respectively.

Results and Discussion

When no adjuvant was included, control of kochia, Russian thistle, and flixweed increased as Kochiavore rate increased at 14 DAT. Within herbicide rates, no adjuvant system increased the efficacy of Kochiavore alone on any species at 14 DAT. By 27 DAT, Russian thistle and flixweed control was complete regardless of herbicide rate or adjuvant, and kochia control was generally best when Kochiavore was applied at 2.5 pt/a. Because kochia naturally reseeded for two years prior to this test, weed pressure was far greater than most producers often face. Where weed pressure is less, 90% efficacy might translate into acceptable control. Furthermore, that level of control would allow a postemergence application of paraquat with atrazine or metribuzin to be successful, which would have otherwise been ineffective due to poor spray coverage.

Table 1. Kochiavore rates and adjuvants for postemergence fallow weed control

Herbicide ^a	Rate	14 days after treatment			27 days after treatment		
		Kochia	Russian thistle	Flixweed	Kochia	Russian thistle	Flixweed
		----- % control -----					
Kochiavore	1.5 pt	75	86	71	76	100	100
Kochiavore	1.5 pt	78	89	78	81	100	100
Destiny HC	1.0 pt						
InterLock	4 oz						
Kochiavore	1.5 pt	78	88	75	80	100	100
AG14039	1.0 pt						
Kochiavore	2.0 pt	83	90	78	83	100	100
Kochiavore	2.0 pt	80	93	80	84	100	100
Destiny HC	1.0 pt						
InterLock	4 oz						
Kochiavore	2.0 pt	79	91	79	90	100	100
AG14039	1.0 pt						
Kochiavore	2.5 pt	85	95	83	91	100	100
Kochiavore	2.5 pt	83	95	83	91	100	100
Destiny HC	1.0 pt						
InterLock	4 oz						
Kochiavore	2.5 pt	83	95	80	85	100	100
AG14039	1.0 pt						
Glyphosate	32 oz	45	89	70	83	100	100
AMS	2%						
Vida	2.0 oz	79	86	81	78	100	100
Banvel	2.0 oz						
2,4-D amine	8.0 oz						
MSO	1%						
Untreated	---	0	0	0	0	0	0
LSD (0.05)		4	3	6	6	NS	NS

^a AG14039 is an experimental adjuvant, AMS is ammonium sulfate, MSO is methylated seed oil.
LSD = Least significant difference.

Efficacy of Preplant and Early Postemergence Herbicides in Corn

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016, comparing the weed control of several herbicide treatments applied sequentially for weed control in irrigated corn. Acuron (metolachlor + atrazine + mesotrione + bicyclopyrone), Clarity (dicamba), Corvus (isoxaflutole + thiencazone), Halex GT (metolachlor + glyphosate + mesotrione), and Lumax EZ (metolachlor + atrazine + mesotrione) were compared when combined at various ratios and timings. All combinations gave similar levels of weed control, allowing a producer to compare these tank mixes head-to-head based on prices alone.

Introduction

Acuron, Clarity, Corvus, Halex GT, and Lumax EZ are very competitive herbicides for weed control in corn. Therefore, it was the objective of this study to measure various combinations and times of applications of these products to allow economic comparisons.

Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated weed control with single and sequential herbicide treatments in corn. The entire plot area was over-seeded with foxtail, crabgrass, and Palmer amaranth, as well as the domestically cultivated sorghum 'Rox orange', quinoa and sunflowers. These serve as proxies for their wild relatives, shattercane, lambsquarters, and wild sunflowers, respectively. Single treatments were applied on May 23, 2016, which was 11 days prior to planting (11 DPP); sequential treatments consisted of 11 DPP treatments followed by early postemergence treatments applied on June 17, 2016. The early postemergence treatments were applied when corn had two true leaves (V2). All herbicides were applied using a tractor-mounted, compressed-CO₂ sprayer delivering 20 GPA at 3.0 mph and 30 psi. Plots were 10- by 35-feet, and treatments were arranged in a randomized complete block with four replications. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Visual weed control was determined on June 2 and August 18, 2016, which was 10 days after the preplant applications (10 DAPP) and 62 days after the early postemergence applications (62 DAPO), respectively. Corn yield was determined September 29, 2016, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 15.5% moisture.

Results and Discussion

Quinoa and common sunflower control was 95 to 100% regardless of treatment or evaluation date (data not shown), while kochia control was 97% or more. At 62 DAPO, Palmer amaranth control was greater than 96% with all herbicides, except Corvus plus atrazine and glyphosate applied 11 DPP (93%). Green foxtail control was generally best (95 to 99%) when sequential herbicides were applied. Corn yields ranged from 138 to 167 bu/a and did not differ between any treatment (data not shown). All herbicide combinations gave similar levels of weed control, allowing producers to compare these tank mixes head-to-head based upon prices alone.

Table 1. Preplant and early postemergence herbicides in corn

Treatment ^a	Rate	Timing ^b	Kochia		Palmer amaranth		Green foxtail	
			10 DAPP ^c	62 DAPO ^c	10 DAPP	62 DAPO	10 DAPP	62 DAPO
	per a		----- % control -----					
Glyphosate	28 oz	11 DPP	0	0	0	0	0	0
AMS	2%	11 DPP						
Acuron	2.5 qt	11 DPP	99	100	100	100	99	89
Atrazine	0.4 qt	11 DPP						
Glyphosate	28 oz	11 DPP						
AMS	2%	11 DPP						
Acuron	2.5 qt	11 DPP	100	100	100	100	100	93
Atrazine	0.4 qt	11 DPP						
Clarity	6 oz	11 DPP						
2,4-D ester	6 oz	11 DPP						
Glyphosate	28 oz	11 DPP						
AMS	2%	11 DPP						
Acuron	1.5 qt	11 DPP	100	100	95	97	100	95
Atrazine	0.25 qt	11 DPP						
Glyphosate	28 oz	11 DPP						
AMS	2%	11 DPP						
Halex GT	3.6 pt	V2						
Atrazine	0.5 qt	V2						
NIS	0.25%	V2						
AMS	2%	V2						
Acuron	1.5 qt	11 DPP	99	100	100	99	100	97
Atrazine	0.25 qt	11 DPP						
Clarity	6 oz	11 DPP						
2,4-D ester	6 oz	11 DPP						
Glyphosate	28 oz	11 DPP						
AMS	2%	11 DPP						
Halex GT	3.6 pt	V2						
Atrazine	0.5 qt	V2						
NIS	0.25%	V2						
AMS	2%	V2						
Acuron	1.25 qt	11 DPP	99	100	100	98	100	98
Atrazine	0.2 qt	11 DPP						
Glyphosate	28 oz	11 DPP						
AMS	2%	11 DPP						
Acuron	1.25 qt	V2						
Atrazine	0.2 qt	V2						
Glyphosate	28 oz	V2						
AMS	2%	V2						

continued

Table 1. Preplant and early postemergence herbicides in corn

Treatment ^a	Rate	Timing ^b	Kochia		Palmer amaranth		Green foxtail	
			10 DAPP ^c	62 DAPO ^c	10 DAPP	62 DAPO	10 DAPP	62 DAPO
	per a		----- % control -----					
Acuron	1.25 qt	11 DPP	100	100	100	98	100	99
Atrazine	0.2 qt	11 DPP						
Clarity	6 oz	11 DPP						
2,4-D ester	6 oz	11 DPP						
Glyphosate	28 oz	11 DPP						
AMS	2%	11 DPP						
Acuron	1.25 qt	V2						
Atrazine	0.2 qt	V2						
Glyphosate	28 oz	V2						
AMS	2%	V2						
Lumax EZ	2.7 qt	11 DPP	100	100	100	98	100	88
Atrazine	0.4 qt	11 DPP						
Glyphosate	28 oz	11 DPP						
AMS	2%	11 DPP						
Corvus	5.6 oz	11 DPP	98	97	97	93	100	92
Atrazine	1.0 qt	11 DPP						
Glyphosate	28 oz	11 DPP						
AMS	2%	11 DPP						
Least significant difference (0.05)			2	2	4	4	1	6

^a AMS is ammonium sulfate and NIS is nonionic surfactant.

^b 11 DPP is 11 days prior to corn planting and V2 is corn with 2 visible leaf collars.

^c DAPP is days after DPP applications, and DAPO is days after V2 application.

Postemergence Weed Control with Diflexx, Diflexx Duo, Capreno, and Atrazine in Corn Resistant to Glufosinate and Glyphosate

R.S. Currie and P.W. Geier

Summary

A study was initiated near Garden City, KS, in 2016, comparing the weed control of several postemergence herbicide treatments in irrigated corn. Control of kochia, Palmer amaranth, and crabgrass was 96% or more effective with all herbicides at 7 days after treatment (DAT). By 62 DAT, control of these three weed species was generally best when glyphosate, atrazine, Diflexx (dicamba) or Clarity (dicamba) were included in the herbicide mixture. Although all herbicide tank mixes increased yield compared to the untreated plots, no tank mix resulted in a superior yield.

Introduction

Capreno (thiencarbazone + tembotrione), Diflexx, Diflexx Duo (dicamba + tembotrione), and Halex GT (metolachlor + glyphosate + mesotrione) have been shown to provide good weed control. With the advent of glyphosate-resistant weeds, information is needed on how to augment the weed control of these compounds with Liberty 280 (glufosinate). Therefore, it was the objective of this study to compare various tank mixes to measure their impact on weed control in irrigated glufosinate-resistant corn.

Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated early postemergence weed control in corn with resistance to glufosinate and glyphosate. The entire plot area was over-seeded with foxtail, crabgrass, and Palmer amaranth, as well as the domestically cultivated sorghum 'Rox orange,' quinoa and sunflowers. These serve as proxies for their wild relatives, shattercane, lambsquarters, and wild sunflowers, respectively. All treatments were applied on June 17, 2016, when corn had two true leaves. A tractor-mounted, compressed-CO₂ sprayer delivering 20 GPA at 3.0 mph and 30 psi was used to apply all treatments. Plots were 10- by 35-feet and arranged in a randomized complete block design with four replications. Soil was a Ulysses silt loam with pH of 8.0, 1.4% organic matter, and cation exchange capacity of 18.4. Weed control was determined visually on June 24 and August 18, 2016, which was 7 and 62 days after treatment (DAT), respectively. Corn yield was determined October 3, 2016, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 15.5% moisture.

Results and Discussion

All herbicides controlled quinoa 100% regardless of the evaluation date (data not shown). Control of kochia, Palmer amaranth, and crabgrass was 96% or more effective with all herbicides at 7 DAT. By 62 DAT, control of these three weed species was generally best when glyphosate, atrazine, Diflexx, or Clarity were included in the herbicide mixture. Herbicide-treated corn yielded 40 to 66 bu/a more grain than untreated corn,

but yields did not differ between any herbicide treatment. Most of these treatments provided excellent weed control. However, glufosinate has no residual grass or broadleaf efficacy, and its control can be extended with the addition of herbicides with residual activity.

Table 1. Postemergence herbicides in resistant corn

Treatment ^a	Rate	Palmer amaranth		Green foxtail		Crabgrass		Corn yield bu/a
		7 DAT ^b	62 DAT	7 DAT	62 DAT	7 DAT	62 DAT	
	per a	----- % control -----						
Halex GT	3.6 pt	100	99	100	99	100	98	117.1
Diflexx	8 oz							
Atrazine	32 oz							
NIS	0.25%							
AMS	2 lb							
Liberty 280	29 oz	100	91	100	89	100	76	113.4
Diflexx Duo	24 oz							
Atrazine	32 oz							
AMS	3 lb							
Liberty 280	29 oz	96	85	100	91	98	86	113.6
Capreno	3 oz							
AMS	3 lb							
Glyphosate	32 oz	100	94	100	98	99	91	139.5
Capreno	3 oz							
Atrazine	32 oz							
Clarity	8 oz							
Superb HC	0.5%							
AMS	2 lb							
Untreated	---	0	0	0	0	0	0	73.1
LSD (0.05)		1	5	NS	6	3	8	26.7

^a AMS is ammonium sulfate and NIS is nonionic surfactant.

^b DAT is days after herbicide treatment.

LSD = Least significant difference.

Palmer Amaranth (*Amaranthus palmeri*) Suppression with Half Rates of Dicamba and Atrazine with Increasing Sorghum (*Sorghum bicolor*) Density and Nitrogen Rate

I.B. Cuvaca, R.S. Currie, and A.J. Foster

Summary

Palmer amaranth (PA) competition can result in severe yield loss in grain sorghum. Increasing sorghum density and nutrient supply could promote early/rapid canopy closure and therefore reduce the amount of light that could otherwise penetrate the canopy and promote PA growth in sorghum. A study was conducted at the Southwest Research-Extension Center near Garden City, KS, to determine if PA could be suppressed with dicamba and atrazine applied as PRE at half rates combined with increasing sorghum density (60,000, 90,000, and 120,000 seeds/a) and nitrogen rate (0, 100, 200 lb/a). Preliminary results indicate that increasing plant density and nitrogen rate did not suppress PA growth. The increase in plant density and nitrogen (N) rate had no effect on reducing PA height, number, and biomass in plots without in-season control (hoeing). In-season control of Palmer amaranth significantly ($P < 0.01$) increased grain yield, sorghum height, and number of heads, and was required to maximize yield. These results suggest that increasing plant density within the row does not reduce light penetration into sorghum canopy to suppress PA growth. Therefore, narrow-row planting will be added to the treatment structure to further determine the effect of plant density on suppressing PA in irrigated sorghum production.

Introduction

Sorghum is an important crop in Kansas. Similar to corn, sorghum is very sensitive to biological stress, especially weeds. Several studies have shown that sorghum cropping systems can suffer substantial yield loss when infested with Palmer amaranth.

This 2- to 3-year study aims to investigate the ability of integrated weed management approaches that combine cultural and chemical measures to control Palmer amaranth while maintaining or improving grain yield of sorghum. Particular research emphasis is aimed to understand the effect(s) of increasing planting density by increasing seeding rate and fertilizer rate with ultra-low herbicide applications on Palmer amaranth control and grain yield in irrigated sorghum cropping systems.

Successful completion of this project will provide a basis for a more comprehensive understanding and management of Palmer amaranth using integrated approaches as alternatives to chemical measures in irrigated sorghum cropping systems.

Experimental Procedures

Experimental Site

In 2016, field experiments were conducted at the Southwest Research-Extension Center, near Garden City, KS. The soil at the site was predominantly Richfield silt loam (fine, montmorillonitic, mesic Aridic Argiustoll).

Experimental Design

Three planting densities (60,000, 90,000, and 120,000 seeds per acre), three fertilizer rates (0, 100, and 200 pounds per acre N), and two in-season weed control levels (hoeing; weed vs. weed free) were evaluated for their ability to suppress Palmer amaranth while maintaining grain yield of sorghum using a completely randomized block design with split-split plot arrangement and four replicates. Planting density, fertilizer rate, and in-season weed control were treated as main plot, sub-plot, and sub-sub-plot factors, respectively.

Plot Establishment and Management

Experimental plots were established using a John Deere Max Emerge planter in a field with natural infestation of Palmer amaranth. Due to limited space each sub-sub-plot was planted to four 22.5-ft-long rows of sorghum. The field was disked and field cultivated to assure a weed-free seedbed at planting, while at the same time creating an optimum environment for both sorghum and Palmer amaranth emergence and establishment. Sorghum, "DK 3707," was planted on June 20, 2016, in rows 30 in. apart and with 8 oz of dicamba tank mixed with 1 pint atrazine + .25% v/v Induce (surfactant) and sprayed across all plots at the spike stage or after sorghum had sprouted but prior to sorghum emergence to avoid potential injury from the herbicide. No other weed species but Palmer amaranth was allowed to grow within the plots to avoid unwanted sources of variation. Further, hand-pulling and hoeing was done as necessary in plots assigned for in-season weed control. Irrigation was supplied to meet 120% of crop evapotranspiration. Sorghum was harvested at physiological maturity, and yields were adjusted to 13% grain moisture.

Data Collection

Yield and other parameters, including sorghum height and headcount and Palmer amaranth number, height, and biomass, were estimated from the two central rows. Other data that were measured include the normalized difference vegetation index (NDVI), which is indicative of the abundance of photosynthetically active vegetation. NDVI was measured using a hand-held Green Seeker model 505 (Trimble Navigation, Sunnyvale, CA) which is an active sensor (i.e. unaffected by time of day or night, nor cloud cover, as it emits its own light), equipped with a COMPAQ iPAQ pocket PC and specific software that collects and stores NDVI data. Leaf area index (LAI) was measured using AccuPAR model LP-80 Ceptomenter (Decagon Devices, Inc., Pullman, WA), which is a portable linear array of photosynthetically active radiation sensors that, together with an external sensor, accurately measures LAI at any location within a plant canopy in real time without destroying the crop regardless of the ambient light conditions.

Data Analysis

Data were analyzed using SAS 9.3 (SAS Institute, Inc., Cary, NC) and Sigmaplot 12.0 software.

Results and Discussion

Preliminary results indicate that increasing planting density and nitrogen rate did not suppress Palmer amaranth growth, number, and biomass (Table 1 and Figure 1), but in-season weed control (hoeing) of Palmer amaranth did increase sorghum height, number of heads, and grain yield (Table 1 and Figure 2). Increasing planting density within the row did not reduce light penetration (data not shown) into sorghum canopy enough to suppress Palmer amaranth growth. In regards to these results, narrow-row planting will be added to the treatment structure in 2017 to further determine the effect of planting density on suppressing Palmer amaranth in irrigated sorghum.

Table 1. Summary statistics; *P*-values and least significant difference (LSD) at $\alpha = .001$

Parameter	Source of variation		
	<i>P</i> -values (LSD)		
	Planting density	N rate	In-season weed control
Sorghum headcount	<.0001(12.306)*	.3820(12.306)	<.0001(10.048)*
Sorghum height	.0982(5.019)	.4126(5.019)	<.0001(4.098)*
Sorghum grain yield	.8867(17.088)	.8685(17.088)	<.0001(13.953)*
Palmer amaranth fresh biomass	.2172(1215.4)	.9329(1215.4)	---
Palmer amaranth dry biomass	.2328(513.29)	.8163(513.29)	---
Palmer amaranth fresh-dry biomass	.2259(726.07)	.9838(726.07)	---
Palmer amaranth height	.5699(51.065)	.2630(51.065)	---
Palmer amaranth per yard of row	.1855(10.463)	.9816(10.463)	---

*Significant at .1% probability level.

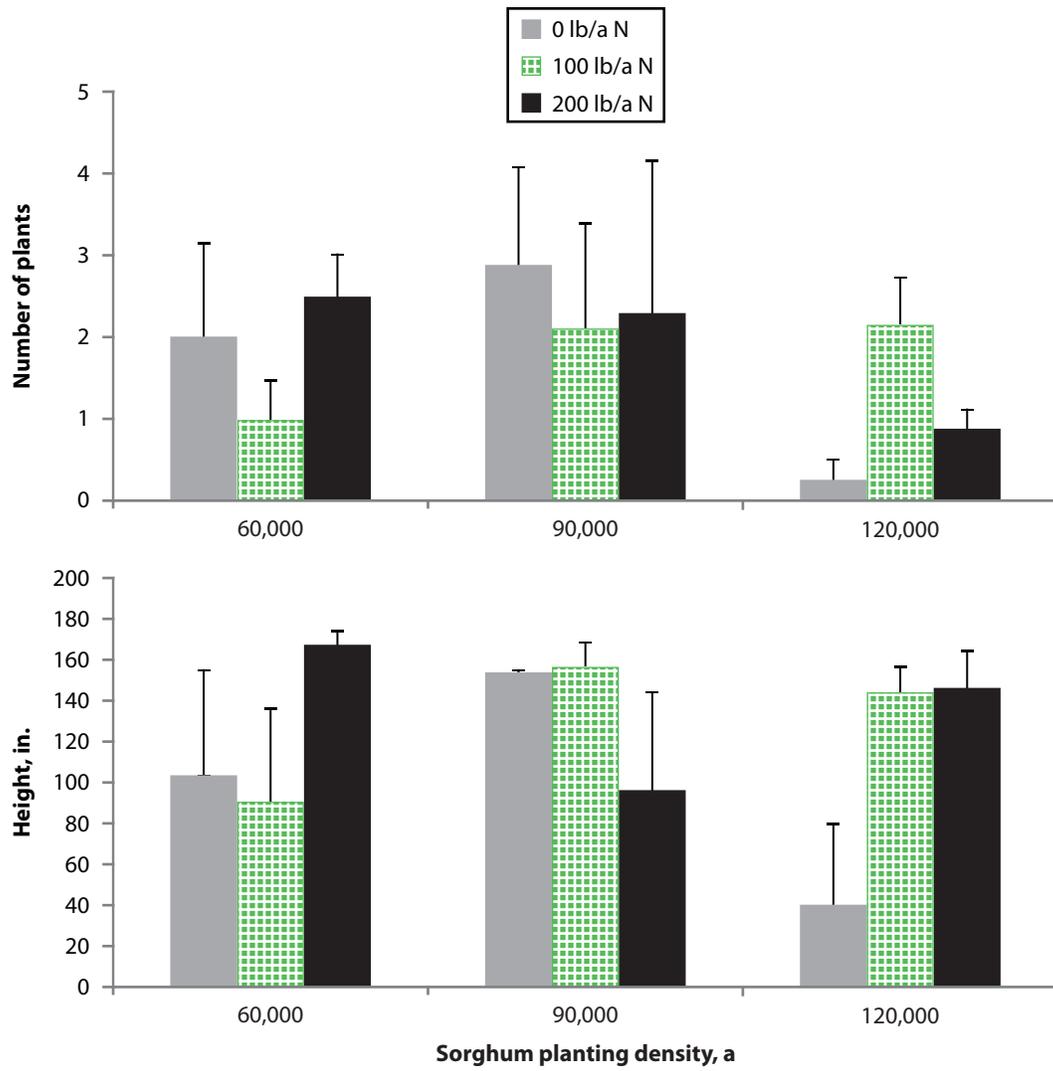


Figure 1. Palmer amaranth number (A) and height (B) by sorghum planting density and nitrogen (N) rate.

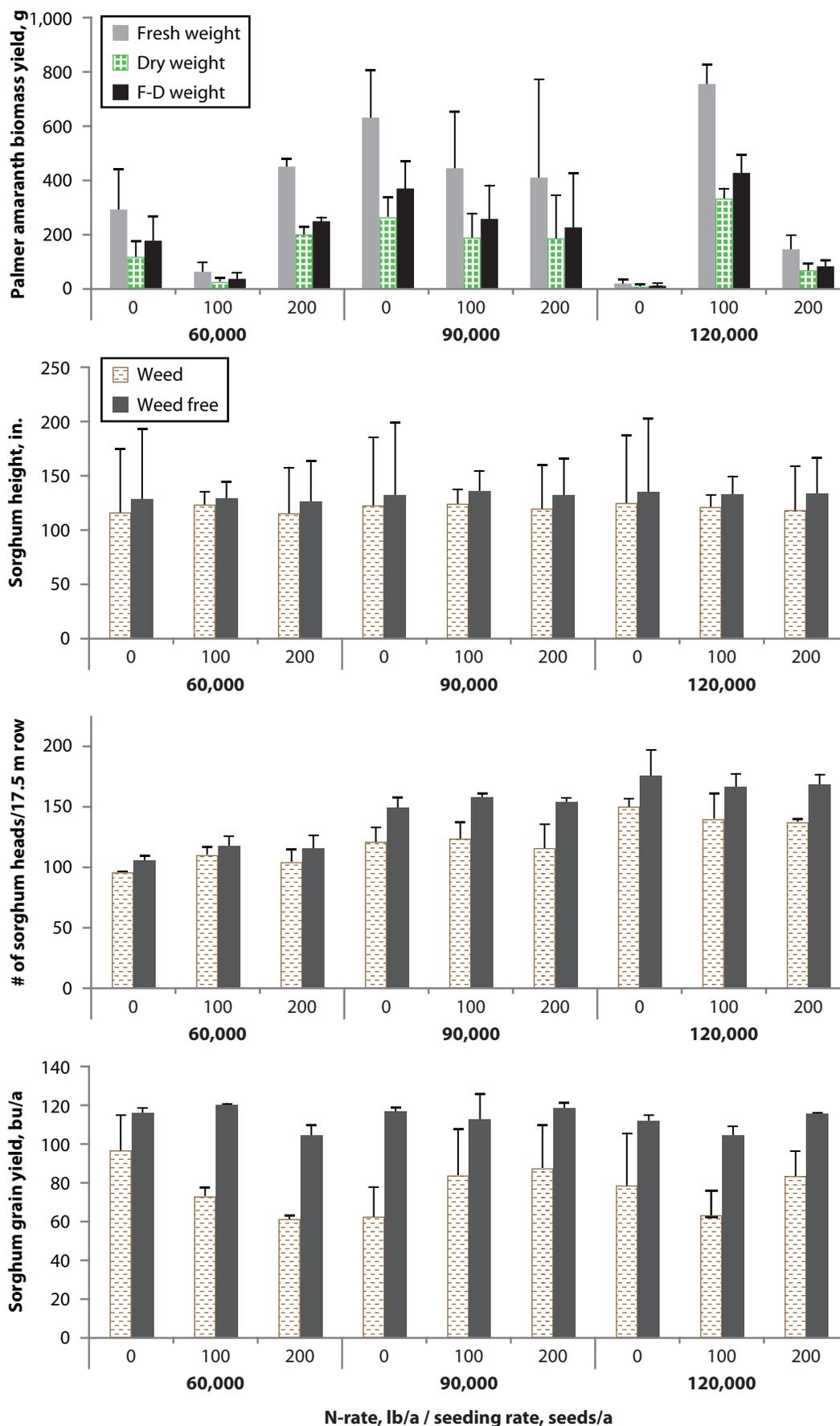


Figure 2. (A) Palmer amaranth biomass, (B) sorghum height, (C) headcount, and (D) grain yield by sorghum planting density and nitrogen rate.

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FIELD DAY 2017

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