SOUTHWEST RESEARCH-EXTENSION CENTER

FIELD DAY 2020

K-STATE
Research and Extension

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

Robert (Bob) Gillen

Southwest Research-Extension Center Head

B.S., Colorado State University
Ph.D., Oregon State University

Bob was appointed head of the Western Kansas Agricultural Research Centers in 2006. His research interests include grazing management systems, grassland ecology, and forage establishment.

Mary Sullivan

Southwest Regional Director

B.S., University of Northern Iowa
M.S., Kansas State University

Mary provides administrative leadership to the Southwest Extension Units, working primarily with agents and Extension Council members.

Jonathan Aguilar

Extension Specialist, Water Resources Engineer

B.S. and M.S., University of the Philippines Los Baños
Ph.D., Kansas State University

Jonathan's extension and research programs focus on irrigation systems, water conservation practices, irrigation scheduling, water quality, new and emerging relevant technologies (such as soil, water, and plant sensors; remote sensing; and GIS), and crop water management.

Cover photo by Jake Thompson.

Rachel Clews

Extension Specialist, Family and Consumer Sciences

B.S., University of Science and Arts of Oklahoma
M.A., Southwestern Theological Seminary
M.S., Texas Woman's University
CFLE, National Council on Family Relations

Rachael joined the staff in June 2019. Her extension duties are to provide subject matter support to regional Family and Consumer Science agents through projects, program development, and professional training. She is passionate about equipping and strengthening individuals and families through education and prevention with an emphasis in family resource management and Family Life Education.

Randall Currie

Weed Scientist

B.S., Kansas State University
M.S., Oklahoma State University
Ph.D., Texas A&M University

Randall joined the staff in 1991. His research focus is on weed control in corn.

Jeff Elliott

Research Farm Manager

B.S., University of Nebraska

Jeff joined the staff as an animal caretaker in 1984 and was promoted to Research Farm Manager in 1989.

John Holman

Cropping Systems Agronomist

B.S., M.S., Montana State University
Ph.D., University of Idaho

John joined the staff in 2006. His research involves crop rotations, forages, and integrated weed management.

SOUTHWEST RESEARCH-EXTENSION CENTER

Field Day 2020

Contents

Weed Science

2020 Southwest Research-Extension Center Staff*

Dewayne Bond	Assistant Scientist, Tribune
David Bowen	Agricultural Technician II
Amanda Burnett	Agricultural Technician II, Tribune
Silvia Galvez De Villatoro	Nutrition Educator
Pat Geier	Assistant Scientist
Lynn Harshbarger	Office Specialist II
Jaylen Koehn	Agricultural Technician II
Scott Maxwell	Agricultural Technician II
Joanna Meier	Accountant II
Bruce Niere	Agricultural Technician II
Mike Pointer	Maintenance and Repair Technician II
Tom Roberts	Assistant Scientist
David Romero, Jr.	Vehicle/Equipment Mechanic
Jeff Slattery	Agricultural Technician II, Tribune
Monty Spangler	Agricultural Technician II, retired May 2020
Nick Sower	Agricultural Technician II
Jake Thompson	Irrigation Extension Assistant
Dennis Tomsicek	Agricultural Technician II
Ashlee Wood	Office Specialist II
Anthony Zukoff	Assistant Scientist

4500 East Mary, Bldg. 947
Garden City, KS 67846
Phone: 620-276-8286
Fax: 620-276-6028

* See previous pages for additional staff and report authors

Weather Information for Garden City, 2019

J. Elliott

Precipitation for 2019 totaled 17.49 inches. This was 1.75 inches below the 30-year average of 19.24 inches. By the end of May, we had received 10.81 inches which was 3.77 inches above normal for that point of the year, resulting in good spring planting conditions. May had 19 days with measurable precipitation which was the most of any month on record. Each month after May 2019 exhibited below normal moisture until a rain event after Christmas pulled the December monthly precipitation above normal. Hail was noted on May 6 and July 20. The largest precipitation event was 2.65 inches falling from May 19 through May 24.

Measurable snowfall occurred in January, February, March, October, and November. Annual snowfall totaled 23.8 inches compared to an average of 19.7 inches. Seasonal snowfall (2018–2019) was 33.4 inches and was 13.67 inches above the average of 19.73 inches.

The average daily wind speed was 4.86 mph compared to the 30-year average of 5.10 mph. Open pan evaporation was measured daily from April through October, and totaled 72.74 inches. This was 2.48 inches above the 30-year mean of 70.26 inches.

Our mean annual temperature was 53.3°F which was similar to the 30-year average of 53.7°F. Triple-digit temperatures were observed on 10 days in 2019, with the highest being 103°F on July 18, 20, and 21 as well as August 1 and 21. No record high temperatures were recorded in 2019.

Sub-zero temperature occurred four times in 2019. The lowest temperature was -3°F noted on March 5. Two record low temperatures were equaled or exceeded: 49°F on June 24 and 6°F on October 31.

The last spring freeze was 30°F on April 19, which was ten days earlier than the 30-year average. The first fall freeze was 17°F on October 11, which was one day earlier than normal, and was unusual because it was a much lower temperature than the normal first fall freeze. This resulted in a 175 day frost-free period, which is ten days longer than the 30-year average.

The 2019 climate information for Garden City is summarized in Table 1.

Table 1. 30-year averages are for the period 1981-2010

Month	2019	Average precipitation 1981-2010	Temperatures: Average 2019 Max	Min	Mean	Average 1981-2010	2019 extremes Max	Min	Wind 2019	Wind Average 1981-2010	Evaporation 2019	Evaporation Average 1981-2010
									---------- mph ----------		----------- in. -----------	
January	0.85	0.46	42.2	19.4	30.8	30.4	60	4	4.45	4.5	n/a	n/a
February	1.42	0.55	39.9	14.5	27.2	33.9	70	-2	5.00	5.24	n/a	n/a
March	1.98	1.31	49.7	24.4	37.1	42.9	80	-3	5.94	6.31	n/a	n/a
April	0.09	1.74	71.2	38.2	54.7	52.3	89	20	5.96	6.42	8.94	8.21
May	6.47	2.98	71.1	46.2	58.7	62.8	91	35	4.01	5.76	7.37	10.04
June	1.20	3.12	86.7	57.5	72.1	72.6	102	41	4.75	5.37	12.30	11.96
July	1.74	2.8	93.5	64.3	78.9	77.9	103	56	5.20	4.59	14.69	13.22
August	1.76	2.51	93.1	64.4	78.8	76.3	103	56	3.83	4.11	11.56	11.28
September	0.12	1.42	90.6	60.4	75.5	67.7	100	48	5.96	4.73	11.92	9.22
October	0.36	1.21	66.9	33.0	50.0	54.9	93	7	5.03	4.89	5.96	6.33
November	0.20	0.55	57.3	23.2	40.3	41.6	80	0	4.43	4.8	n/a	n/a
December	1.30	0.59	51.8	20.2	36.0	31.4	69	10	3.73	4.45	n/a	n/a
Annual	17.49	19.24	67.8	38.8	53.3	53.7	103	-3	4.86	5.10	72.74	70.26

	Average	2019
Latest spring freeze	April 29	April 19
Earliest fall freeze	October 12	October 11
Frost free period	165 days	175 days

Weather Information for Tribune

D. Bond and J. Slattery

In 2019, annual precipitation of 19.59 in. was recorded, which is 1.69 in. above normal. Only five months had above-normal precipitation. July (3.84 in.) was the wettest month. The largest single amount of precipitation was 2.00 in. on July 21. April, the driest month, only recorded 0.20 in. of precipitation.

Snowfall for the year totaled 38.1 in. (15.7 in. above normal); January, February, March, April, October, November and December had 11.3, 12.0, 5.2, 0.1, 5.0, 3.5, and 1.0 in., respectively. There was a total of 35 days of snow cover, which is nine days above normal. The longest consecutive period of snow cover, 14 days, occurred February 23 through March 8.

Record-high temperatures were recorded on 2 days: February 4 (73°F) and September 3 (103°F). Historical record-high temperatures were tied on 2 days: August 20 (100°F) and 21 (102°F). Record-low temperatures were recorded on 5 days: June 10 (38°F); October 11 (14°F) and 31 (2°F); and November 1 (8°F) and 12 (0°F). A historical record-low temperature was tied on October 12 (19°F). July was the warmest month with a mean temperature of 76.3°F. The hottest day of the year (105°F) occurred on July 20. The coldest day of the year (-6°F) occurred on February 8. February was the coldest month with a mean temperature of 25.4°F. Of special note, the average minimum temperature for October (29.7°F) broke the historic record (31.1°F) set in 1995.

The mean air temperature was below normal for 7 months. September had the greatest departure above normal (6.1°F), and February had the greatest departure below normal (-8.1°F). Temperatures were 100°F or higher on 13 days, which is 2 days above normal. Temperatures were 90°F or higher on 64 days, which is 1 day above normal. The latest spring freeze was May 22, which is 16 days later than normal; the earliest fall freeze fell on October 10, which is 3 days later than normal. This produced a frost-free period of 141 days, which is 13 days less than the normal of 154 days.

Open-pan evaporation from April through September totaled 63.72 in., which is 7.68 in. below normal. Wind speed for this period averaged 4.0 mph, which is 1.3 mph less than normal.

The 2019 weather information for Tribune is summarized in Table 1.

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

			Monthly average temperatures									
	Precipitation		2019		Normal		2019 extreme		Wind		Evaporation	
Month	2019	Normal	Max	Min	Max	Min	Max	Min	2019	Normal	2019	Normal
	-------- in. --------		----------------------------- °F -----------------------------						------- mph -------		-------- in. --------	
January	0.96	0.49	44.7	18.6	44.0	16.2	63	4	---	---	---	---
February	1.16	0.52	39.2	11.6	47.5	19.4	73	-6	---	---	---	---
March	2.00	1.22	49.3	22.8	56.3	26.8	79	-4	---	---	---	---
April	0.20	1.45	70.2	35.0	65.7	34.9	87	19	4.2	6.0	8.24	8.27
May	3.73	2.38	68.4	41.8	75.1	46.4	93	30	3.8	5.6	7.03	11.75
June	2.60	2.94	84.7	52.9	85.7	56.6	100	38	4.0	5.2	12.44	14.04
July	3.84	2.85	92.4	60.1	91.8	61.7	105	52	3.7	5.2	13.69	15.58
August	2.29	2.33	91.2	60.4	89.4	60.4	102	52	3.3	4.7	11.06	12.16
September	1.15	1.18	88.4	56.0	81.5	50.6	103	47	5.0	5.0	11.26	9.60
October	0.60	1.49	62.7	29.7	68.9	37.1	92	2	3.9*	4.5*	5.48*	6.09*
November	0.34	0.55	53.0	21.4	54.9	25.7	74	0	---	---	---	---
December	0.72	0.50	48.5	19.5	44.7	17.0	67	8	---	---	---	---
Annual	19.59	17.90	66.2	36.0	67.1	37.7	105	-6	4.0	5.3	63.72	71.40

Normal latest freeze (32°F) in spring: May 6. In 2019: May 22.
Normal earliest freeze (32°F) in fall: October 7. In 2019: October 10.
Normal frost-free (>32°F) period: 154 days. In 2019: 141 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 not included in annual totals.

Wheat and Grain Sorghum in Four-Year Rotations

A. Schlegel, J. Holman, and A. Burnett

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 1.5 in. less for the second sorghum crop compared to sorghum following wheat. The 2019 grain yields of both wheat and grain sorghum in all rotations were much greater than the long-term average. Grain yield of recrop wheat averaged about 75% of the yield of wheat following sorghum. Grain yield of continuous wheat averaged about 60% 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 averages ~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 for the first two years where 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 2019, available soil water was greater for wheat following two sorghum crops than one sorghum crop, while normally they are similar. Soil water was less for WW than for the second wheat crop in WWSF. Available 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 approximately 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), and available water at sorghum planting in 2019 was greater than the long-term average. Soil water was similar following one or two wheat crops. 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 1.53 in. more available water at planting than the second crop.

Grain Yields

In 2019, wheat yields in all rotations were much greater than the long-term average (Table 1). Averaged across 23 years, recrop wheat (the second wheat crop in a WWSF rotation) yielded about 75% 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 many years, continuous wheat yields have been similar to recrop wheat yields. In other years (2003, 2007, 2009, 2014, and 2018), recrop wheat yields were considerably greater than continuous wheat yields. In 2019, continuous wheat yields were 8 bu/a less than recrop wheat yields (63 vs. 71 bu/a) and averaged 6 bu/a less than recrop wheat.

Sorghum yields in 2019 for all rotations were much higher than the long-term average yields (Table 2). This is the fifth year in a row of above average sorghum yields. Sorghum yields following wheat were about 47 bu/a greater than the long-term average. Recrop sorghum yields were 34 bu/a greater than the long-term average. Sorghum yields were similar following one or two wheat crops, which was consistent with the long-term average. The second sorghum crop yields were 68% of the first sorghum crop in 2019, which was similar to the long-term average of about 65%.

Table 1. Wheat response to dryland crop rotation, Tribune, KS, 1997–2019

	Rotation					ANOVA (P > F)		
Year	Wssf[1]	Wwsf	wWsf	WW	LSD 0.05	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		
2017	20	20	4	6	4	0.001		
2018	52	51	24	24	9	0.001		
2019	88	96	71	63	6	0.001		
Mean	42 a	40 b	31 c	25 d	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.

Table 2. Grain sorghum response to crop rotation, Tribune, KS, 1996–2019

	Rotation				ANOVA (P > F)		
Year	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		
2017	147	119	157	15	0.002		
2018	125	64	137	13	0.001		
2019	134	91	137	15	0.001		
Mean	87 a	57 b	89 a	3	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.

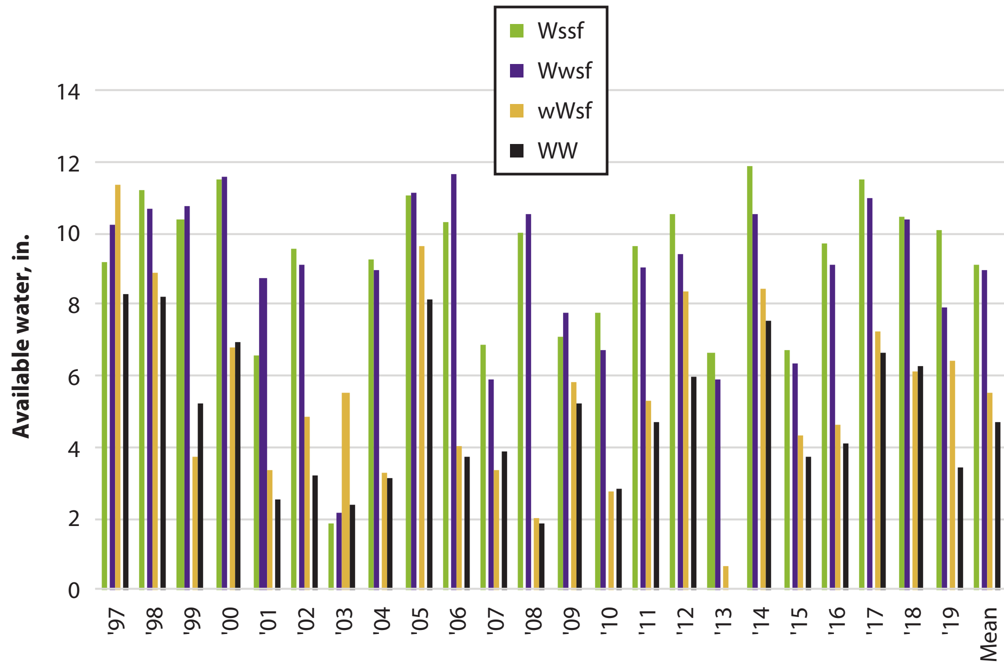

Figure 1. Available soil water in 6-ft profile at planting of wheat in four rotations at Tribune, KS, 1997–2019. Capital letter denotes current crop in rotation (W, wheat; S, sorghum). The last set of bars (Mean) is the average across years. Wheat-sorghum-sorghum-fallow (WSSF), wheat-wheat-sorghum-fallow (WWSF), and continuous wheat (WW).

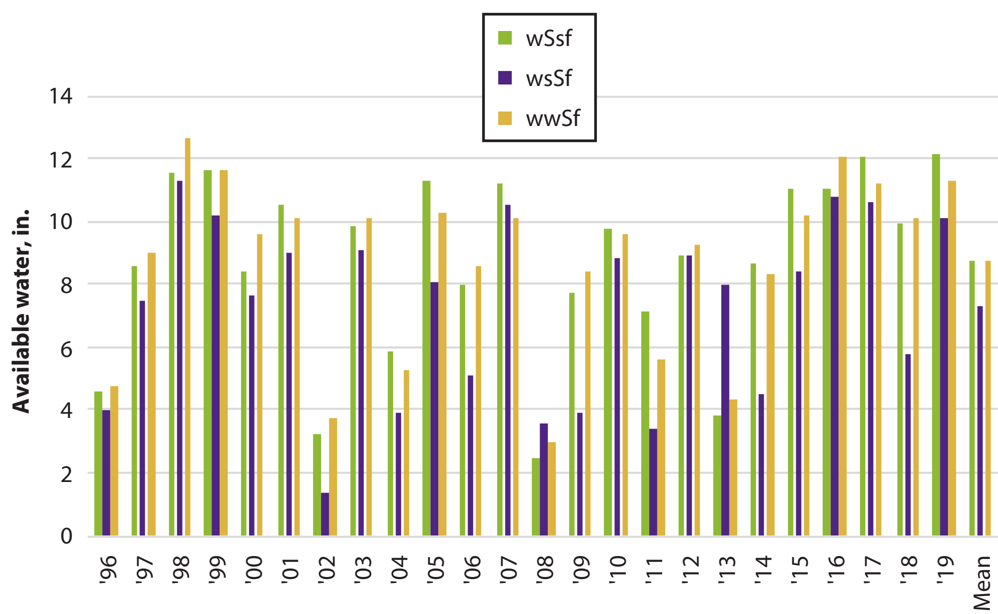

Figure 2. Available soil water in 6-ft profile at planting of sorghum in three rotations at Tribune, KS, 1996–2019. Capital letter denotes current crop in rotation (W, wheat; S, sorghum). The last set of bars (Mean) is the average across years. Wheat-sorghum-sorghum-fallow (WSSF) and wheat-wheat-sorghum-fallow (WWSF).

Large-Scale Dryland Cropping Systems

A. Schlegel, L. Haag, and A. Burnett

Summary
This study was conducted from 2008–2019 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 had little effect on wheat yields. Corn and grain sorghum yields were about 45–50% greater when following wheat than when following corn or grain sorghum. Grain sorghum yields were about 45% 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 (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 102% of normal (17.90 in.) across the 12-yr study period and was near normal (+/- 15%) in 8 out of 12 years with three 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 were 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 (~18%) following wheat and only 22% 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 (16–22%).

Wheat yields were greatly above normal in 2019 with yields exceeding 100 bu/a in the 3-yr rotations (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 12 years, cropping system had little effect (5 bu/a or less) on wheat yields.

Grain sorghum yields were very good in 2019 with yields greater than 100 bu/a when following wheat (Figure 3). Sorghum following corn produced 36 bu/a less yield than following wheat, and continuous sorghum yields were 14 bu/a greater than following corn. Average grain sorghum yields following wheat were approximately 50% greater than following corn or sorghum.

Similar to grain sorghum, corn yields were very good in 2019 (Figure 4) with all rotations yielding 90 bu/a or more. 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 45% 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 >85 bu/a (Figure 5). These yields were about 45% greater than corn following wheat (wCf or wCsf). Sorghum yields following wheat were about 50% greater than sorghum following corn or sorghum (wcSf or SS), while corn yields following wheat (wCf or wCsf) were about 45% greater than following sorghum.

Acknowledgments

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

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, 2008–2019

Crop	Rotation	Fallow accumulation	Fallow efficiency	Profile ASW at planting[2]	Crop water use
		inch	%	------------- inch	-------------
Wheat	Wf[1]	6.82 a	28 a	9.88 a	18.55 a
	Wsf	3.12 bc	19 b	6.54 b	14.68 b
	Wcf	2.67 c	15 c	6.48 b	14.69 b
	Wscf	3.30 b	19 b	7.02 b	15.03 b
	Wcsf	3.20 b	18 b	6.51 b	14.71 b
$LSD_{0.05}$		0.49	2	0.58	0.51
Corn	wCf	2.65 a	18 b	6.14 a	14.09 a
	wCsf	2.60 a	18 b	6.08 a	14.05 a
	wsCf	1.62 b	22 a	5.18 b	13.19 b
$LSD_{0.05}$		0.33	3	0.53	0.34
Grain sorghum	wSf	2.57 b	16 c	6.13 b	13.54 b
	wScf	3.11 a	19 b	6.68 a	13.91 a
	wcSf	1.55 d	16 c	5.36 c	12.92 c
	SS	2.06 c	22 a	5.51 c	12.99 c
$LSD_{0.05}$		0.34	3	0.53	0.33

[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.
W = wheat. F = fallow. S = sorghum. C = corn. SS = continuous grain sorghum.

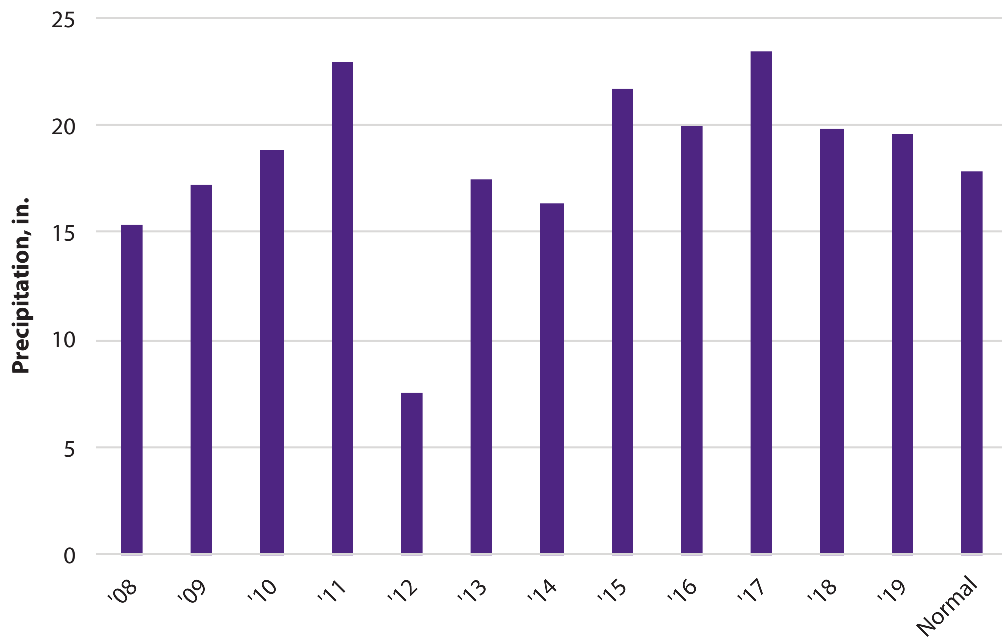

Figure 1. Annual (2008–2019) and normal precipitation (1981–2010, last bar), Tribune, KS.

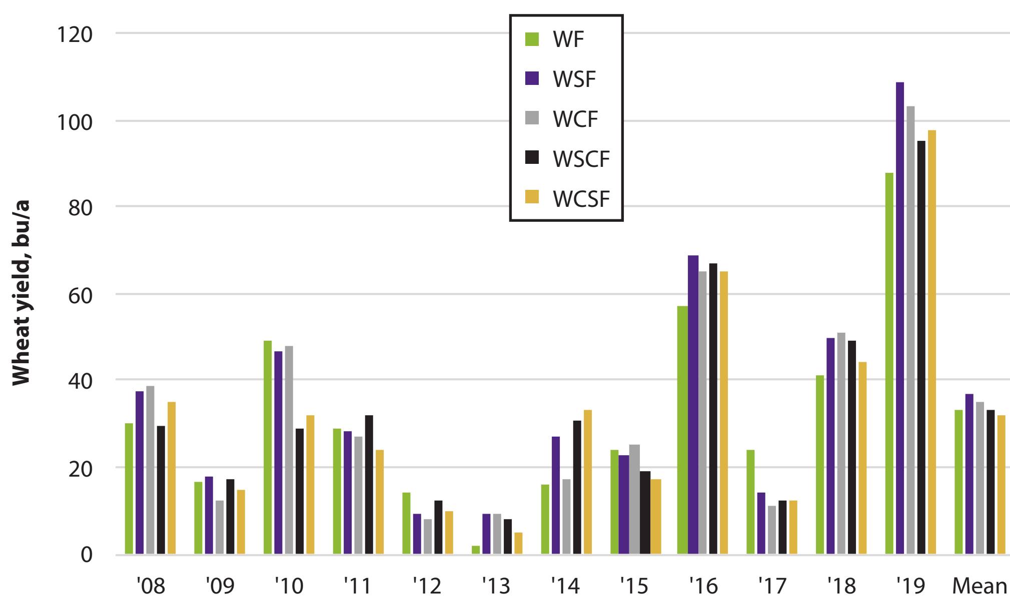

Figure 2. Wheat yields by cropping system, 2008–2019. Last set of columns are treatment means. Wheat-fallow (WF), wheat-sorghum-fallow (WSF), wheat-corn-fallow (WCF), wheat-corn-sorghum-fallow (WCSF), and wheat-sorghum-corn-fallow (WSCF).

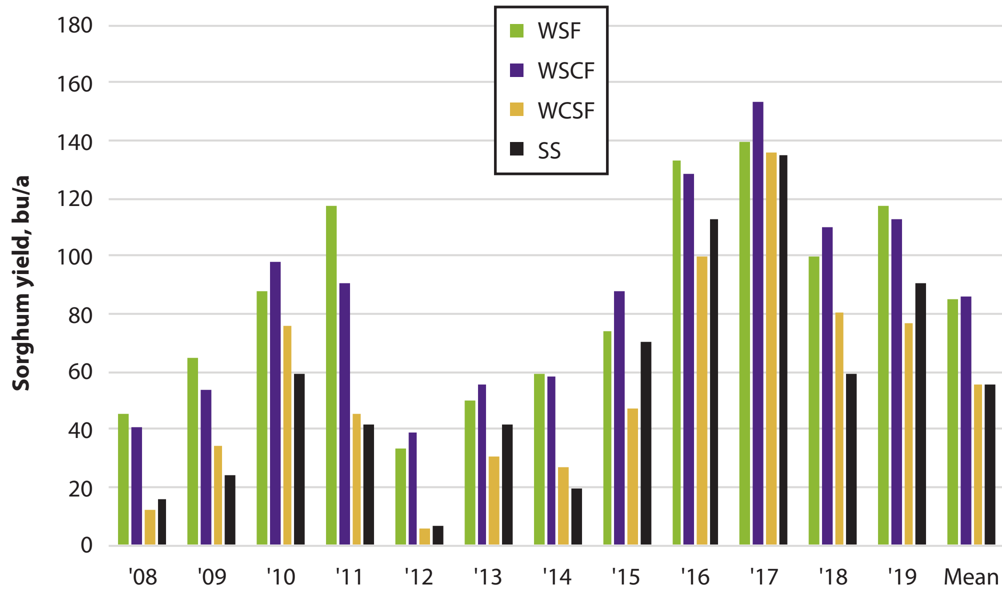

Figure 3. Grain sorghum yields by cropping system, 2008–2019. Last set of columns are treatment means. Wheat-sorghum-fallow (WSF), wheat-sorghum-corn-fallow (WSCF), wheat-corn-sorghum-fallow (WCSF), and continuous grain sorghum (SS).

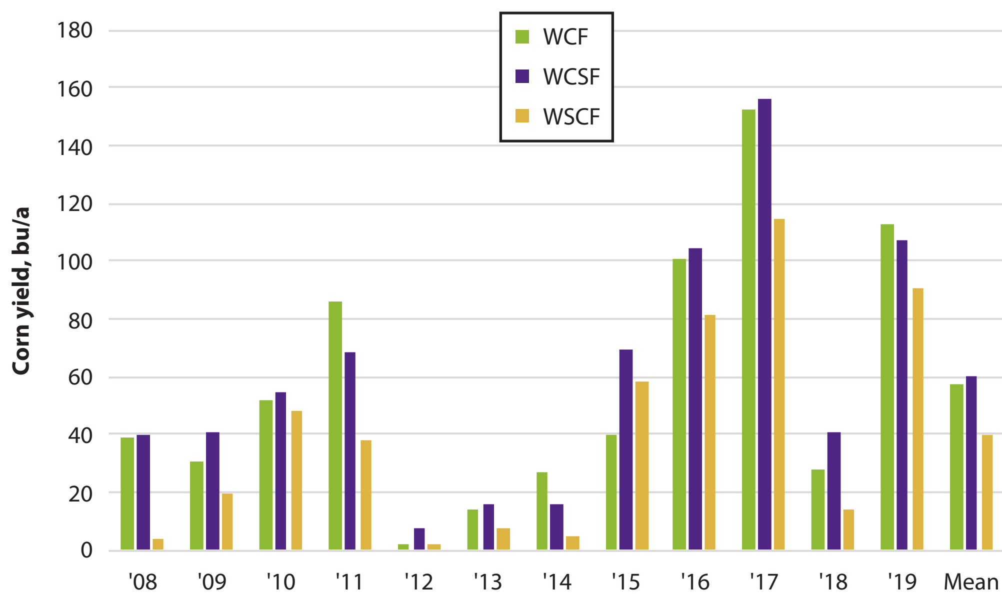

Figure 4. Corn yields by cropping system, 2008–2019. Last set of columns are treatment means. Wheat-corn-fallow (WCF), wheat-corn-sorghum-fallow (WCSF), and wheat-sorghum-corn-fallow (WSCF).

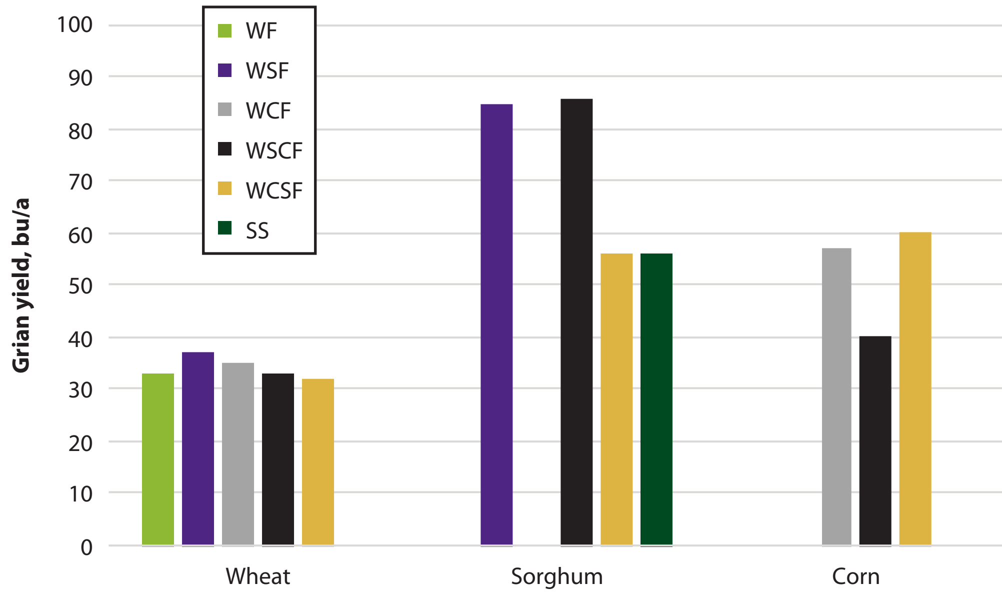

Figure 5. Average grain yields by cropping system, 2008–2019. Wheat-fallow (WF), wheat-sorghum-fallow (WSF), wheat-corn-fallow (WCF), wheat-sorghum-corn-fallow (WSCF), wheat-corn-sorghum-fallow (WCSF), and continuous grain sorghum (SS).

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

A. Schlegel and A. Burnett

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 2019, available soil water at sorghum planting was greater for no-tillage (NT) than reduced tillage (RT) which was greater than conventional tillage (CT). For wheat there was a similar pattern as sorghum, with available soil water at wheat planting being in the order of NT>RT>CT. Averaged across the 19-yr study, available soil water at wheat planting was similar for NT and RT and approximately 1 inch greater than CT. Average available soil water at sorghum planting was greater in the order RT≥NT>CT. Averaged across the past 19 years, NT wheat yields were 5 bu/a greater than RT and 9 bu/a greater than CT. Grain sorghum yields in 2019 were 50% greater in long-term NT compared to short-term NT with the lowest yields with CT. Averaged across the past 19 years, sorghum yields with long-term NT have been 58% greater than with short-term NT (79 vs. 50 bu/a).

Experimental Procedures

Research on different tillage intensities in a WSF rotation at the Tribune, KS, 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 4 to 5 tillage operations per year, usually with a blade plow or field cultivator. The RT system originally used a combination of herbicides (1 to 2 spray operations) and tillage (2 to 3 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 (0–8 ft) at wheat planting varied greatly from year to year (Figure 1). In 2019, available soil water at wheat planting was greater with NT than RT and least with CT. Averaged across the 19-yr study, available soil water at wheat planting was similar for RT and NT (~ 8 inches) and approximately 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 2019, available soil water at sorghum planting was greater with NT than RT and least with CT. On average, available soil water at sorghum planting was similar for NT and RT and about 1.5 inches greater than CT.

Grain Yields

Wheat yields in 2019 were much greater than the long-term average (Table 1). Since 2001, wheat yields have been depressed in 11 of 19 years, primarily because of lack of precipitation, winterkill (2015), and disease (2017). Reduced tillage and NT increased wheat yields. On average, wheat yields were 9 bu/a higher for NT (30 bu/a) than CT (21 bu/a). Wheat yields for RT were 4 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 19 years.

Grain sorghum yields in 2019 were greater than the long-term average for NT and RT but not for CT (Table 2). Sorghum yields were 50% greater with NT than RT (127 vs. 85 bu/a) while CT yields were the least (23 bu/a). The yield benefit from reducing tillage is greater for grain sorghum than wheat. Grain sorghum yields for RT averaged 20 bu/a more than CT, whereas NT averaged 29 bu/a more than RT. 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. This yield benefit with long-term vs. short-term NT has been observed in most years since the RT system was changed in 2001. Averaged across the past 19 years, sorghum yields with long-term NT have been 58% greater than with short-term NT (79 vs. 50 bu/a).

Acknowledgment

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

Table 1. Wheat response to tillage in a wheat-sorghum-fallow rotation, Tribune, KS, 2001–2019

	Tillage				ANOVA (*P* > *F*)		
Year	Conventional	Reduced	No-tillage	LSD (0.05)	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		
2017	13	12	12	9	0.970		
2018	46	48	64	4	0.001		
2019	78	98	109	14	0.004		
Mean	21 c	25 b	30 a	2	0.001	0.001	0.001

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

Table 2. Grain sorghum response to tillage in a wheat-sorghum-fallow rotation, Tribune, KS, 2001–2019

	Tillage				ANOVA ($P > F$)		
Year	Conventional	Reduced	No-tillage	LSD (0.05)	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		
2017	121	163	159	33	0.038		
2018	35	57	116	33	0.003		
2019	23	85	127	7	0.001		
Mean	30 c	50 b	79 a	5	0.001	0.001	0.001

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

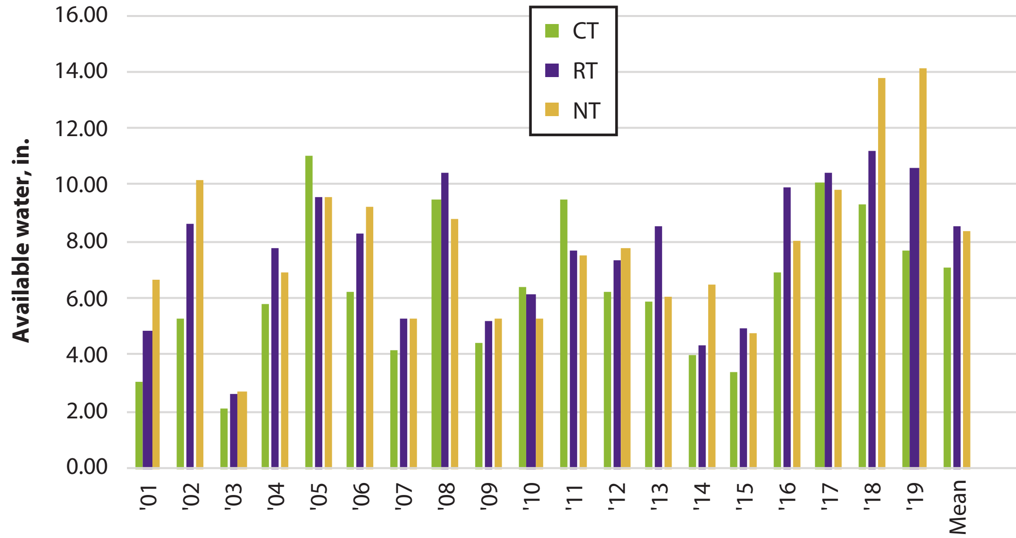

Figure 1. Available soil water in 8-ft profile at planting of wheat in a wheat-sorghum-fallow rotation as affected by tillage intensity, Tribune, KS, 2001–2019. The last set of bars (Mean) is the average across years. CT = conventional tillage, RT = reduced tillage, NT = no-tillage.

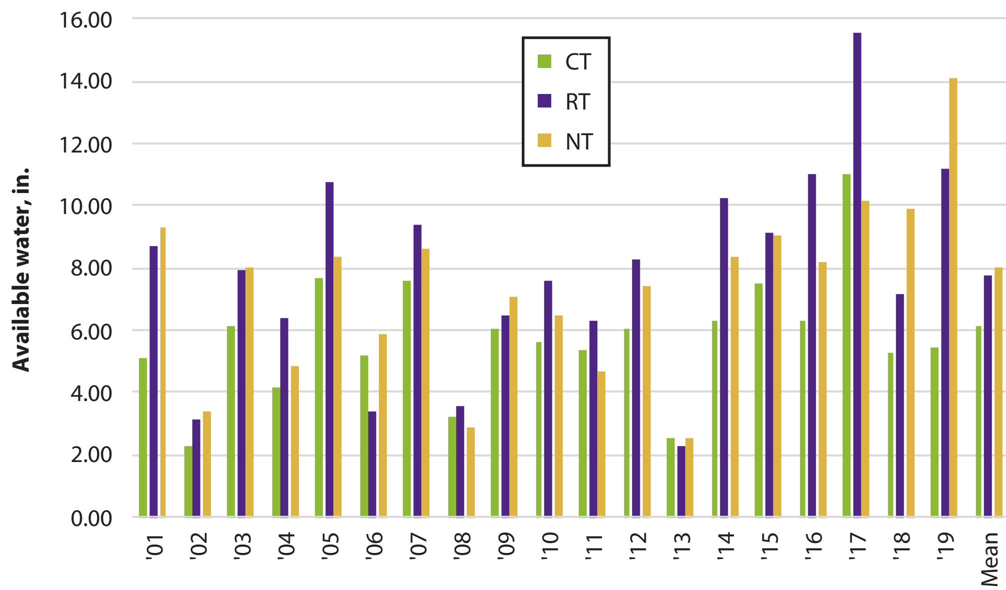

Figure 2. Available soil water in 8-ft profile at planting of grain sorghum in a wheat-sorghum-fallow rotation as affected by tillage intensity, Tribune, KS, 2001–2019. The last set of bars (Mean) is the average across years. CT = conventional tillage, RT = reduced tillage, NT = no-tillage.

Alternative Cropping Systems with Limited Irrigation

A. Schlegel and D. Bond

Summary
A limited irrigation study involving four cropping systems and evaluating four crop rotations was initiated in 2012 at the Southwest Research-Extension Center near Tribune, KS. 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 2019, corn yields were similar for all rotations, although averaged across the past 7 years, corn yields were greater following wheat than following corn. There were no significant differences in grain sorghum yields in 2019, which was similar to the multi-year average. Wheat yields were greater than the multi-year average.

Experimental Procedures
A crop rotation study under sprinkler irrigation at the Kansas State University Southwest Research-Extension Center near Tribune, KS, 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 per 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 sorghum, and 120 lb N/a for wheat). Corn was planted on April 29, 2019, and harvested on September 26, 2019. Grain sorghum was planted on June 7, 2019, and harvested on October 19, 2019. Wheat was planted on September 27, 2018, and harvested on June 28, 2019.

Results and Discussion
Wheat yields in 2019 (74 bu/a) were greater than the long-term average (53 bu/a) (Tables 1 and 2). Precipitation was near normal from April through September (12.49 inches in 2019 vs. normal of 12.93 inches). Corn yields in 2019 were slightly greater than the long-term average with no differences among rotations. Grain sorghum yields were slightly below the long-term average with no differences among rotations. On average, corn yields are greatest following wheat and least following corn, with little differences in grain sorghum yields following corn or sorghum (Table 2).

Available soil water at corn and sorghum planting and harvest was similar for all rotations in 2019 (Table 3). Precipitation delayed sorghum harvest in 2018 resulting in greater available soil water at sorghum harvest, causing less fallow accumulation following sorghum than corn. Averaged across the 7-year period, fallow accumulation prior to corn was greater following wheat than following sorghum or corn; however, fallow efficiency was greatest following sorghum (shortest fallow period). There were no differences in fallow accumulation or efficiency for grain sorghum following corn or sorghum. There were no differences in crop water use due to rotation for either crop.

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

Table 1. Grain yield of three crops under limited irrigation as affected by rotation in 2019

Rotation	Corn	Wheat	Sorghum
	---------- bu/a ----------		
Continuous corn	185	---	---
Corn-wheat	226	74	---
Corn-sorghum	191	---	125
Continuous sorghum	---	---	130
LSD $_{0.05}$	40	---	22
ANOVA (P > F)			
System	0.088	---	0.571

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

Table 2. Grain yields of three crops under limited irrigation as affected by rotation across years 2013–2019

Rotation	Corn	Wheat	Sorghum
	---------- bu/a ----------		
Continuous corn	176 b	---	---
Corn-wheat	201 a	53	---
Corn-sorghum	188 ab	---	137
Continuous sorghum	---	---	135
LSD $_{0.05}$	17	---	7
ANOVA (P > F)			
System	0.037	---	0.320

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

Table 3. Profile available soil water, crop water use, and fallow accumulation for crop rotations under limited irrigation, Tribune, KS, 2019

		Available water					
Crop	Rotation	Previous harvest	Planting	Harvest	Crop water use	Fallow accumulation	Fallow efficiency
		inches					%
Corn	C-C	10.90 b	15.02	11.06	26.30	4.13 a	41 a
	C-W	11.54 b	14.31	9.15	27.49	2.77 b	17 b
	C-GS	13.46 a	13.56	9.15	26.74	0.10 c	2 c
LSD $_{0.05}$		1.87	1.79	2.60	1.26	1.05	8
ANOVA (P > F)							
System		0.036	0.217	0.199	0.145	0.001	0.001
Wheat	C-W	11.53	11.53	8.05	21.99	---	---
ANOVA (P > F)							
System		---	---	---	---	---	---
Sorghum	C-GS	10.73	15.78	12.24	21.42	5.04	34 a
	GS-GS	13.35	15.17	11.24	21.80	1.82	18 b
LSD $_{0.05}$		3.63	2.46	3.22	0.79	1.76	12
ANOVA (P > F)							
System		0.106	0.488	0.397	0.218	0.100	0.020

Note: All crops received ~10 inches of irrigation.
In-season rainfall for corn (4/29/2019 - 9/25/2019) = 12.35 inches; sorghum (6/10/2019 – 10/16/2019) = 8.03 inches; and wheat (9/19/2018 - 7/10/2019) = 16.89.
C = corn.
W = wheat.
GS = grain sorghum.
LSD = least significant difference.
ANOVA = analysis of variance.

Table 4. Profile available soil water, crop water use, and fallow accumulation for crop rotations under limited irrigation across years, Tribune, KS, 2013–2019

		Available water					
Crop	Rotation	Previous harvest	Planting	Harvest	Crop water use	Fallow accumulation	Fallow efficiency
		inches					%
Corn	C-C	11.74	14.08 a	12.06 a	26.36	2.34 b	24 b
	C-W	11.23	14.08 a	11.83 a	26.59	2.85 a	19 b
	C-GS	10.88	12.58 b	10.53 b	26.39	1.70 c	33 a
$LSD_{(0.05)}$		0.84	0.64	0.79	0.63	0.44	6
ANOVA (P > F)							
System		0.128	0.001	0.001	0.732	0.001	0.001
Year		0.001	0.001	0.001	0.001	0.001	0.001
System × year		0.001	0.001	0.001	0.004	0.002	0.001
Wheat	C-W	11.82	11.82	10.95	19.95	---	---
ANOVA (P > F)							
System		---	---	---	---	---	---
Year		0.001	0.001	0.001	0.001	---	---
System × year		---	---	---	---	---	---
Sorghum	C-GS	10.19	13.62	11.82	23.45	3.43 a	29
	GS-GS	10.63	13.26	11.49	23.42	2.62 b	29
$LSD_{(0.05)}$		0.80	0.65	0.69	0.38	0.47	6
ANOVA (P > F)							
System		0.272	0.266	0.333	0.880	0.001	0.923
Year		0.001	0.001	0.001	0.001	0.001	0.001
System × year		0.001	0.001	0.004	0.404	0.077	0.001

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.

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 generally not affected by a single tillage operation every 3 years in a WSF rotation. Grain yield varied greatly by year from 2014 to 2019. Wheat yields ranged across years from mid-20s to 90 bu/a at Tribune and less than 10 to near 100 bu/a at Garden City. Grain sorghum yields ranged from 40 to greater than 140 bu/a, depending upon year and location. In 2019, wheat yields at Garden City were less when tillage was implemented post-wheat in 2016. There were no other years or locations were grain yields were significantly affected by a single tillage operation. However, at Tribune, when averaged across the 6-year period, a single tillage after wheat harvest reduced grain sorghum yields compared to a complete no-till (NT) system. At Garden City, averaged across the 6-year period, wheat yields were greatest following a one-time tillage prior to wheat. This indicates that if a single tillage operation is needed to control troublesome weeds, tillage during fallow prior to wheat planting may be better than tillage after wheat harvest. Furthermore, if herbicide-resistant weed populations were high enough to cause yield reductions, then tillage might improve yields.

Introduction
Previous research has shown lower dryland wheat and grain sorghum yields with reduced tillage compared with NT in a wheat-sorghum-fallow (WSF) rotation (Schlegel et al., 2018). The reduced tillage systems generally used four or more tillage operations in the 3-year rotation. With increased incidence of herbicide-resistant weeds, the use of a complete NT system may not be economical and tillage may be needed for effective control. The objective of this research project is to determine the effect of a single tillage operation every 3 years on grain yields in a WSF rotation.

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, KS, was initiated in 2012. The three tillage treatments in this study are a single tillage in May or June during fallow, a single tillage after wheat harvest, and a complete NT system. A sweep plow (Minimizer by Premier Tillage) 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

Weeds were effectively controlled in all treatments and there were no visual differences in weed population across treatments.

At Tribune, wheat yields were much greater in 2019 (89 to 93 bu/a) compared with 49 to 51 bu/a for the 6-year average (Table 1). There were no significant yield differences among tillage treatments in any year or across years. Grain sorghum yields were very good in 2019 ranging from 129 to 132 bu/a (Table 2). Similar to wheat, there were no significant yield differences among tillage treatments in any year. However, averaged across years, no-till produced greater yields than tillage post-wheat harvest.

At Garden City, wheat yields in 2018 were very low at 2 to 7 bu/a (Table 3). Between November 1, 2017, and April 1, 2018, 0.4 inches of precipitation was received, compared to the long-term period average of 3.46 inches. Wheat yields in 2014 were severely reduced by hail. Wheat yield in 2019 was much greater (83 to 100 bu/a) compared with the 40 to 44 bu/a 6-year average (Table 1). Across the 6 years, wheat yields averaged greater with a single tillage ahead of wheat planting. At this location, winter triticale forage yields have been more with a single tillage compared to NT due to more plant available water at wheat planting with a single tillage (Holman et al., 2020). In 2019 wheat yields at Garden City were less when tillage was implemented post-wheat in 2016. It is possible the lower wheat yield in 2019 was a result of lower average grain sorghum yield in the post-wheat tillage treatment in 2017. However, grain sorghum yield was not affected by treatment in any year or across years. Grain sorghum yields in 2018 were good, with all yields near 90 bu/a or greater (Table 4). Grain sorghum yields were lower in 2019 averaging 40 bu/a. Across years, there were no differences in grain sorghum yields averaging 70 bu/a.

In other research (Schlegel et al., 2018), reduced tillage systems (with four tillage operations) produced lower yields than a complete no-tillage system in a WSF rotation. However, in this study, a single tillage operation during fallow prior to wheat planting in a 3-year WSF rotation generally had little effect on wheat or grain sorghum yields from 2014 to 2019 at Garden City or Tribune, KS.

There is a tendency for wheat yields at Garden City and grain sorghum yields at Tribune to be less following a single tillage post-wheat compared to no-till or single tillage prior to wheat. These results suggest if a single tillage is needed for weed control the best timing may be prior to wheat during the fallow year.

Acknowledgment

This research was supported in part by the Ogallala Aquifer Program, a consortium between USDA Agricultural Research Service, Kansas State University, Texas AgriLife Research, Texas AgriLife Extension Service, Texas Tech University, and West Texas A&M University.

References

Holman, J., A. Obour, A. Schlegel, and L. Simon. 2020. Long-term forage rotation yields, soil water use, and profitability. Proceedings of the Great Plains Soil Fertility Conference. Vol. 18, p.158-164.

Schlegel, A.J., Y. Assefa, L.A. Haag, C.R. Thompson, and L.R. Stone. 2018. Long-term tillage on yield and water use of grain sorghum and winter wheat. Agron. J. 110:269-280.

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 2019 near Tribune, KS

	Year						
Tillage	2014	2015	2016	2017	2018	2019	Average
	bu/a						
No-tillage	28	24	75	30	57	93	51
June in fallow	22	22	81	25	58	89	50
July post-harvest	23	21	77	27	57	89	49
ANOVA (P > F)							
Treatment	0.427	0.599	0.174	0.477	0.857	0.202	0.204
Year	---	---	---	---	---	---	0.001
Year × treatment	---	---	---	---	---	---	0.453

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 2019 near Tribune, KS

	Year						
Tillage	2014	2015	2016	2017	2018	2019	Average
	bu/a						
No-tillage	77	133	129	147	130	132	125
June in fallow	84	114	129	145	123	129	121
July post-harvest	86	108	126	141	115	131	118
ANOVA (P > F)							
Treatment	0.573	0.104	0.280	0.567	0.065	0.779	0.045
Year	---	---	---	---	---	---	0.001
Year × treatment	---	---	---	---	---	---	0.099

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 2018 near Garden City, KS

	Year						
Tillage	2014	2015	2016	2017	2018	2019	Average
	bu/a						
No-tillage	8	34	55	20	4	90ab	40
June in fallow	6	35	60	19	3	100a	44
July post-harvest	9	30	56	23	7	83b	40
ANOVA (P > F)							
Treatment	0.601	0.363	0.369	0.420	0.199	0.029	0.117
Year	---	---	---	---	---	---	<0.0001
Year × treatment	---	---	---	---	---	---	0.061

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 2018 near Garden City, KS

	Year						
Tillage	2014	2015	2016	2017	2018	2019	Average
	bu/a						
No-tillage	58	63	116	51	98	41	71
June in fallow	57	62	121	46	88	41	69
July post-harvest	47	73	118	44	93	40	69
ANOVA (P>F)							
Treatment	0.110	0.464	0.642	0.579	0.572	0.946	0.913
Year	- -	- -	- -	- -	- -	- -	<0.0001
Year × treatment	- -	- -	- -	- -	- -	- -	0.986

ANOVA = analysis of variance.

Wheat Stubble Height on Subsequent Corn and Grain Sorghum Crops

A. Schlegel, A. Burnett, 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 2019 were greater than the long-term average. When averaged from 2007 through 2019, corn grain yields were 8–9 bu/a greater when planted into either high or strip-cut stubble than into low-cut stubble. Average grain sorghum yields were 5 bu/a greater in high-cut stubble than low-cut stubble. Similarly, water use efficiency was greater for high or strip-cut stubble for corn and greater for 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 2019, 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 2019, these heights were 16, 8, and 24 in. (cut after 2018 wheat harvest). In 2019, 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 100 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 2019 growing season was generally normal or slightly above in precipitation (19.59 inch in 2019 vs. normal of 17.90 inch) and below normal in open pan evaporation (63.72 inch vs. normal of 71.40 inch). This produced above average yields for both corn and sorghum (Tables 1–4). With the good growing conditions, stubble height had little effect on corn yield or other parameters. When averaged across years 2007 to 2019, corn yields were 8–9 bu/a greater in high or strip-cut than low-cut wheat stubble (Table 2). Biomass production and water use efficiency were also greater with the taller stubble.

Grain sorghum yields in 2019 were not affected by stubble height (Table 3). When averaged across years from 2007 through 2019, the highest yields were obtained in the high-cut stubble and the lowest yields in the low-cut stubble (Table 4). 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.

Table 1. Corn yield, biomass, and yield components as affected by stubble height, Tribune, KS, 2019

Stubble height	Yield	Plant population	Ear population	Biomass	Residue	1,000-seed weight	Kernels	WUE[1]
	bu/a	----------- 10^3/a -----------		--------- lb/a ---------		oz	no./ear	lb/in.
Low	120	13.7	14.7	14996	9337	10.94	666	387
High	123	14.0	15.1	14688	8862	11.02	663	400
Strip	121	13.2	14.9	17134	11385	11.03	663	398
$LSD_{0.05}$	9	0.8	0.8	2272	2346	0.39	44	31
ANOVA (P > F)								
Stubble height	0.712	0.127	0.586	0.074	0.082	0.871	0.985	0.612

[1]Water use efficiency (lb of grain/inch of water use).
LSD = least significant difference.
ANOVA = analysis of variance.

Table 2. Average corn yield, biomass, and yield components as affected by stubble height, Tribune, KS, 2007–2019

Stubble height	Yield	Plant population	Ear population	Biomass	Residue	1,000-seed weight	Kernels	WUE[1]
	bu/a	----------- 10^3/a -----------		--------- lb/a ---------		oz	no./ear	lb/in.
Low	86 b	13.9	13.9	10367 b	6313 b	11.05	527	313 b
High	94 a	13.9	14.2	11160 a	6692 ab	11.35	520	345 a
Strip	95 a	13.9	14.3	11536 a	7056 a	11.27	545	346 a
$LSD_{0.05}$	4	0.4	0.5	561	500	0.25	66	17
ANOVA (P > F)								
Year	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Stubble height	0.001	0.987	0.208	0.001	0.015	0.051	0.735	0.001
Year × stubble height	0.992	0.993	0.988	0.271	0.065	0.882	0.964	0.960

[1]Water use efficiency (lb of grain/inch of water use).
LSD = least significant difference.
ANOVA = analysis of variance.

Table 3. Sorghum yield and yield components as affected by stubble height, Tribune, KS, 2019

Stubble height	Yield	Head population	Biomass	Residue	1,000-seed weight	Kernels	WUE[1]
	bu/a	10^3/a	---------- lb/a ----------		oz	no./head	lb/in.
Low	123	63.5	12200	6194	0.86	2029	429
High	129	67.9	12859	6561	0.85	1999	450
Strip	125	65.5	13138	7003	0.86	1994	451
$LSD_{0.05}$	5	3.6	953	809	0.03	108	23
ANOVA (P > F)							
Stubble height	0.107	0.063	0.129	0.133	0.830	0.741	0.099

[1]Water use efficiency (lb of grain/inch of water use).
LSD = least significant difference.
ANOVA = analysis of variance.

Table 4. Average sorghum yield, biomass, and yield components as affected by stubble height, Tribune, KS, 2007–2019

Stubble height	Yield	Head population	Biomass[2]	Residue[2]	1,000-seed weight	Kernels	WUE[1]
	bu/a	10^3/a	---------- lb/a ----------		oz	no./head	lb/in.
Low	105 b	56.5 b	11242	6133	0.89	1898	401 b
High	110 a	58.6 a	11779	6417	0.90	1948	427 a
Strip	107 ab	57.8 ab	11350	6108	0.88	1888	415 ab
$LSD_{0.05}$	4	2.0	477	428	0.02	94	17
ANOVA (P > F)							
Year	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Stubble height	0.024	0.131	0.066	0.288	0.140	0.395	0.009
Year × stubble height	0.998	0.930	0.981	0.860	0.738	0.015	0.972

[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.

Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn

A. Schlegel and H.D. Bond

Summary
Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated corn in western Kansas. In 2019, N applied alone increased yields by 71 bu/a, whereas P applied alone increased yields 10 bu/a. Nitrogen and P applied together increased yields up to 131 bu/a, which is 10 bu/a less than the 10-year average of 141 bu/a. Application of 120 lb N/a (with highest P rate) produced 97% of maximum yield in 2019, which is slightly greater than the 10-year average. Application of 80 instead of 40 lb P_2O_5/a increased average yields 4 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 P_2O_5/bu). At the highest N and P rate, apparent fertilizer nitrogen recovery in the grain ($AFNR_g$) was 41% and apparent fertilizer phosphorus recovery in the grain ($AFPR_g$) was 60%.

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.

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 P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O. The treatments were changed in 1992; the K variable was replaced by a higher rate of P (80 lb/a P_2O_5). All fertilizers were broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids [Pioneer 1173H (2010), Pioneer 1151XR (2011), Pioneer 0832 (2012–2013), Pioneer 1186AM (2014), Pioneer 35F48 AM1 (2015), Pioneer 1197 (2016), Pioneer 0801 (2017–2018), and Pioneer 0339 (2019)] were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2010, 2015, 2017, and 2019 crops. The corn is 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 ($AFPR_g$). Grasshoppers were treated by aerial application of insecticide.

Results

Corn yields in 2019 were only 2% higher than the 10-year average (Table 1). Nitrogen alone increased yields 71 bu/a, whereas P alone increased yields 7–10 bu/a. However, N and P applied together increased corn yields up to 131 bu/a. Maximum yield was obtained with 200 lb/a N with 80 lb/a P_2O_5. Corn yields in 2019 (averaged across all N rates) were 4 bu/a greater with 80 than with 40 lb/a P_2O_5 applied.

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. Nitrogen removal (lb/a) was greater at the higher yield levels. Maximum N removal (116 lb/a) was attained with 200 lb N and 80 lb P_2O_5/a. At the highest N and P rate, $AFNR_g$ was 41% and AFPRg was 60%. 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 29 lb P/a at the highest yields.

Acknowledgment

The International Plant Nutrition Institute partially supported this research project.

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2010–2019

Fertilizer		Yield										
N	P_2O_5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
------ lb/a ------						bu/a						
0	0	20	92	86	70	86	92	74	44	82	76	72
0	40	21	111	85	80	95	103	78	47	93	86	80
0	80	28	105	94	91	98	104	86	52	99	83	84
40	0	23	114	109	97	106	113	105	60	110	93	93
40	40	67	195	138	125	153	164	145	92	160	156	139
40	80	61	194	135	126	149	162	135	90	159	154	137
80	0	34	136	128	112	117	131	118	70	117	117	108
80	40	85	212	197	170	187	195	196	132	212	183	177
80	80	90	220	194	149	179	193	193	129	207	189	174
120	0	28	119	134	114	115	124	109	62	102	95	100
120	40	90	222	213	204	213	212	212	142	218	193	192
120	80	105	225	211	194	216	216	223	162	243	201	200
160	0	49	157	158	122	128	144	142	84	139	133	125
160	40	95	229	227	199	211	215	226	154	230	196	198
160	80	95	226	239	217	233	216	238	165	251	191	207
200	0	65	179	170	139	144	162	159	114	158	147	144
200	40	97	218	225	198	204	214	216	148	231	186	194
200	80	104	231	260	220	238	221	235	174	243	207	213

continued

Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2010–2019

Fertilizer		Yield										
N	P_2O_5	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
------ lb/a ------		------------------------------ bu/a ------------------------------										
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
N × P		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
MEANS												
Nitrogen, lb/a												
0		23 e	103 d	88 f	80 e	93 e	100 e	79 e	48 e	91 d	82 d	79 e
40		50 d	167 c	127 e	116 d	136 d	146 d	129 d	81 d	143 c	135 c	123 d
80		70 c	189 b	173 d	143 c	161 c	173 c	169 c	110 c	179 b	163 b	153 c
120		74 bc	189 b	186 c	171 b	181 b	184 b	182 b	122 b	188 b	163 b	164 b
160		80 ab	204 a	208 b	179 ab	190 ab	192 ab	202 a	134 a	207 a	173 ab	177 a
200		89 a	209 a	218 a	186 a	196 a	199 a	203 a	145 a	211 a	180 a	184 a
$LSD_{(0.05)}$		9	13	10	10	10	9	10	11	13	13	8
P_2O_5, lb/a												
0		36 b	133 b	131 c	109 b	116 c	128 b	118 b	72 c	118 c	110 b	107 b
40		76 a	198 a	181 b	163 a	177 b	184 a	179 a	119 b	191 b	167 a	163 a
80		81 a	200 a	189 a	166 a	186 a	185 a	185 a	129 a	200 a	171 a	169 a
$LSD_{(0.05)}$		7	9	7	7	7	6	7	8	9	9	6

*Note: Hail events on 7/23/2010, 5/28/2015, 8/18/2017, and 9/20/2019.
LSD = least significant difference. ANOVA = analysis of variance.

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2010–2019

Fertilizer		Grain				Grain removal			
N	P_2O_5	N	P	N	P	N	P	*$AFNR_g$	*$AFPR_g$
------ lb/a ------		-------- % -------		----- lb/bu -----		------ lb/a ------		---------- % ----------	
0	0	0.99	0.228	0.47	0.108	33	8	---	---
0	40	0.94	0.306	0.45	0.145	35	12	---	22
0	80	0.94	0.318	0.45	0.151	36	13	---	14
40	0	1.17	0.183	0.55	0.087	51	8	44	---
40	40	0.96	0.297	0.46	0.141	62	20	74	67
40	80	0.97	0.317	0.46	0.150	61	21	72	36
80	0	1.26	0.178	0.60	0.084	63	9	38	---
80	40	1.04	0.249	0.49	0.118	86	21	66	72
80	80	1.01	0.305	0.48	0.145	82	25	62	49
120	0	1.28	0.172	0.60	0.081	60	8	23	---
120	40	1.12	0.226	0.53	0.107	101	20	57	71
120	80	1.08	0.293	0.51	0.139	101	28	57	56
160	0	1.26	0.176	0.59	0.083	74	10	26	---
160	40	1.16	0.241	0.55	0.114	108	22	47	83
160	80	1.14	0.275	0.54	0.130	111	27	49	53
200	0	1.22	0.189	0.58	0.090	82	13	25	---
200	40	1.17	0.234	0.55	0.111	106	21	37	77
200	80	1.15	0.288	0.55	0.136	116	29	41	60

continued

Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2010–2019

Fertilizer		Grain				Grain removal			
N	P_2O_5	N	P	N	P	N	P	*$AFNR_g$	*$AFPR_g$
------ lb/a ------		-------- % -------		----- lb/bu -----		------ lb/a ------		---------- % ----------	
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	---
N × P		0.001	0.001	0.001	0.001	0.001	0.001	0.022	0.090
MEANS									
Nitrogen, lb/a									
0		0.96 e	0.284 a	0.45 e	0.134 a	35 e	11 e	---	18 c
40		1.03 d	0.266 b	0.49 d	0.126 b	58 d	16 d	64 a	52 b
80		1.10 c	0.244 c	0.52 c	0.116 c	77 c	18 c	55 b	61 a
120		1.16 b	0.230 d	0.55 b	0.109 d	87 b	19 bc	45 c	63 a
160		1.19 a	0.231 d	0.56 a	0.109 d	98 a	20 ab	41 d	68 a
200		1.18 ab	0.237 cd	0.56 ab	0.112cd	101 a	21 a	34 e	68 a
$LSD_{(0.05)}$		0.02	0.011	0.01	0.005	4	1	5	9
P_2O_5, lb/a									
0		1.19 a	0.188 c	0.57 a	0.089 c	60 b	9 c	31 b	---
40		1.07 b	0.259 b	0.50 b	0.122 b	83 a	19 b	56 a	65 a
80		1.05 b	0.299 a	0.50 b	0.142 a	85 a	24 a	56 a	45 b
$LSD_{(0.05)}$		0.02	0.008	0.01	0.004	3	1	4	5

*$AFNR_g$ = Apparent fertilizer N recovery (grain). $AFPR_g$ = Apparent fertilizer P recovery (grain). LSD = least significant difference. ANOVA = analysis of variance.

Long-Term Nitrogen, Phosphorus, and Potassium Fertilization of Irrigated Grain Sorghum

A. Schlegel and H.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 2019, N applied alone increased yields 66 bu/a, whereas N and P applied together increased yields up to 85 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 78 bu/a. Application of 160 lb/a N (with P) produced the maximum yield in 2019, which is slightly more than the 10-year 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 0.16 lb/bu (0.34 lb P_2O_5/bu) and grain K content reached a maximum of 0.19 lb/bu (0.23 lb K_2O/bu). At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 31% for N, 65% for P, and 38% 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.

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 N without P and K; with 40 lb/a P_2O_5 and zero K; and with 40 lb/a P_2O_5 and 40 lb/a K_2O. All fertilizers are broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. Grain sorghum (Pioneer 85G46 in 2010–2011, Pioneer 84G62 in 2012–2014, Pioneer 86G32 in 2015, Pioneer 84G62 in 2016–2017, and Pioneer 85P44 in 2018–2019) 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

Grain sorghum yields in 2019 were 3% lower than the 10-year average (Table 1). Nitrogen alone increased yields 66 bu/a while P alone increased yields 6 bu/a. However, N and P applied together increased yields up to 85 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 78 bu/a. In 2019, 40 lb/a N (with P) produced about 74% of maximum yield, which is less than the 10-year average of 83%. The 10-year average for 80 lb/a N (with P) and 120 lb/a N (with P) was 93 and 94% 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 P_2O_5/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 22 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 22 to 26 lb/a. At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 31% for N, 65% for P, and 38% for K.

Acknowledgment

The International Plant Nutrition Institute partially supported this research project.

Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2010–2019

Fertilizer			Yield										
N	P_2O_5	K_2O	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
------------ lb/a ------------			------------ bu/a ------------										
0	0	0	51	75	78	62	90	89	80	70	77	68	74
0	40	0	51	83	90	77	94	102	91	79	87	74	83
0	40	40	55	88	93	72	96	97	91	80	83	67	82
40	0	0	66	106	115	94	115	122	106	87	93	94	100
40	40	0	77	121	140	114	144	160	142	120	126	113	126
40	40	40	73	125	132	110	142	155	137	118	131	114	124
80	0	0	73	117	132	102	120	133	120	104	103	109	111
80	40	0	86	140	163	136	151	173	154	123	144	145	141
80	40	40	84	138	161	133	164	178	160	129	140	139	143
120	0	0	70	116	130	100	116	127	108	93	91	102	105
120	40	0	88	145	172	137	162	177	164	121	128	139	143
120	40	40	90	147	175	142	170	178	170	131	143	150	150
160	0	0	74	124	149	117	139	150	135	120	107	129	124
160	40	0	92	152	178	146	171	181	173	137	134	153	152
160	40	40	88	151	174	143	176	179	161	131	139	142	148
200	0	0	78	128	147	119	139	155	151	123	121	134	130
200	40	0	84	141	171	136	165	177	167	131	134	140	145
200	40	40	87	152	175	138	170	179	170	131	130	149	148

continued

Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2010–2019

Fertilizer			Yield										
N	P_2O_5	K_2O	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Mean
------------ lb/a ------------			---------- bu/a ----------										
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			0.892	0.278	0.826	0.644	0.117	0.806	0.943	0.727	0.549	0.789	0.726
N × P-K			0.229	0.542	0.186	0.079	0.012	0.002	0.001	0.084	0.003	0.001	0.001
MEANS													
Nitrogen, lb/a													
0			52 c	82 d	87 d	70 d	94 e	96 d	87 d	76 d	82 c	70 d	80 d
40			72 b	117 c	129 c	106 c	134 d	146 c	129 c	108 c	117 b	107 c	116 c
80			81 a	132 b	152 b	124 b	145 c	161 b	145 b	119 b	129 a	131 b	132 b
120			82 a	136 ab	159 ab	126 b	149 bc	161 b	147 b	115 bc	121 ab	130 b	133 b
160			84 a	142 a	167 a	135 a	162 a	170 a	156 a	129 a	127 a	142 a	142 a
200			83 a	141 a	165 a	131 ab	158 ab	170 a	163 a	129 a	128 a	141 a	141 a
$LSD_{(0.05)}$			5	8	9	8	9	8	8	9	9	7	6
P_2O_5-K_2O, lb/a													
0 - 0			68 b	111 b	125 b	99 b	120 b	129 b	117 b	99 b	99 b	106 b	107 b
40 - 0			80 a	130 a	152 a	124 a	148 a	162 a	149 a	119 a	126 a	127 a	132 a
40 - 40			79 a	133 a	152 a	123 a	153 a	161 a	148 a	120 a	128 a	127 a	132 a
$LSD_{(0.05)}$			4	6	6	5	6	5	6	6	6	5	4

**Note: Hail events on 7/23/2010, 5/28/2015, 8/18/2017, and 9/20/2019.
LSD = least significant difference.
ANOVA = analysis of variance.

Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain nutrient content and removal by irrigated grain sorghum, Tribune, KS, 2010-2019

Fertilizer			Grain						Grain Removal					
N	P_2O_5	K_2O	N	P	K	N	P	K	N	P	K	*$AFNR_g$	*$AFPR_g$	*$AFKR_g$
------------ lb/a ------------			--------------- % ---------------			------------- lb/bu -------------			------------ lb/a ------------			----------------- % -----------------		
0	0	0	1.04	0.251	0.354	0.51	0.123	0.173	37	9	13	---	---	---
0	40	0	1.03	0.313	0.380	0.51	0.153	0.186	41	13	15	---	21	---
0	40	40	1.03	0.311	0.380	0.50	0.152	0.186	41	12	15	---	20	7
40	0	0	1.15	0.227	0.341	0.56	0.111	0.167	55	11	17	45	---	---
40	40	0	1.11	0.315	0.368	0.54	0.155	0.180	68	19	23	76	60	---
40	40	40	1.11	0.309	0.364	0.54	0.152	0.178	67	19	22	73	56	28
80	0	0	1.35	0.212	0.337	0.66	0.104	0.165	73	12	18	44	---	---
80	40	0	1.21	0.293	0.352	0.60	0.144	0.173	83	20	24	57	64	---
80	40	40	1.19	0.305	0.356	0.58	0.149	0.174	83	21	25	56	70	37
120	0	0	1.41	0.196	0.334	0.69	0.096	0.164	72	10	17	29	---	---
120	40	0	1.31	0.279	0.350	0.64	0.137	0.172	91	19	25	45	60	---
120	40	40	1.32	0.300	0.354	0.65	0.147	0.173	96	22	26	49	74	39
160	0	0	1.40	0.224	0.342	0.69	0.110	0.167	85	14	21	30	---	---
160	40	0	1.39	0.301	0.354	0.68	0.148	0.173	103	22	26	41	76	---
160	40	40	1.36	0.276	0.349	0.67	0.135	0.171	98	20	25	38	63	38
200	0	0	1.41	0.230	0.346	0.69	0.113	0.169	89	15	22	26	---	---
200	40	0	1.39	0.280	0.355	0.68	0.137	0.174	98	20	25	30	62	---
200	40	40	1.39	0.284	0.352	0.68	0.139	0.173	100	20	26	31	65	38

continued

Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain nutrient content and removal by irrigated grain sorghum, Tribune, KS, 2010-2019

Fertilizer			Grain						Grain Removal					
N	P_2O_5	K_2O	N	P	K	N	P	K	N	P	K	*$AFNR_g$	*$AFPR_g$	*$AFKR_g$
------------ lb/a ------------			--------------- % ---------------			------------- lb/bu -------------			------------ lb/a ------------			----------------- % -----------------		
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	0.007	0.001	0.001	0.007	0.001	0.001	0.001	0.001	0.050	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	0.736	---
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			0.589	0.876	0.758	0.589	0.876	0.758	0.985	0.779	0.823	---	---	---
N × P-K			0.060	0.013	0.082	0.060	0.013	0.082	0.120	0.001	0.001	0.045	0.041	---
MEANS														
Nitrogen, lb/a														
0			1.03 e	0.292 a	0.371 a	0.51 e	0.143 a	0.182 a	40 e	11 d	15 d	---	21 c	7 c
40			1.12 d	0.284 a	0.358 b	0.55 d	0.139 a	0.175 b	63 d	16 c	21 c	65 a	58 b	28 b
80			1.25 c	0.270 b	0.348 c	0.61 c	0.132 b	0.171 c	80 c	18 abc	23 b	53 b	67 a	37 a
120			1.35 b	0.258 b	0.346 c	0.66 b	0.127 b	0.169 c	86 b	17 bc	23 b	41 c	67 a	39 a
160			1.38 ab	0.267 b	0.348 c	0.68 ab	0.131 b	0.171 c	95 a	19 a	24 a	36 c	69 a	38 a
200			1.40 a	0.264 b	0.351 c	0.68 a	0.130 b	0.172 c	96 a	18 ab	24 a	29 d	64 ab	38 a
$LSD_{(0.05)}$			0.04	0.013	0.006	0.02	0.006	0.003	5	1	1	6	8	5
P_2O_5-K_2O, lb/a														
0 - 0			1.29 a	0.223 b	0.342 b	0.63 a	0.109 b	0.168 b	69 b	12 b	18 b	35 b	---	---
40 - 0			1.24 b	0.297 a	0.360 a	0.61 b	0.145 a	0.176 a	81 a	19 a	23 a	50 a	57	---
40 - 40			1.23 b	0.298 a	0.359 a	0.60 b	0.146 a	0.176 a	81 a	19 a	23 a	49 a	58	---
$LSD_{(0.05)}$			0.03	0.009	0.004	0.01	0.004	0.002	3	1	1	5	5	---

*$AFNR_g$ = Apparent fertilizer N recovery (grain).
$AFPR_g$ = Apparent fertilizer P recovery (grain).
$AFKR_g$ = Apparent fertilizer K recovery (grain).
LSD = least significant difference.
ANOVA = analysis of variance.

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

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

Summary
Forage production is important for the 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.

Study Objectives
1. Quantify yield relationship of winter, spring, and summer forages with PAW and GSP.
2. Determine 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, KS. Plant available water, growing season precipitation, and forage yield were measured annually. Data for winter triticale and forage sorghum were available from 2008 through 2019, and spring triticale from 2012 through 2019.

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 26% and GSP explained 29% of the variability in forage yield (Figures 1 and 2). Together, PAW and GSP explained 57% of the variability in forage yield (Figure 3). For every inch of water used (soil water plus GSP), yield was increased by 540 lb/a. Averaged across the study period, yield was 3,900 lb/a.

Spring Triticale

Spring triticale forage yield was significantly correlated to PAW and GSP, and yield response was variable. Plant available water explained 12% and GSP explained 8% of the variability in forage yield (Figures 4 and 5). Together, PAW and GSP explained 22% of the yield variability; suggesting something other than moisture, most likely temperature greatly impacts yield (Figure 6). For every inch of water used (soil water plus GSP), yield was increased by 214 lb/a. Averaged across the study period, yield was 1,500 lb/a.

Forage Sorghum

Forage sorghum forage yield was correlated to PAW and GSP, and yield response was variable. Plant available water explained approximately 20% and GSP explained 7% of the variability in forage yield (Figures 7 and 8). Together, PAW and GSP explained 30% of the variability in forage yield (Figure 9). For every inch of water used (soil water plus GSP), yield was increased by 460 lb/a. Averaged across the study period, yield was 5,600 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.

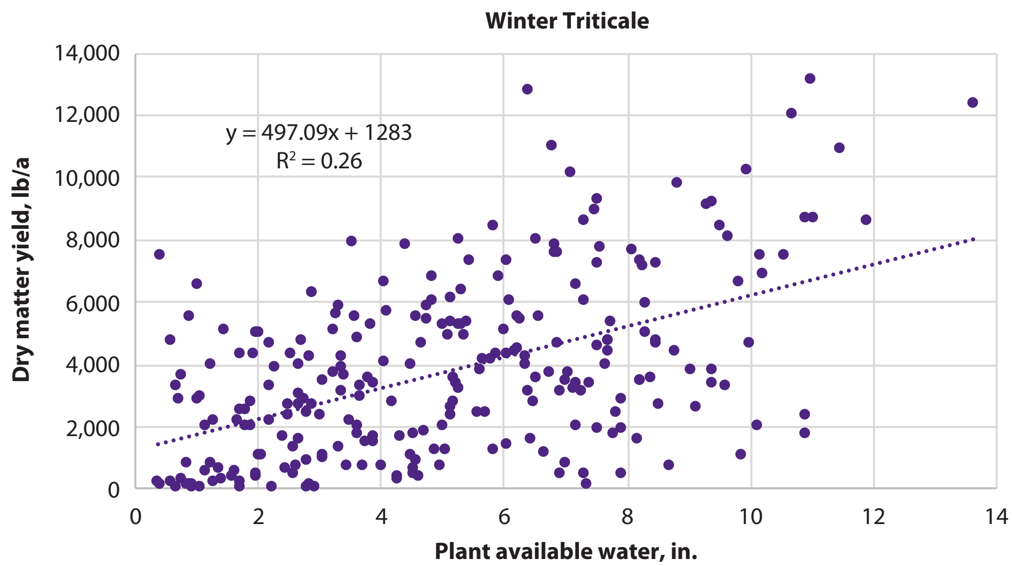

Figure 1. Winter triticale yield response to plant available water at planting.

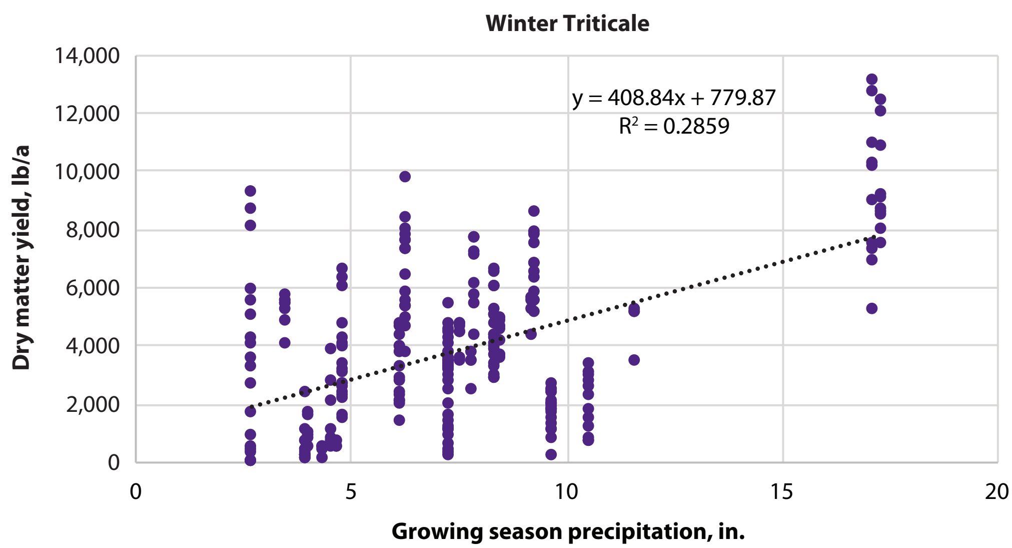

Figure 2. Winter triticale yield response to growing season precipitation.

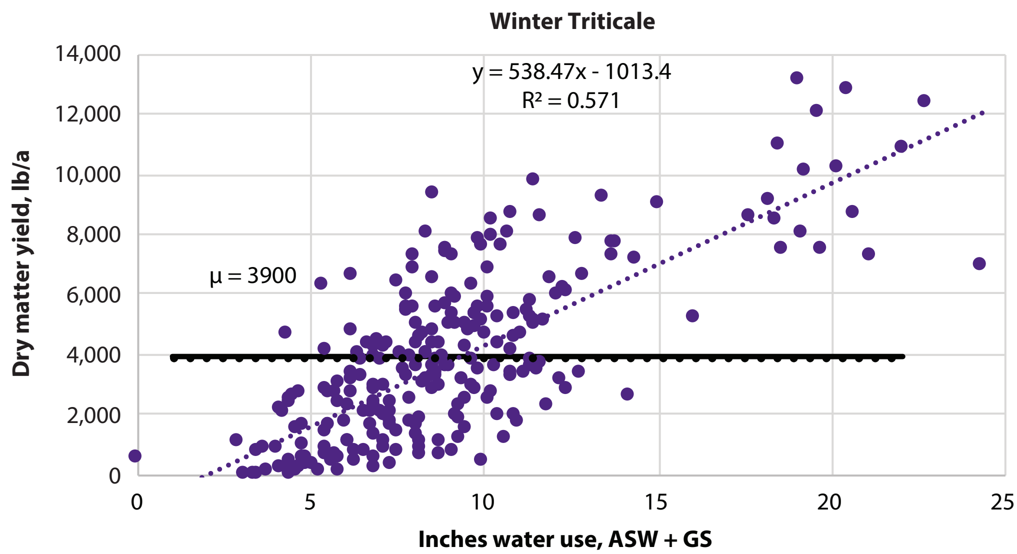

Figure 3. Winter triticale yield response to water use (soil water plus growing season precipitation) and average yield (bold line) across the study period.

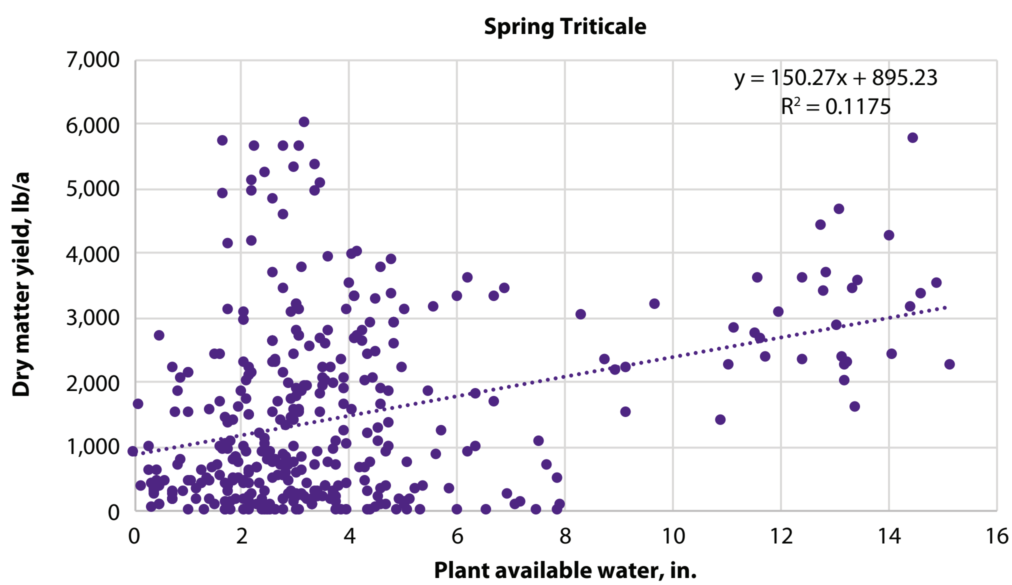

Figure 4. Spring triticale yield response to plant available water at planting.

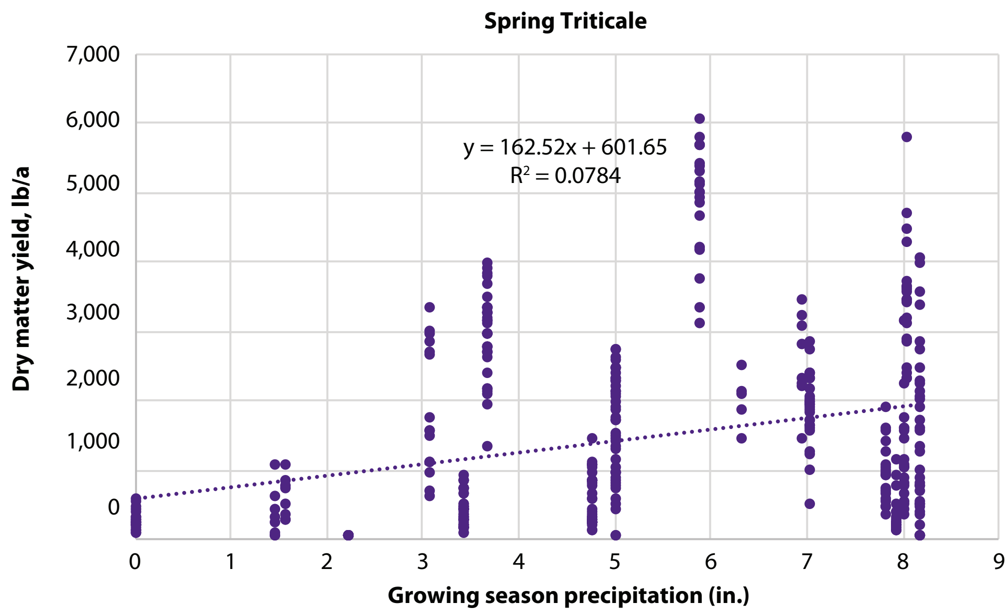

Figure 5. Spring triticale yield response to growing season precipitation.

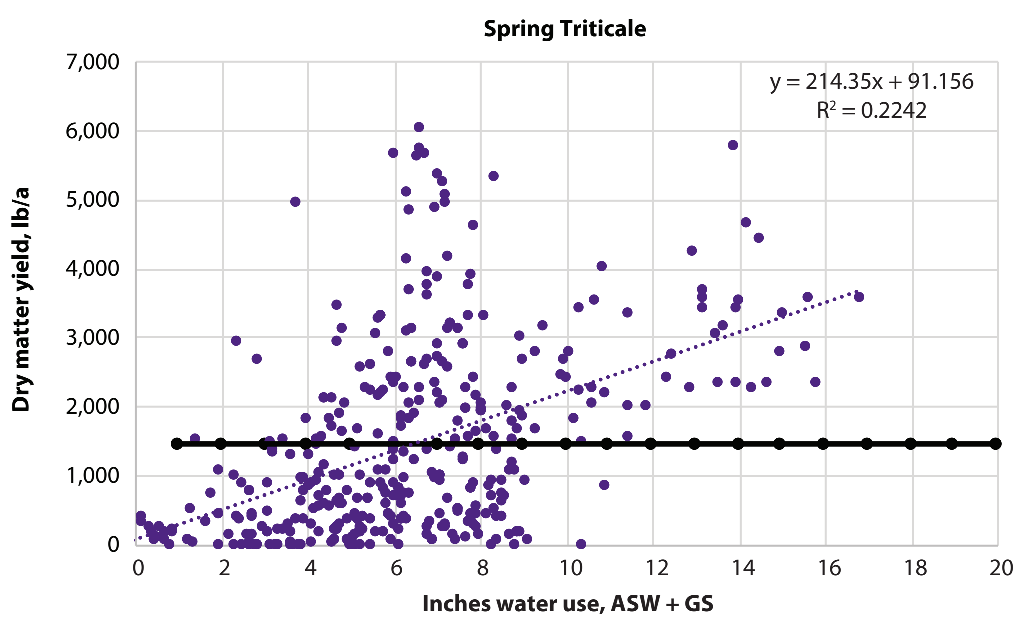

Figure 6. Spring triticale yield response to water use (soil water plus growing season precipitation) and average yield (bold line) across the study period.

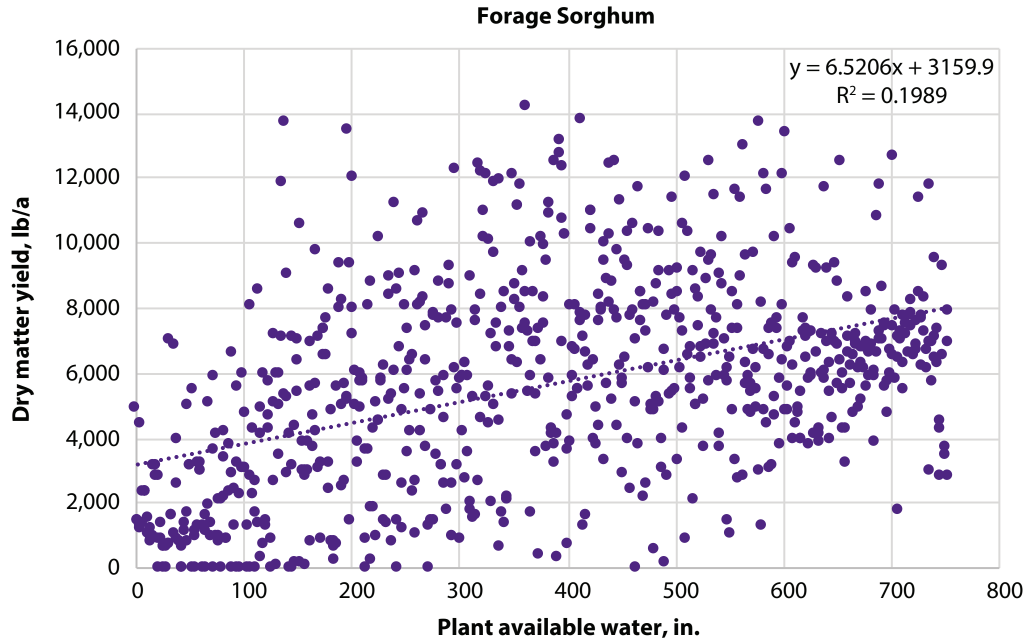

Figure 7. Forage sorghum yield response to plant available water at planting.

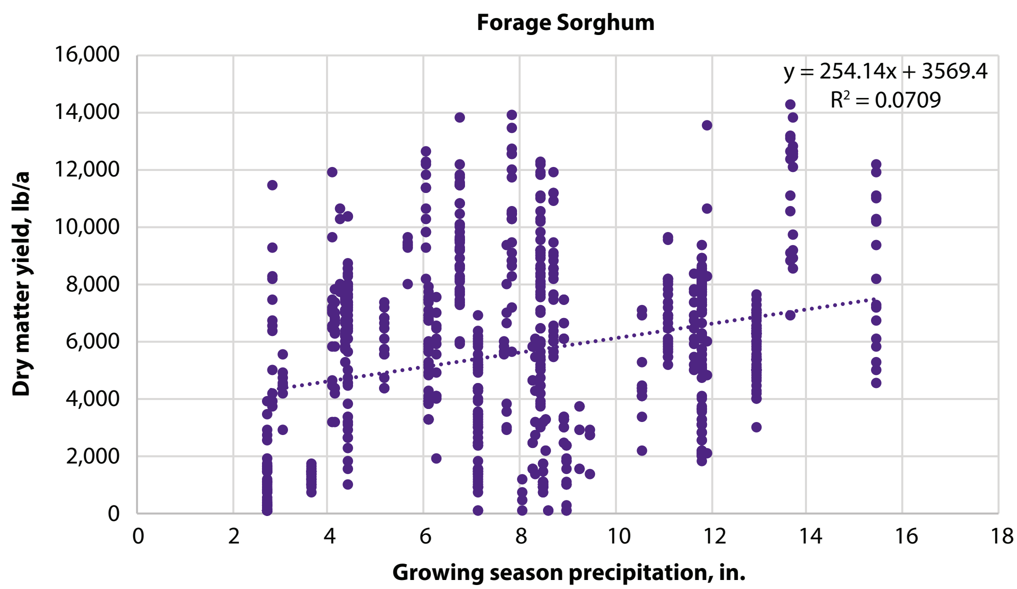

Figure 8. Forage sorghum yield response to growing season precipitation.

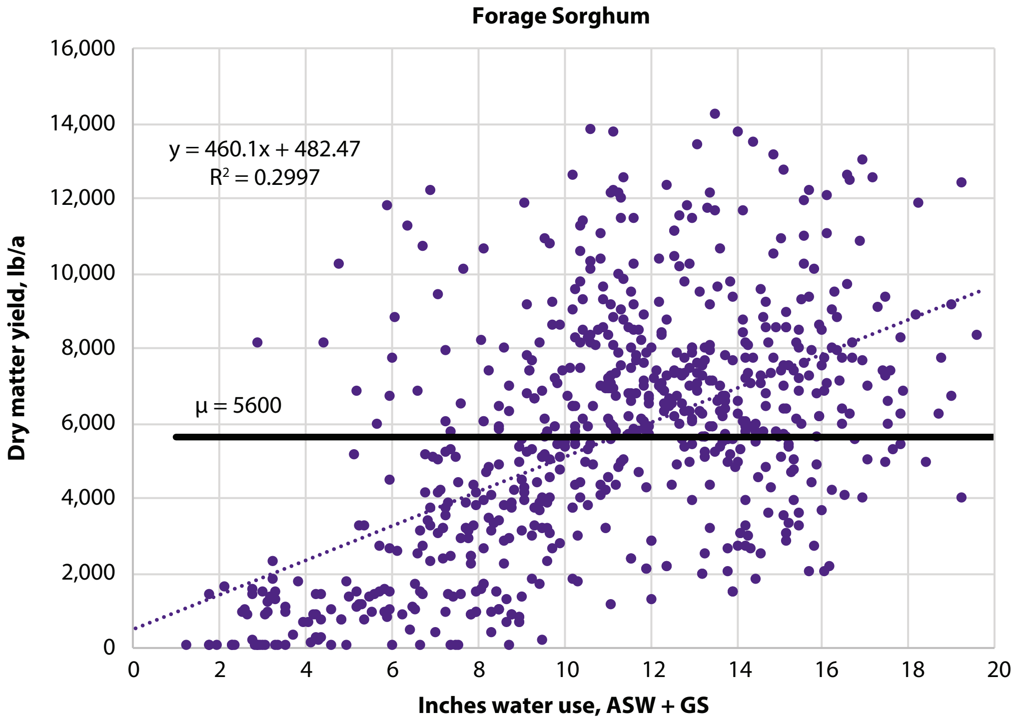

Figure 9. Forage sorghum yield response to water use (soil water plus growing season precipitation) and average yield (bold line) across the study period.

Early Postemergence and Sequential Herbicides for Weed Control in Corn

R.S. Currie and P.W. Geier

Summary
In this study, herbicides were tested to compare sequential and split rates for weed control in corn. Control of green foxtail, Russian thistle, and quinoa was excellent regardless of herbicide treatment, and most herbicides provided good kochia and Palmer amaranth control. Minor corn injury occurred with some herbicides applied early postemergence or postemergence, but did not persist. All herbicide treatments increased grain yield 56 to 78% compared to the weedy control, but yields did not differ between herbicide treatments.

Introduction
Historically, herbicides such as Acuron, Degree Xtra, Resicore, and Warrant were applied preemergence to corn to provide residual weed control until the crop became established and competitive with the weeds. As resistance issues to postemergence herbicides have increased, applying reduced rates of these residual herbicides preemergence and as part of a planned postemergence application has become increasingly popular. Applying these herbicides in a sequential program not only extends the residual weed control but also increases the modes of action used in the postemergence component. The objective of this study was to compare residual herbicides applied sequentially at split rates for efficacy in corn.

Experimental Procedures
An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to compare various herbicides applied preemergence (PRE) followed by postemergence (POST) or early postemergence (EPOST) for weed control in corn. All herbicides were applied using a tractor-mounted, compressed CO_2 sprayer delivering 19.4 GPA at 4.1 mph and 30 psi. Application, environmental, and weed information are shown in Table 1. Plots were 10 by 35 feet and arranged in a randomized complete block design with four replications. Soil was a Beeler silt loam with 2.4% organic matter and pH of 7.6. Visual estimates of weed control were taken on June 17, July 8, and July 22, 2019. These dates were 7, 28, and 42 days after the POST applications (DA-C), respectively. Corn injury ratings were determined on June 7, June 17, and June 27, 2019, and these dates were 4 days after the EPOST applications (DA-B) and 7 or 17 DA-C. Yields were determined on September 19, 2019, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 15.5% moisture.

Results and Discussion
All herbicides controlled Russian thistle, quinoa, and green foxtail 96% or more regardless of rating date, and did not differ between treatments (data not shown). Kochia control at 7 and 42 DA-C was slightly less with Capreno (thiencarbazone/tembotrione) plus Degree Xtra (acetochlor/atrazine), Clarity (dicamba), and glyphosate

applied EPOST compared to the other herbicides and with Diflexx Duo (dicamba/tembotrione) plus Degree Xtra and glyphosate applied EPOST at 42 DA-C (Table 2). All herbicides except Acuron (atrazine/*S*-metolachlor/mesotrione/bicyclopyrone) PRE followed by Acuron plus glyphosate POST controlled Palmer amaranth 98% or more at 7 and 28 DA-C. By 42 DA-C, no differences occurred among herbicides for Palmer amaranth control. Corn chlorosis was 6 to 11% with the EPOST herbicides at 4 DA-B but did not persist (Table 3). All POST treatments containing mesotrione (Acuron, Harness Max, and Resicore) caused 11 to 19% corn chlorosis at 7 DA-C, but visible corn injury at 17 DA-C was 5% or less regardless of herbicide treatment. Grain yields were 38 to 52 bu/a more from herbicide-treated corn than from the nontreated controls. However, corn yields did not differ between herbicide treatments.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Application information

Application timing	Preemergence	Early postemergence	Postemergence
Application date	May 1, 2019	June 3, 2019	June 10, 2019
Air temperature (°F)	51	68	66
Relative humidity (%)	75	67	45
Soil temperature (°F)	53	67	63
Wind speed (mph)	3 to 6	5 to 8	4 to 6
Wind direction	South-southeast	South-southwest	South-southwest
Soil moisture	Good	Good	Good
Corn			
Height (inch)	PRE	5 to 8	8 to 12
Leaves (number)	---	2 to 3	4 to 5
Kochia			
Height (inch)	PRE	1 to 2	1 to 2
Density (plants/10 ft^2)	---	5	2
Palmer amaranth			
Height (inch)	PRE	0.5 to 2	1 to 2
Density (plants/10 ft)	---	5	1
Russian thistle			
Height (inch)	PRE	1 to 2	0
Density (plants/10 ft^2)	---	2	0
Quinoa			
Height (inch)	PRE	1 to 3	0
Density (plants/10 ft^2)	---	2	0
Green foxtail			
Height (inch)	PRE	0.5 to 1	1 to 2
Density (plants/10 ft^2)	---	5	1

Table 2. Sequential and early postemergence weed control in corn

Treatment[1]	Rate	Timing[2]	Kochia			Palmer amaranth		
			7 DA-C[3]	28 DA-C	42 DA-C	7 DA-C	28 DA-C	42 DA-C
	oz/a		% visual					
Corvus	3.3	PRE	100	100	100	98	99	96
Atrazine	32	PRE						
Harness Max	40	POST						
Atrazine	16	POST						
Glyphosate	32	POST						
NIS	0.5%	POST						
AMS	1.0%	POST						
Balance Flexx	3.0	PRE	100	100	99	100	100	99
Harness Xtra 5.6	48	PRE						
Capreno	3.0	POST						
Atrazine	16	POST						
Glyphosate	32	POST						
Superb HC	0.5%	POST						
AMS	1.0%	POST						
Balance Flexx	3.0	PRE	100	100	100	100	99	98
Harness Xtra 5.6	48	PRE						
Laudis	3.0	POST						
Atrazine	16	POST						
Warrant	48	POST						
Glyphosate	32	POST						
Superb HC	0.5%	POST						
AMS	1.0%	POST						
Resicore	40	PRE	100	100	100	100	99	98
Atrazine	32	PRE						
Resicore	40	POST						
Atrazine	16	POST						
Glyphosate	32	POST						
NIS	0.5%	POST						
AMS	1.0%	POST						
Harness Xtra 5.6	41	PRE	100	100	100	100	100	100
Atrazine	32	PRE						
Harness Max	40	POST						
Atrazine	16	POST						
Glyphosate	32	POST						
NIS	0.5%	POST						
AMS	1.0%	POST						
Acuron	40	PRE	99	100	99	95	94	95
Acuron	40	POST						
Glyphosate	32	POST						
NIS	0.5%	POST						
AMS	1.0%	POST						

continued

Table 2. Sequential and early postemergence weed control in corn

Treatment[1]	Rate	Timing[2]	Kochia			Palmer amaranth		
			7 DA-C[3]	28 DA-C	42 DA-C	7 DA-C	28 DA-C	42 DA-C
	oz/a		% visual					
Balance Flexx	3.0	PRE	100	100	100	100	99	100
Degree Xtra	48	PRE						
Laudis	3.0	POST						
Degree Xtra	48	POST						
Glyphosate	32	POST						
Superb HC	0.5%	POST						
AMS	1.0%	POST						
Diflexx Duo	32	EPOST	98	96	96	100	100	100
Degree Xtra	3.0	EPOST						
Glyphosate	32	EPOST						
Superb HC	0.5%	EPOST						
AMS	1.0%	EPOST						
Capreno	3.0	EPOST	93	95	94	100	100	100
Degree Xtra	96	EPOST						
Clarity	8.0	EPOST						
Glyphosate	32	EPOST						
Superb HC	0.5%	EPOST						
AMS	1.0%	EPOST						
LSD (0.05)			3	NS	3	3	4	NS

[1] NIS = nonionic surfactant. AMS = ammonium sulfate.
[2] PRE = preemergence. POST = postemergence. EPOST = early postemergence.
[3] DA-C = days after postemergence treatment.

Table 3. Crop response to sequential and early postemergence herbicides applied in corn

Treatment[1]	Rate	Timing[2]	Chlorosis 4 DA-B[3]	Chlorosis 7 DA-C[3]	Stunting 4 DA-B	Necrosis 17 DA-C	Yield
	oz/a		--------------------- % visual ---------------------				bu/a
Untreated		---	0	0	0	0	67.2
Corvus	3.3	PRE	0	19	0	5	104.8
Atrazine	32	PRE					
Harness Max	40	POST					
Atrazine	16	POST					
Glyphosate	32	POST					
NIS	0.5%	POST					
AMS	1.0%	POST					
Balance Flexx	3.0	PRE	0	5	0	3	117.7
Harness Xtra 5.6	48	PRE					
Capreno	3.0	POST					
Atrazine	16	POST					
Glyphosate	32	POST					
Superb HC	0.5%	POST					
AMS	1.0%	POST					
Balance Flexx	3.0	PRE	0	5	0	1	110.0
Harness Xtra 5.6	48	PRE					
Laudis	3.0	POST					
Atrazine	16	POST					
Warrant	48	POST					
Glyphosate	32	POST					
Superb HC	0.5%	POST					
AMS	1.0%	POST					
Resicore	40	PRE	0	16	0	5	108.0
Atrazine	32	PRE					
Resicore	40	POST					
Atrazine	16	POST					
Glyphosate	32	POST					
NIS	0.5%	POST					
AMS	1.0%	POST					
Harness Xtra 5.6	41	PRE	0	19	0	5	114.8
Atrazine	32	PRE					
Harness Max	40	POST					
Atrazine	16	POST					
Glyphosate	32	POST					
NIS	0.5%	POST					
AMS	1.0%	POST					
Acuron	40	PRE	0	11	0	1	113.7
Acuron	40	POST					
Glyphosate	32	POST					
NIS	0.5%	POST					
AMS	1.0%	POST					

continued

Table 3. Crop response to sequential and early postemergence herbicides applied in corn

Treatment[1]	Rate	Timing[2]	Chlorosis 4 DA-B[3]	Chlorosis 7 DA-C[3]	Stunting 4 DA-B	Necrosis 17 DA-C	Yield
	oz/a		--------------------- % visual			---------------------	bu/a
Balance Flexx	3.0	PRE	0	1	0	0	111.2
Degree Xtra	48	PRE					
Laudis	3.0	POST					
Degree Xtra	48	POST					
Glyphosate	32	POST					
Superb HC	0.5%	POST					
AMS	1.0%	POST					
Diflexx Duo	32	EPOST	6	3	4	1	110.1
Degree Xtra	3.0	EPOST					
Glyphosate	32	EPOST					
Superb HC	0.5%	EPOST					
AMS	1.0%	EPOST					
Capreno	3.0	EPOST	11	3	10	0	119.8
Degree Xtra	96	EPOST					
Clarity	8.0	EPOST					
Glyphosate	32	EPOST					
Superb HC	0.5%	EPOST					
AMS	1.0%	EPOST					
LSD (0.05)			3	5	5	3	22.8

[1] NIS = nonionic surfactant. AMS = ammonium sulfate.
[2] PRE = preemergence. POST is postemergence. EPOST = early postemergence.
[3] DA-B = days after early postemergence applications. DA-C = days after postemergence applications.

Residual Weed Control With Preemergence Herbicides in Grain Sorghum

R.S. Currie and P.W. Geier

Summary
In this study, herbicides were tested to compare preemergence (PRE) application for weed control in grain herbicides. All herbicides controlled quinoa and crabgrass similarly, as well as Russian thistle late in the season. Halex GT at either rate with atrazine as well as Bicep Lite II Magnum controlled Palmer amaranth less than 90% late in the season. Similarly, these herbicides along with Degree Xtra provided less than 90% kochia control late. Grain yields did not differ between herbicide-treated and non-treated sorghum.

Introduction
Residual weed control is important in any summer annual crop, and particularly important in grain sorghum. Postemergence weed control options in sorghum are limited compared to other crops, especially for grass weeds. Therefore, maximizing the length of the time the crop can grow without weed competition is critical. The objective of this study was to compare preemergence herbicides for efficacy in grain sorghum.

Experimental Procedures
An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to compare various preemergence herbicides for residual weed control in grain sorghum. All herbicides were applied using a tractor-mounted, compressed CO_2 sprayer delivering 19.4 GPA at 4.1 mph and 30 psi. Application, environmental, and weed information are shown in Table 1. 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 7.9 and organic matter of 3.4%. Visual weed control estimates were made on July 16 and August 9, 2019. These dates were 7 and 31 days after the postemergence treatment (DA-B), respectively. Sorghum yields were determined on October 15, 2019, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 14.0% moisture.

Results and Discussion
All herbicides controlled quinoa 88% or more at 7 DA-B and 95% or more at 50 DA-B, and did not differ between treatments. Similarly, crabgrass control was 95% or more regardless of herbicide treatment or rating date (data not shown). Kochia control at 7 DA-B was 93% or more with all herbicides except Halex GT (*S*-metolachlor/glyphosate/mesotrione) at 64 oz/a plus atrazine PRE or Degree Xtra (acetochlor/atrazine) PRE (Table 2). These treatments, along with Halex GT at 80 oz/a plus atrazine PRE and Bicep Lite II Magnum (atrazine/*S*-metolachlor) PRE controlled kochia less than 90% at 50 DA-B. Lumax EZ and Lexar EZ (both *S*-metolachlor/atrazine/mesotrione) PRE were the only treatments to control Russian thistle more than 80% at 7 DA-B. However, no differences between herbicide treatments occurred for Russian thistle control at 50 DA-B. Palmer amaranth control was similar among herbicides at 7 DA-B.

At 50 DA-B, Halex GT at 64 or 80 oz/a plus atrazine PRE and Bicep Lite II Magnum PRE provided less than 90% Palmer amaranth control. Grain yields were 88 to 106 bu/a from herbicide-treated sorghum plots, but did not differ from sorghum receiving no herbicide treatment (83 bu/a) (data not shown).

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Application information

Application timing	Preemergence	25 Days after planting
Application date	June 14, 2019	July 7, 2019
Air temperature (°F)	96	74
Relative humidity (%)	41	73
Soil temperature (°F)	78	72
Wind speed (mph)	2 to 5	4 to 7
Wind direction	South	South
Soil moisture	Fair	Fair
Grain sorghum		
Height (inch)	0	2 to 3
Leaves (number)	---	1
Kochia		
Height (inch)	0	2 to 4
Density (plants/10 ft^2)	---	1
Russian thistle		
Height (inch)	0	2 to 4
Density (plants/10 ft^2)	---	1
Quinoa		
Height (inch)	0	2 to 4
Density (plants/10 ft^2)	---	1
Palmer amaranth		
Height (inch)	0	2 to 3
Density (plants/10 ft^2)	---	1
Crabgrass		
Height (inch)	0	0
Density (plants/10 ft^2)	---	---

Table 2. Weed control and grain yield with preemergence herbicides in grain sorghum

			Kochia		Russian thistle		Palmer amaranth	
Treatment[1]	Rate	Timing[2]	7 DA-B[3]	50 DA-B[3]	7 DA-B	50 DA-B	7 DA-B	50 DA-B
	oz/a		% visual					
Lumax EZ	86	PRE	98	95	85	83	100	98
Lexar EZ	96	PRE	100	98	90	83	95	95
Halex GT Atrazine	64 21	PRE PRE	91	88	73	78	93	80
Halex GT Atrazine	80 21	PRE PRE	93	85	70	80	93	85
Bicep Lite II Magnum	48	PRE	94	85	80	80	85	78
Bicep Lite II Magnum Dual II Magnum	48 21	PRE POST	95	90	80	88	95	95
Degree Xtra	72	PRE	85	83	80	78	93	90
Verdict Outlook	10 10	PRE PRE	96	100	75	85	98	98
LSD (0.05)			8	10	9	NS	NS	10

[1] NIS = nonionic surfactant. AMS = ammonium sulfate.
[2] PRE = preemergence. POST = 25 days after planting.
[3] DA-B = days after the postemergence treatment.

Single and Sequential Herbicide Treatments for Efficacy in Corn

R.S. Currie and P.W. Geier

Summary
In this study, herbicides were tested to compare application of single and sequential treatments for weed control in corn. Quinoa and Russian thistle control was 95% or more regardless of herbicide treatment. Anthem Maxx, Resicore, and Corvus followed by Harness Max provided good control of Palmer amaranth. Acuron applied preemergence and Anthem Maxx plus Callisto and atrazine early postemergence were less effective on kochia than other herbicides, whereas Anthem Maxx plus Callisto and atrazine applied preemergence and Halex GT applied early postemergence were less effective on green foxtail. Grain yields from all herbicide-treated corn were substantially greater than for the nontreated control plots.

Introduction
As of 2019, 28 weed species have been reported to have herbicide resistance in Kansas. Use of herbicides with multiple modes of action and sequential applications of herbicides are two effective strategies to combat the development of herbicide-resistant weed species. The objective of this study was to compare single applications of herbicides with multiple modes of action to sequential applications for efficacy in corn.

Experimental Procedures
An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to compare preemergence (PRE), early postemergence (EPOST), or PRE followed by postemergence (POST) herbicides for weed control in corn. All herbicides were applied using a tractor-mounted, compressed CO_2 sprayer delivering 19.4 GPA at 4.1 mph and 30 psi. Application, environmental, and weed information are shown in Table 1. Plots were 10 by 35 feet and arranged in a randomized complete block design with four replications. Soil was a Beeler silt loam with 2.4% organic matter and pH of 7.6. Visual weed control ratings were taken on June 27 and July 23, 2019. These dates were 1 and 27 days after the POST treatment (DA-C), respectively. Corn yields were determined on September 19, 2019, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 15.5% moisture.

Results and Discussion
Quinoa and Russian thistle control was essentially complete with all herbicides regardless of rating date (data not shown). All herbicide treatments containing Anthem Maxx (pyroxasulfone/fluthiacet) PRE controlled Palmer amaranth 95 to 100% at 1 and 27 DA-C, as did the treatment of Resicore (acetochlor/mesotrione/clopyralid) PRE (Table 2). Corvus (isoxaflutole/thiencarbazone) plus atrazine PRE followed by Harness Max (acetochlor/mesotrione) plus atrazine and glyphosate POST also controlled Palmer amaranth 95% at 27 DA-C. Kochia control at 1 and 27 DA-C was slightly less with Acuron (*S*-metolachlor/atrazine/mesotrione/bicyclopyrone) PRE or Anthem Maxx plus Callisto (mesotrione) and atrazine EPOST, compared to the most efficacious treat-

ments. Green foxtail control was 95% or more with all herbicides except Anthem Maxx plus Callisto and atrazine PRE and Halex GT (*S*-metolachlor/glyphosate/mesotrione) plus atrazine EPOST at 27 DA-C. Yields of herbicide-treated corn plots ranged from 99.8 to 115.4 bu/a, which was 61 to 77 bu/a more than nontreated corn.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Application information

Application timing	Preemergence	Early postemergence	Postemergence
Application date	May 18, 2019	June 10, 2019	June 26, 2019
Air temperature (°F)	51	68	68
Relative humidity (%)	64	34	61
Soil temperature (°F)	60	69	71
Wind speed (mph)	0 to 2	3 to 6	3 to 5
Wind direction	North	South-southwest	South
Soil moisture	Good	Good	Good
Corn			
Height (inch)	0	6 to 9	15 to 20
Leaves (number)	---	2 to 3	6 to 7
Palmer amaranth			
Height (inch)	0	1 to 3	2 to 4
Density (plants/10 ft^2)	---	10	1
Kochia			
Height (inch)	0	1 to 3	2 to 3
Density (plants/10 ft^2)	---	10	1
Russian thistle			
Height (inch)	0	1 to 3	3 to 5
Density (plants/10 ft^2)	---	3	1
Quinoa			
Height (inch)	0	1 to 2	0
Density (plants/10 ft^2)	---	2	---
Green foxtail			
Height (inch)	0	1 to 2	2 to 3
Density (plants/10 ft^2)	---	10	1

Table 2. Single and sequential herbicide efficacy in corn

Treatment[1]	Rate	Timing[2]	Palmer amaranth 1 DA-C[3]	Palmer amaranth 27 DA-C	Kochia 1 DA-C	Kochia 27 DA-C	Green foxtail 1 DA-C	Green foxtail 27 DA-C	Corn yield
	oz/a		% visual						bu/a
Untreated			---	---	---	---	---	---	38.3
Anthem Maxx	4.0	PRE	98	99	100	100	96	95	105.3
Balance Flexx	3.0	PRE							
Atrazine	48	PRE							
Anthem Maxx	4.0	PRE	100	100	100	100	95	93	110.1
Callisto	4.0	PRE							
Atrazine	32	PRE							
Corvus	5.6	PRE	85	86	100	100	96	95	99.8
Atrazine	48	PRE							
Acuron	80	PRE	91	89	91	90	100	96	107.6
Resicore	80	PRE	98	100	99	96	100	99	109.7
Anthem Maxx	3.0	EPOST	89	90	94	93	100	99	108.7
Callisto	3.0	EPOST							
Atrazine	32	EPOST							
Glyphosate	28	EPOST							
AMS	1.0%	EPOST							
Halex GT	58	EPOST	89	86	99	95	96	94	115.4
Atrazine	32	EPOST							
NIS	0.25%	EPOST							
AMS	1.0%	EPOST							
Anthem Maxx	4.0	PRE	95	100	100	100	98	100	104.0
Callisto	3.0	PRE							
Atrazine	48	PRE							
Status	4.0	POST							
Glyphosate	28	POST							
AMS	1.0%	POST							
Corvus	5.6	PRE	86	95	95	99	100	99	104.9
Atrazine	32	PRE							
Harness Max	40	POST							
Atrazine	16	POST							
Glyphosate	28	POST							
AMS	1.0%	POST							
LSD (0.05)			8	9	5	6	3	5	15.4

[1] NIS = nonionic surfactant. AMS = ammonium sulfate.

[2] PRE = preemergence. EPOST = early postemergence. POST = postemergence.

[3] DA-C = days after the postemergence treatments.

Efficacy of KFD-365-02 Rates and Mixtures in Imidazolinone-Tolerant Grain Sorghum

R.S. Currie and P.W. Geier

Summary
This study compared various tank mixes of generic *S*-metolachlor/mesotrione and imazamox for weed control in imidazolinone-tolerant grain sorghum. All herbicides provided more than 90% control of Russian thistle, velvetleaf, and green foxtail, and kochia control late in the season was 85% or more. Puncturevine control late in the season was 80 to 90% with all herbicides except Coyote followed by KFD-365-02 and by KFD-365-02 at 6 oz/a plus atrazine followed by 2,4-D. Only Coyote followed by KFD-365-02 plus atrazine or 2,4-D controlled Palmer amaranth more than 78% late.

Introduction
Postemergence grass weed control in grain sorghum is one of the toughest challenges producers face. Until recently, only atrazine and quinclorac have been labeled for grass control in sorghum, but herbicide-resistant sorghum hybrids are in development. Igrowth sorghum has been bred with resistance to imazamox herbicide. The use of imazamox in sorghum can control grasses such as shattercane, seedling Johnsongrass, and foxtails. This study examined the use of imazamox (KFD-365-02) preemergence and postemergence in Igrowth sorghum.

Experimental Procedures
An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to compare imazamox preemergence and postemergence with various tank mix partners for weed control in grain sorghum. All herbicides were applied using a tractor-mounted, compressed CO_2 sprayer delivering 19.4 GPA at 4.1 mph and 30 psi. Application, environmental, and weed information are shown in Table 1. Plots were 10 by 35 feet and arranged in a randomized complete block design with four replications. Soil was a Beeler silt loam with 2.4% organic matter and pH of 7.6. Visual weed control ratings were made on June 20 and July 10, 2019. These dates were 17 days after the preemergence applications (DA-B) and 19 days after the postemergence applications (DA-C), respectively.

Results and Discussion
Control of Russian thistle, velvetleaf, and green foxtail was 91% or more regardless of herbicide or evaluation date (data not shown). Palmer amaranth control at 17 DA-B and 19 DA-C was best when Coyote (*S*-metolachlor/mesotrione) was applied 20 days preplant (DPP) followed by KFD-365-02 with atrazine or 2,4-D postemergence (POST) (Table 2). The lack of Palmer amaranth control from POST applications of KFD-365-02 was due to resistance of the weed biotype to imidazolinone herbicides. Most herbicides controlled kochia 88 to 96% at 17 DA-B; KFD-365-02 at 6 or 9 oz/a PRE followed by atrazine POST did not. By 19 DA-C, no difference occurred among herbicides for kochia control. Similarly, puncturevine control at 17 DA-B was similar among herbicide treatments. By 19 DA-C, puncturevine control was 80% or more with

all herbicides except Coyote PRE followed by KFD-356-02 POST or KFD-365-02 at 6 oz/a plus atrazine PRE followed by 2,4-D POST. No visible crop injury was observed from any treatment, and grain yields could not be determined due to the intense Palmer amaranth pressure.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Application information

Application timing	20 days preplant	Preemergence	Early postemergence
Application date	May 14, 2019	June 3, 2019	June 21, 2019
Air temperature (°F)	65	86	71
Relative humidity (%)	61	45	75
Soil temperature (°F)	56	83	73
Wind speed (mph)	1 to 4	8 to 11	5 to 8
Wind direction	South	South-southwest	North
Soil moisture	Good	Good	Good
Grain sorghum			
Height (inch)	0	0	1 to 3
Leaves (number)	---	---	1 to 3
Palmer amaranth			
Height (inch)	0	0	1 to 5
Density (plants/10 ft^2)	---	---	10
Kochia			
Height (inch)	0	0	1 to 3
Density (plants/10 ft^2)	---	---	8
Puncturevine			
Diameter (inch)	0	0	3 to 6
Density (plants/10 ft^2)	---	---	3
Russian thistle			
Height (inch)	0	0	1 to 3
Density (plants/10 ft^2)	---	---	2
Velvetleaf			
Height (inch)	0	0	0.5 to 2
Density (plants/10 ft^2)	---	---	5
Green foxtail			
Height (inch)	0	0	2 to 3
Density (plants/10 ft^2)	---	---	1

Table 2. Weed control in imidazolinone-resistant sorghum

Treatment[1]	Rate	Timing[2]	Palmer amaranth 17 DA-B[3]	Palmer amaranth 19 DA-C[3]	Kochia 17 DA-B	Kochia 19 DA-C	Puncturevine 17 DA-B	Puncturevine 19 DA-C
	oz/a		% visual					
Glyphosate AMS	22 1.0%	PRE PRE	---	---	---	---	---	---
Coyote KFD-365-02 COC	64 6 1.0%	20 DPP POST POST	86	78	94	90	88	70
Coyote KFD-365-02 Atrazine COC	64 6 32 1.0%	20 DPP POST POST POST	95	96	95	95	85	83
Coyote KFD-365-02 2,4-D amine	64 6 8	20 DPP POST POST	89	88	96	88	85	80
KFD-365-02 Atrazine Glyphosate AMS 2,4-D amine	6 32 22 1.0% 8	PRE PRE PRE PRE POST	79	58	95	98	88	75
KFD-365-02 Atrazine Glyphosate AMS 2,4-D amine	9 32 22 1.0% 8	PRE PRE PRE PRE POST	76	50	95	93	98	80
KFD-365-02 Moccasin II Plus Glyphosate AMS Atrazine COC	6 16 22 1.0% 32 1.0%	PRE PRE PRE PRE POST POST	78	65	88	98	95	83
KFD-365-02 Moccasin II Plus Glyphosate AMS Atrazine COC	9 16 22 1.0% 32 1.0%	PRE PRE PRE PRE POST POST	73	68	88	88	95	85
KFD-365-02 Glyphosate AMS Atrazine COC	6 22 1.0% 32 1.0%	PRE PRE PRE POST POST	78	64	84	88	90	80
KFD-365-02 Glyphosate AMS Atrazine COC	9 22 1.0% 32 1.0%	PRE PRE PRE POST POST	78	60	80	85	95	81

continued

Table 2. Weed control in imidazolinone-resistant sorghum

Treatment[1]	Rate	Timing[2]	Palmer amaranth		Kochia		Puncturevine	
			17 DA-B[3]	19 DA-C[3]	17 DA-B	19 DA-C	17 DA-B	19 DA-C
	oz/a		% visual					
Moccasin II Plus	16	PRE	78	60	90	90	98	90
Glyphosate	22	PRE						
AMS	1.0%	PRE						
Atrazine	32	POST						
COC	1.0%	POST						
Moccasin II Plus	16	PRE	80	64	91	93	100	85
Atrazine	32	PRE						
Glyphosate	22	PRE						
AMS	1.0%	PRE						
KFD-365-02	6	POST						
COC	1.0%	POST						
Moccasin II Plus	16	PRE	78	65	98	100	100	90
Atrazine	32	PRE						
Glyphosate	22	PRE						
AMS	1.0%	PRE						
KFD-365-02	6	POST						
2,4-D amine	8	POST						
Moccasin II Plus	16	PRE	78	48	95	98	93	80
Atrazine	32	PRE						
Glyphosate	22	PRE						
AMS	1.0	PRE						
2,4-D amine	8	POST						
LSD (0.05)			11	17	11	NS	NS	10

[1] AMS = ammonium sulfate. COC = crop oil concentrate.

[2] 20 DPP = 20 days preplant. PRE = preemergence. POST = early postemergence.

[3] 17 DA-B = 17 days after the preemergence treatments. 19 DA-C = 19 days after the early postemergence applications.

Comparison of Terbuthylazine and Atrazine Preemergence in Grain Sorghum

R.S. Currie and P.W. Geier

Summary
Terbuthylazine is an atrazine analog that is used in Europe as a replacement for atrazine. This study compares terbuthylazine with common herbicide tank mixes for weed control in this region. All herbicides controlled quinoa and crabgrass 95% or more, whereas Bicep II Magnum controlled kochia, Palmer amaranth, and Russian thistle the best late in the season. No herbicide visibly injured grain sorghum in this experiment. Grain yields increased 18 to 32 bu/a when herbicides were applied compared to the nontreated controls except with atrazine at 24 oz/a.

Introduction
Terbuthylazine is a photosynthesis-inhibiting herbicide similar to atrazine. In areas where atrazine use is restricted, such as Europe, terbuthylazine is used for preemergence weed control in corn. In the United States, terbuthylazine is not currently marketed as an herbicide. This study was conducted to compare terbuthylazine with atrazine for weed control in grain sorghum.

Experimental Procedures
An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to compare terbuthylazine and atrazine alone and in combinations for preemergence weed control in grain sorghum. All herbicides were applied using a tractor-mounted, compressed CO_2 sprayer delivering 19.4 GPA at 4.1 mph and 30 psi. Application, environmental, and weed information are shown in Table 1. 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 7.9 and 3.4% organic matter. Visual estimates of weed control were determined on July 16 and July 29, 2019. These dates were 28 and 41 days after herbicide treatment (DAT). Sorghum yields were determined by mechanically harvesting the center two rows of each plot and adjusting grain weights to 14.0% moisture.

Results and Discussion
Quinoa and crabgrass control with all herbicides was 95% or more regardless of evaluation date and did not differ (data not shown). At 28 DAT, kochia and Palmer amaranth control was 80% or more with all herbicides except terbuthylazine at 23 oz/a or atrazine at 24 oz/a (Table 2). By 41 DAT, control of each of these species was best (85%) when Bicep II Magnum (*S*-metolachlor/atrazine) at 64 oz/a was applied. All herbicides controlled Russian thistle similarly at 28 DAT. Bicep II Magnum provided the best Russian thistle control at 41 DAT (88%), and only terbuthylazine at 23 oz/a and atrazine at 24 oz/a were less efficacious. No visible sorghum injury was observed from any of the herbicides tested. Grain yields were increased 31 to 54% by most herbicide treatments compared to nontreated sorghum. However, sorghum treated with atrazine at 24 oz/a yielded similarly to the nontreated controls.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Application information

Application timing	Preemergence
Application date	June 18, 2019
Air temperature (°F)	88
Relative humidity (%)	62
Soil temperature (°F)	86
Wind speed (mph)	3 to 6
Wind direction	West-southwest
Soil moisture	Fair

Table 2. Terbuthylazine and atrazine comparisons in sorghum

			Kochia		Russian thistle		Palmer amaranth		Sorghum
Treatment	Rate	Timing[1]	28 DAT[2]	41 DAT	28 DAT	41 DAT	28 DAT	41 DAT	yield
	oz/a		% visual						bu/a
Untreated	---	---	---	---	---	---	---	---	58.6
Terbuthylazine	23	PRE	70	63	83	65	68	60	77.7
Terbuthylazine	31	PRE	80	78	86	83	80	70	76.9
Atrazine	24	PRE	78	73	88	75	73	65	66.9
Atrazine	32	PRE	81	75	90	80	81	73	80.9
Terbuthylazine Dual II Magnum	23 16	PRE PRE	84	75	88	83	80	75	78.9
Atrazine Dual II Magnum	24 16	PRE PRE	84	73	90	78	83	73	83.5
Bicep II Magnum	67	PRE	85	85	93	88	89	85	90.4
LSD (0.05)			6	7	NS	12	11	10	18.0

[1] PRE = preemergence.
[2] DAT = days after treatment.

Vida Tank Mixtures for Postemergence Weed Control in Fallow

R.S. Currie and P.W. Geier

Summary
The objective of the study was to compare Vida (pyraflufen ethyl) with various tank mix partners for weed control in fallow. All herbicides controlled flixweed and tansymustard 96% or more by 16 days after treatment. Treatments containing Spartan provided faster and better kochia control compared to other herbicides, and these treatments were the only ones to control kochia 95% or more late in the season.

Introduction
Kochia has become one of the most difficult-to-control weeds in the Central Great Plains. One population of kochia in Kansas had demonstrated resistance to four different herbicide modes of action, including atrazine, dicamba, and glyphosate. Therefore, the use of herbicide tank mixtures that utilize novel modes of action is critical for effective control of this weed. The objective of the study was to compare Vida with various tank mix partners for weed control in fallow.

Experimental Procedures
An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to compare Vida tank mixtures for weed control in fallow. Herbicides were applied postemergence using a tractor-mounted, compressed CO_2 sprayer delivering 19.4 GPA at 30 psi and 4.1 mph. Application, environmental, and weed information is shown in Table 1. Plots were 10 by 35 feet and arranged in a randomized complete block with 4 replications. Soil was a Ulysses silt loam with 3.4% organic matter and pH of 7.9. Visual weed control was determined on May 17, May 29, and June 10, 2019. These dates were 4, 16, and 28 days after treatment (DAT), respectively.

Results and Discussion
Tank mixtures containing Spartan (sulfentrazone) controlled kochia, pinnate tansymustard, and flixweed better than most other treatments at 4 DAT, but did not exceed 65% (Table 2). Similarly, kochia control at 16 DAT was 97% or more with all treatments containing Spartan, and 93% with the treatment of Vida plus glyphosate and dicamba. Pinnate tansymustard and flixweed control was 96% or more regardless of treatment at 16 DAT and did not differ between treatments. By 28 DAT, Vida with glyphosate, glyphosate and 2,4-D, or glyphosate and dicamba controlled kochia 75 to 89%, whereas Spartan-containing treatments controlled kochia 95 to 97%. All herbicide treatments completely controlled pinnate tansymustard and flixweed at 28 DAT.

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Persons using such products assume responsibility for their use in accordance with current label directions of the manufacturer.

Table 1. Application information

Application timing	Postemergence
Application date	May 23, 2019
Air temperature (°F)	75
Relative humidity (%)	56
Soil temperature (°F)	60
Wind speed (mph)	3 to 6
Wind direction	Southeast
Soil moisture	Good
Kochia	
Height (inch)	3 to 5
Density (plants/ft^2)	10
Pinnate tansymustard	
Height (inch)	10 to 15
Density (plants/ft^2)	1
Flixweed	
Height (inch)	15 to 25
Density (plants/ft^2)	1

Table 2. Pyraflufen tank mixtures for postemergence weed control in fallow

Treatment[1]	Rate	Kochia 4 DAT[2]	Kochia 16 DAT	Kochia 28 DAT	Pinnate tansymustard 4 DAT	Pinnate tansymustard 16 DAT	Pinnate tansymustard 28 DAT	Flixweed 4 DAT	Flixweed 16 DAT	Flixweed 28 DAT
	oz/a	% visual								
Vida	2.0	43	85	76	40	98	100	35	97	100
Glyphosate	24									
COC	1%									
AMS	3 lb									
Vida	2.0	45	88	75	40	98	100	40	97	100
Glyphosate	24									
2,4-D amine	8.0									
COC	1%									
AMS	3 lb									
Vida	2.0	65	98	97	53	99	100	50	98	100
Spartan 4F	6.0									
Glyphosate	24									
COC	1%									
AMS	3 lb									
Spartan 4F	6.0	60	97	96	53	98	100	50	96	100
Glyphosate	24									
COC	1%									
AMS	3 lb									
Vida	2.0	63	97	95	53	98	100	50	97	100
Spartan 4F	6.0									
2,4-D amine	8.0									
Glyphosate	24									
COC	1%									
AMS	3 lb									
Vida	2.0	45	93	89	40	97	100	43	97	100
Glyphosate	24									
Dicamba	8.0									
COC	1%									
AMS	3 lb									
Vida	2.0	65	97	97	53	98	100	50	97	100
Spartan 4F	6.0									
Dicamba	8.0									
Glyphosate	24									
COC	1%									
AMS	3 lb									
LSD (0.05)		9	4	6	6	NS	NS	5	NS	NS

[1] COC = crop oil concentrate. AMS = ammonium sulfate.
[2] DAT = days after treatment.

Acknowledgments

The staffs of the Southwest Research-Extension Center and Kansas State University appreciate and acknowledge the following companies, foundations, and individuals for their support of the research that has been conducted in the past year.

Donations

American Implement
Bayer
Bayer Crop Science
BASF Corp
Ceres Imaging
Chromatin
Corteva
Crop Quest
DuPont Pioneer
Ehmke Seed
Garden City Farm Equipment
Gowen
Great Plains Canola Association
Hydro Resources
Kansas Corn Commission
Kansas Forage and Grassland Council
Nutrien
Pioneer Hi-Bred
Poole Chemical Co, Inc
Premier Tillage
Servi-Tech
Sharp Brothers Seed
Shield Ag Equipment
Soil Health Insurance
Teeter Irrigation
UPL NA, Inc.

Grant Support

BASF Corp.
Bayer CropScience
Corteva
Deere and Company
Foundation for Food and Agriculture Research
Gowan
Groundwater Management District #1
Great Plains Canola Association
Indigo
International Plant Nutrition Institute
Irrigation Innovation Consortium
Kansas Corn Commission
Kansas Grain Sorghum Commission
Kansas Water Office
Land O'Lakes
Minerals Technology Inc
Sipcam Agro.
Syngenta
United Sorghum Checkoff Program
UPL NA, Inc.
U.S. Canola Association
USDA Agricultural Research Service
USDA Canola Project
USDA National Institute of Food and Agriculture
USDA National Resources Conservation Service CIG
USDA Ogallala Aquifer Project
USDA Ogallala Water Coordinated Agriculture Project
USDA Risk Management Agency
Valent BioSciences
Winfield Solutions

Cooperators/Collaborators

Colorado State University
Dodge City Community College
Kansas State University Research Foundation
USDA Agricultural Research Service, Bushland, TX

Performance Tests

Advanta Seed
AgriLead
Alta Seeds
American Hybrids
Arrow Seed
Browning Seed
Channel Seed
Chromatin
CHS Seed Resources
Coffey Seeds Inc.
Dyna-Gro Seed
Fontanelle
Gayland Ward Seed
Mojo Seed
Monsanto Company
Richardson Seed
Scott Seed
Sharp Brothers Seed
Sorghum Partners
Star Seed
Walter Moss Seed
Watley Seed
Winfield United
W-L Alfalfa

Bertha Mendoza
EFNEP/FNP Area Agent

B.S., Kansas State University
M.S., Fort Hays State University

Bertha joined the staff in October 2009. She delivers nutrition education programs and emphasizes the importance of physical activity for a healthy lifestyle to low-income families from several cultural backgrounds in southwest Kansas.

Alan Schlegel
Agronomist-in-Charge, Tribune

B.S., Kansas State University
M.S., Ph.D., Purdue University

Alan joined the staff in 1986. His research involves fertilizer and water management in reduced-tillage systems.

Amy M. Sollock
Southwest Area 4-H Specialist

B.S., University of Illinois at Urbana Champaign
M.S., Oklahoma State University

Amy began her role as Area 4-H Specialist in early 2016. She provides leadership and resources to 24 counties in the area of 4-H youth development, including community clubs, school enrichment, camping and afterschool programs. She is passionate about teaching young people of all backgrounds valuable life skills so that they can reach their fullest potential in adulthood.

Monte Vandeveer
Extension Agricultural Economist

B.S., M.S., Kansas State University
Ph.D., Purdue University

Monte joined the staff in February of 2016. His extension duties are to provide educational programs on farm management topics across southwest Kansas and the rest of the state. He has particular interest in crop insurance and risk management in general.

Justin Waggoner
Extension Specialist, Beef Systems

B.S., M.S., Kansas State University
Ph.D., New Mexico State University

Justin joined the staff in 2007. His extension program focuses primarily on beef cattle and livestock production.

Sarah Zukoff
Extension Specialist, Entomologist

B.S. and M.S., Georgia Southern University
Ph.D., University of Missouri

Sarah has a joint research and extension appointment. Her work focuses on arthropods in field and forage crops as well as rangeland systems.

SOUTHWEST RESEARCH-EXTENSION CENTER

FIELD DAY 2020

This publication is intended for distribution at Southwest Research-Extension Center Field Day 2020. Full reports are also available at ***http://newprairiepress.org/kaesrr***

Chemical Disclaimer

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Experiments with pesticides on nonlabeled crops or target species do not imply endorsement or recommendation of nonlabeled use of pesticides by Kansas State University. All pesticides must be used consistent with current label directions. Current information on weed control in Kansas is available in *2020 Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland*, Report of Progress 1155, available from the KSRE Bookstore, Umberger Hall, Kansas State University, or at: ***www.bookstore.ksre.ksu.edu*** (type Chemical Weed Control in search box).

Publications from Kansas State University are available at: ***www.bookstore.ksre.ksu.edu***

KANSAS STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION AND COOPERATIVE EXTENSION SERVICE

K-State Research and Extension is an equal opportunity provider and employer.

August 2020