

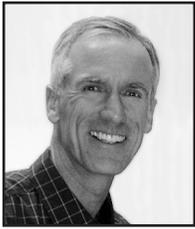


SOUTHWEST RESEARCH-EXTENSION CENTER

# FIELD DAY 2019

**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.



**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.

# FIELD DAY 2019

## Contents

III	2019 Southwest Research-Extension Center Staff
	<i>Weather</i>
1	Weather Information for Tribune
3	Weather Information for Garden City, 2018
	<i>Cropping and Tillage Systems</i>
5	Determining Profitable Forage Rotations
15	Estimating Annual Forage Yields with Plant Available Water and Growing Season Precipitation
21	Integrated Grain and Forage Rotations
29	Alternative Cropping Systems with Limited Irrigation
33	Occasional Tillage in a Wheat-Sorghum-Fallow Rotation
37	Large-Scale Dryland Cropping Systems
42	Tillage Intensity in a Long-Term Wheat-Sorghum-Fallow Rotation
47	Wheat and Grain Sorghum in Four-Year Rotations
52	Seeding Rate for Dryland Wheat
67	Wheat Stubble Height on Subsequent Corn and Grain Sorghum Crops
71	Mobile Drip Irrigation for Water Limited Crop Production: Initial Results
82	2018 Kansas Summer Annual Forage Hay and Silage Variety Trial

### ***Soil Fertility***

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

### ***Weed Science***

- 123 Application Timing Efficacy of Enlist Duo in Irrigated Corn
- 127 Efficacy of Zest Application Timings in Irrigated Acetolactase Synthase-Resistant Grain Sorghum
- 132 Zest Efficacy and Crop Response in Two Acetolactase Synthase-Tolerant Grain Sorghum Hybrids
- 137 Comparisons of Terbutylazine and Atrazine Rates and Tank Mixtures in Irrigated Corn
- 141 Liberty Compared to Glyphosate Products in Irrigated Corn
- 146 Anthem Maxx Tank Mixture Comparisons in Irrigated Corn
- 151 Vida Alone and in Tank Mixtures for Kochia Control in Fallow
- 155 Comparisons of Acuron, Surestart II, and Valor for Residual Weed Control in Grain Sorghum
- 157 Comparison of Preemergence Herbicides for Residual Weed Control in Grain Sorghum
- 161 Split Applications of Coyote and Lumax for Efficacy in Grain Sorghum
- 163 Efficacy of Sequential Herbicide Applications in Glufosinate- and Glyphosate-Resistant Corn
  
- 166 Acknowledgments

# 2019 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 III
Jaylen Koehn	Agricultural Technician II
Scott Maxwell	Agricultural Technician II
Joanna Meier	Accountant I
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
Nick Sower	Agricultural Technician II
Jake Thompson	Irrigation Extension Assistant
Dennis Tomsicek	Agricultural Technician II
Sabrina Valenzuela	Nutrition Assistant
Ashlee Wood	Office Specialist II
Anthony Zukoff	Assistant Scientist

Southwest Research-Extension Center

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 Tribune

## *D. Bond and J. Slattery*

In 2018, annual precipitation of 19.81 in. was recorded, which is 1.91 in. above normal. Only five months had above-normal precipitation. October (3.42 in.) was the wettest month. The largest single amount of precipitation was 1.50 in. on August 7. March, the driest month, only recorded 0.25 in. of precipitation.

Snowfall for the year totaled 17.6 in.; January, February, April, October, November, and December had 5.0, 5.8, 0.5, 1.0, 3.0, and 2.3 in., respectively, for a total of 15 days of snow cover. The longest consecutive period of snow cover, 4 days, occurred December 27 through December 30.

Record-high temperatures were recorded on 3 days: April 13 (89°F); June 16 (105°F); and October 4 (95°F). Record-high temperatures were tied on 6 days: January 11 (72°F), 20 (74°F), and 31 (72°F); March 4 (79°F); and June 6 (101°F) and 10 (103°F). Record-low temperatures were recorded on 3 days: April 7 (13°F); and October 15 (14°F) and 16 (19°F). July was the warmest month with a mean temperature of 76.5°F. The hottest day of the year (105°F) occurred on June 16. The coldest day of the year (-10°F) occurred on January 1. February was the coldest month with a mean temperature of 30.1°F.

Mean air temperature was above normal for 6 months. May had the greatest departure above normal (5.8°F), and October had the greatest departure below normal (-4.0°F). Temperatures were 100°F or higher on 13 days, which is 2 days above normal. Temperatures were 90°F or higher on 77 days, which is 14 days above normal. The latest spring freeze was April 27, which is 9 days earlier than normal; the earliest fall freeze fell on October 10, which is 3 days later than normal. This produced a frost-free period of 166 days, which is 12 days more than the normal of 154 days.

Open-pan evaporation from April through September totaled 68.03 in., which is 3.37 in. below normal. Wind speed for this period averaged 4.7 mph, which is 0.6 mph less than normal.

The 2018 weather information for Tribune is summarized in Table 1.

# WEATHER

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

Month	Precipitation		Monthly average temperatures						Wind		Evaporation	
	2018	Normal	2018		Normal		2018 extreme		2018	Normal	2018	Normal
	in.		Max	Min	Max	Min	Max	Min	mph		in.	
	°F											
January	0.34	0.49	49.1	12.4	44.0	16.2	74	-10	---	---	---	---
February	0.46	0.52	46.1	14.2	47.5	19.4	74	0	---	---	---	---
March	0.25	1.22	63.1	24.5	56.3	26.8	87	12	---	---	---	---
April	1.45	1.45	63.3	29.5	65.7	34.9	90	13	5.5	6.0	7.59	8.27
May	1.84	2.38	82.6	50.5	75.1	46.4	97	38	4.9	5.6	12.93	11.75
June	3.29	2.94	94.0	58.7	85.7	56.6	105	46	5.8	5.2	16.04	14.04
July	2.75	2.85	92.8	60.1	91.8	61.7	103	48	4.3	5.2	13.76	15.58
August	3.15	2.33	86.5	57.5	89.4	60.4	97	48	3.2	4.7	9.28	12.16
September	1.52	1.18	82.9	52.5	81.5	50.6	98	38	4.8	5.0	8.43	9.60
October	3.42	1.49	62.8	35.2	68.9	37.1	95	14	3.5*	4.5*	3.62*	6.09*
November	0.39	0.55	52.6	23.4	54.9	25.7	69	3	---	---	---	---
December	0.95	0.50	46.8	17.0	44.7	17.0	65	2	---	---	---	---
Annual	19.81	17.90	68.7	36.4	67.1	37.7	105	-10	4.7	5.3	68.03	71.40

Normal latest freeze (32°F) in spring: May 6. In 2018: April 27.

Normal earliest freeze (32°F) in fall: October 7. In 2018: October 10.

Normal frost-free (>32°F) period: 154 days. In 2018: 166 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.

# Weather Information for Garden City, 2018

*J. Elliott*

Precipitation for 2018 totaled 25.31 inches. This was 6.07 inches above the 30-year average of 19.24 inches and was the second consecutive year with above normal moisture. The year started out dry, with total moisture for January through May at 48 percent of normal. Then, excellent moisture in June and July resulted in very good summer crop yields. September and October also had above normal rainfall and favorable wheat planting conditions. Small hail was noted on March 18. The largest precipitation events were 3.99 inches falling from June 20 through 25 and 8.63 inches during the last week of July.

Measurable snowfall occurred in January, February, April, October, November, and December. Annual snowfall totaled 13.3 inches compared to an average of 19.7 inches. Seasonal snowfall (2017-2018) was only 1.30 inches, the lowest total since records began in 1956.

Average daily wind speed was 5.13 mph compared to the 30-year average of 5.10 mph. Open pan evaporation was measured daily from April through October, and totaled 76.25 inches. This was 7.51 inches above the 30-year mean of 70.26 inches.

Our mean annual temperature was 54.2°F which was similar to the 30-year average of 53.7°F. Triple-digit temperatures were observed on 10 days in 2018, with the highest being 104°F on July 20. Five record high temperatures were equaled or exceeded in 2018: 74°F on January 11, 87°F on March 24, 95°F on April 13, 102°F on June 2, and 97°F on October 4.

Sub-zero temperature occurred three times in 2018. The lowest temperature was -8°F noted on January 1. Six record low temperatures were equaled or exceeded: -8°F on January 1, 15°F on April 15, 23°F on April 16, 52°F on August 1, and 21°F again on October 15 and 16.

The last spring freeze was 32°F on April 26, which was three days earlier than the 30-year average. The first fall freeze was 31°F on October 14, which was two days later than normal. This resulted in a 171 day frost-free period, which is six days longer than the 30-year average.

The 2018 climate information for Garden City is summarized in Table 1.

# WEATHER

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

Month	Precipitation		Monthly temperatures						Wind		Evaporation	
	2018	avg.	2018 avg.			2018 extreme			2018	30-year avg.	2018	30-year avg.
			Max	Min	Mean	Max	Min	30-year avg.				
	----- in. -----		°F						----- mph -----		----- in. -----	
January	0	0.46	50.0	13.5	31.8	30.4	74	-8	3.93	4.50	--	--
February	0.02	0.55	48.1	15.2	31.6	33.9	78	1	5.16	5.24	--	--
March	0.37	1.31	64.0	28.3	46.1	42.9	87	13	6.05	6.31	--	--
April	0.78	1.74	64.5	30.1	47.3	52.3	95	15	7.03	6.42	8.38	8.21
May	2.18	2.98	85.1	54.4	69.7	62.8	97	40	5.78	5.76	12.03	10.04
June	4.2	3.12	93.3	63.1	78.2	72.6	103	47	6.64	5.37	16.65	11.96
July	8.84	2.8	92.6	64.8	78.7	77.9	104	53	4.29	4.59	14.19	13.22
August	1.63	2.51	88.4	60.9	74.6	76.3	100	52	4.13	4.11	10.68	11.28
September	2.05	1.42	83.2	57.8	70.5	67.7	103	42	5.68	4.73	9.45	9.22
October	3.07	1.21	65.2	38.4	51.8	54.9	97	21	4.57	4.89	4.87	6.33
November	0.25	0.55	52.9	23.3	38.1	41.6	67	3	4.26	4.80	--	--
December	1.92	0.59	47.1	17.8	32.5	31.4	62	2	4.06	4.45	--	--
Annual	25.31	19.24	69.5	38.9	54.2	53.7	104	-8	5.13	5.10	76.25	70.26

Normal latest spring freeze (32°F): April 29. In 2018: April 26.

Normal earliest fall freeze (32°F): Oct. 12. In 2018: Oct 14.

Normal frost-free period (>32°F): 165 days. In 2018: 171 days.

30-year averages are for the period 1981-2010. All recordings were taken at 8:00 a.m.

# Determining Profitable Forage Rotations

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

## Summary

Annual forages are an important crop in the High Plains, yet the region lacks recommended annual forage rotations compared to those developed for grain crops. Forages are important for the region's livestock and dairy industries and are becoming increasingly important as irrigation capacity and grain prices decrease. Forages require less water than grain crops and may allow for increased cropping system intensity and opportunistic cropping. A study was initiated in 2012 at the Southwest Research-Extension Center near Garden City, KS, comparing several 1-, 3-, and 4-year forage rotations with no-tillage and minimum-tillage. Data presented are from 2013 through 2018. Tillage generally increased winter triticale yields by 700 lb/a or 30% compared to no-till yields, due largely to increased plant available water. Plant available water at planting winter triticale averaged 5.9 in./a in min-till and 3.9 in./a in no-till. Double-crop forage sorghum yielded 17% less than full-season forage sorghum and yields were not affected by tillage. Oat yields were lower than forage sorghum or winter triticale, averaging 2,100 lb/a across years. Subsequent years will be used to further compare forage rotations, develop crop-water relationships, and establish partial enterprise budgets.

## Introduction

To stabilize crop yields, dryland rotations in western Kansas commonly include fallow to accumulate soil water. Fallow is relatively inefficient at storing and utilizing precipitation when compared to storage and utilization of precipitation received during the growing season. Fallow periods increase soil erosion and organic matter loss (Blanco and Holman, 2012), and represent a large economic cost to producers. Forages are valuable feedstuff to the cow/calf, stocker, cattle feeding, and dairy industries throughout the region (Hinkle et al., 2010). Forages do not require as much water to make a crop as grain crops. Forages grown in place of fallow can increase precipitation use efficiency, improve soil quality, and increase profitability (Holman et al., 2018). This study tests several forage rotations for water use efficiency, forage quality, yield, and profitability.

Annual forages are grown for a shorter period and require less water than traditional grain crops. Including annual forages into the crop rotation might enable increasing cropping system 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. Wheat yields following spring annual forages such as oat (O) were similar to wheat yields following fallow in a wheat-fallow rotation in non-drought years, but wheat yields were reduced in drought years (Holman et al., 2012). This indicates the opportunity to intensify the cropping system in favorable years. Forage producers in the region commonly grow continuous winter triticale (T), winter triticale or summer crop silage, or forage sorghum hay (S). However, they lack a proven rotation concept for forages such as that developed for grain crops (e.g. winter wheat-summer crop-fallow). Continuous winter triticale often develops winter annual grass problems, while continuous forage sorghum produces lower quality forage than triticale. Producers are interested in identifying forage rota-

tions that increase pest management control options, spread out equipment and labor resources over the year, reduce the impact of variable weather risks, and increase profitability. Growing forages throughout the year greatly reduces the risk of crop failure due to variable precipitation.

Growing winter triticale (T) or forage sorghum (S) double cropped (T/S/T), yielded 30% less than non-double crop yields (T-S-O) ( $P \leq 0.05$ ) near Garden City, KS, between 2007 and 2010. Double cropping increased forage production's annual yield 40% more than growing one crop annually (Holman et al., 2012). However, crop establishment was more challenging and crop growth was highly dependent on growing season precipitation in the double-crop rotation compared to annual cropping. Due to the high cropping intensity it was also challenging to implement timely field operations in the double crop system. An intermediate cropping intensity of three crops grown in two years or four crops in three years might be a successful crop rotation in western Kansas.

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

### ***Study Objectives***

1. Identify and characterize profitable forage cropping systems.
2. Determine the effect of occasional strategic tillage on herbicide-tolerant weeds, forage system yield, profit, and soil health.

### **Experimental Procedures**

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

### ***Treatments Included***

1. Continuous forage sorghum (no-tillage): (S-S)
2. Year 1: winter triticale/double-crop forage sorghum; Year 2: forage sorghum; Year 3: spring oat (no-tillage): (T/S-S-O no-tillage)

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

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

## Results and Discussion

### *Rotation Yield*

Annual rotation yield was determined by measuring total yield for the rotation and dividing by the number of years in the rotation. This method allowed for comparing rotations of different years to each other for annual forage production (Table 1 and Figure 1). A very dry year in 2013 resulted in low crop yields and no spring oat yield. In 2013, S-S produced the highest annual yield. In 2014, annual yield was comparable across treatments except for T/S-S-O (no-tillage), which had lower yield than T/S-S-S-O (min-tillage) and was comparable to all other treatments. The crop rotation of T-S-O was not in phase until 2015, so no comparison was made to that rotation until 2015. In 2015, T/S-S-O (no-tillage) yielded less than S-S, but more than T-S-O and comparable to all other treatments. The T-S-O annual yield was less than all other treatments in 2015. Between 2016 and 2018, precipitation primarily occurred in late spring and summer, which favored forage sorghum yield. The highest yielding rotations in 2016 through 2018 were S-S, followed by T/S-S-S-O, and T-S-O yielded the least. Tillage generally increased the yield of triticale and thus the yield of T/S-S-O was im-

proved with tillage, but yield improvement in the 4-yr rotation was not as evident due to triticale occurring less frequently in the rotation.

Forage yield per crop harvest was determined for each rotation since planting and harvesting expenses are the major expenses to growing a crop; yield and value per ton are the major income components. Crop rotations with greater yield per harvest are likely to be more profitable compared to rotations with low yield per harvest since some of the variable and fixed expenses are less. Although oat and triticale yield less than forage sorghum, they are also higher in crude protein and digestibility and are worth more per unit than forage sorghum. A full economic analysis of rotations will be completed at the conclusion of this study. In 2013, S-S had the greatest yield per harvest, and all other rotations had similar yields per harvest (Table 1 and Figure 2). In 2014, T/S-S-O (no-tillage) had lower average harvest yields than S-S or T/S-S-S-O (min-tillage), but was similar to T/S-S-O (min-tillage) and T/S-S-S-O (no-tillage). In 2015, S-S had the greatest yield per harvest, and T-S-O had the lowest yield per harvest, which was less than S-S or T/S-S-S-O (no-tillage), but comparable to the other treatments. Between 2016 and 2018, S-S had the greatest yield per harvest and T-S-O had the least. Sorghum has the greatest yield potential of the three crops investigated, but S-S does not allow for crop diversification, improved weed management, higher forage quality (oats and triticale), or the ability to reduce weather risk by growing a crop during different times of the year.

### ***Crop Yield***

Full-season sorghum either grown after T/S or S yielded similarly across rotations (Figure 3). Double-crop forage sorghum yielded less than full-season forage sorghum, but varied greatly from year to year based on precipitation during the growing season. Double crop forage sorghum yielded 70% less than full-season in 2013, 7% less in 2014, 12% less in 2015, 10% less in 2016, 38% less in 2017, and 15% less in 2018. Across all years, double-crop (6,160 lb/a) averaged 17% less than full-season forage sorghum (7,460 lb/a). The lower yield of double-crop forage sorghum was due to less available soil moisture at planting. Sorghum yield was not affected by tillage or length of rotation, although there was a tendency for no-till forage sorghum yields to be greater than min-till yields.

Triticale yield was not affected by length of rotation but was affected by tillage. Averaged across years, triticale in min-tillage (3,260 lb/a) yielded 128% more than no-tillage (2,550 lb/a). The only tillage in this study occurred in the fallow period before triticale and, in this study, benefitted the triticale crop. The exception was in 2017 when no-till (1,869 lb/a) yielded more than min-till (1,518 lb/a). Other studies and producers have found tillage ahead of a winter wheat crop has minimal impact on yield and can improve weed control, but tillage ahead of grain sorghum often reduced grain yield. For these reasons, tillage was only used ahead of triticale and, similar to winter wheat, did not reduce yields, but actually increased yields in the first 4 years of this study.

Oats failed to make a crop in 2013 due to drought conditions and varied by year due to differences in growing season conditions. Oat forage yield was 400 lb/a in 2014, 4,900 lb/a in 2015, 2,300 lb/a in 2016, 883 lb/a in 2017, and 300 lb/a in 2018. Yields

in 2015 and 2016 were higher than other years due to very favorable spring precipitation and cool temperatures. Oat yield was not affected by tillage or crop rotation.

### ***Soil Water***

Plant available water at planting was measured to a 6-foot soil depth, and soil water content varied by year and planting period. Soil water was greatest for full-season forage sorghum planting averaging 7.7 in. across treatments, which was more than double crop forage sorghum that averaged 5.6 in. No-till triticale (3.9 in.) was less than min-till triticale (5.9 in.). At oat planting (March) PAW averaged 3.9 in. (Figure 4).

Water use efficiency (WUE) was greatest in forage sorghum, with full-season averaging 597 lb/a/in. and double-crop producing 555 lb/a/in. Water use efficiency for winter triticale averaged 343 lb/a/in., and oat was 250 lb/a/in. The yield potential and thus water use efficiency was greater with forage sorghum than triticale or oat. However, when precipitation was favorable during a particular growing season, such as oat in 2015, the WUE of oat was comparable to forage sorghum. In years with moisture stress, WUE of double-crop forage sorghum was less than full-season, but in favorable moisture years WUE of double-crop was greater than full-season (Figure 5).

Precipitation storage efficiency (PSE) varied by fallow period and ranged from 9% ahead of winter triticale to 40% for full-season forage sorghum. Precipitation storage ahead of double-crop forage sorghum was 32% and ahead of oat planting was 22% (Figure 6).

## **References**

- Blanco, H. and J. Holman. 2012. Cover crops reduce wind and water erosion. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Report of Progress. SRP1070:7-11.
- Hinkle, J.B., J.T. Vasconcelos, S.A. Furman, A.S. deMello, L.S. Senaratne, S. Pokharel, C.R. Calkins. 2010. Sensory attributes of beef from steers fed field peas. 2010 Nebraska Beef Report pg. 117-118. University of Nebraska-Lincoln, Dept. of Animal Science.
- Holman, J.D., K. Arnet, J. Dille, S. Maxwell, A.K. Obour, T. Roberts, K. Roozeboom, and A. Schlegel. 2018. Can cover (or forage) crops replace fallow in the semiarid central Great Plains? *Crop Sci.* 58:1-13.
- Holman, J., T., Dumler, T. Roberts, and S. Maxwell. 2012. Fallow replacement crop effects on wheat yield. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Report of Progress. 1070:24-29.
- 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

# CROPPING AND TILLAGE SYSTEMS

**Table 1. Rotation treatment yields across years between 2013 and 2018**

Crop rotation	2013	2014	2015	2016	2017	2018	2015–18	2013–18
							Average <sup>†</sup>	Average <sup>‡</sup>
Total treatment yield (DM lb/a)								
S-S	4262	7426	10244	8025	5954	5799	7505	6952
T/S-S-O (no-till)	3451	13322	25732	16067	13387	12290	16869	14042
T/S-S-O (min-till)	4020	20130	28742	18404	11690	14548	18346	16256
T/S-S-S-O (no-till)	7702	27260	38091	27320	19382	19268	26015	23171
T/S-S-S-O (min-till)	8896	30266	36394	23831	17411	20451	24522	22875
T-S-O <sup>§</sup>	*	*	18404	10060	9583	6853	11225	---
Annualized treatment yield (DM lb/a)								
S-S	4262	7426	10244	8025	5954	5799	7505	6952
T/S-S-O (no-till)	1150	4441	8577	5356	4462	4097	5623	4681
T/S-S-O (min-till)	1340	6710	9581	6135	3897	4849	6115	5419
T/S-S-S-O (no-till)	1926	6815	9523	6830	4845	4817	6504	5793
T/S-S-S-O (min-till)	2224	7566	9099	5958	4353	5113	6130	5719
T-S-O	*	*	6135	3353	3194	2284	3742	3742
LSD <sub>0.05</sub> <sup>¶</sup>	1508	3038	1488	801	1391	1306	789	---
Yield per harvest (DM lb/a)								
S-S	4262	7426	10244	8025	5954	5799	7505	6952
T/S-S-O (no-till)	863	3331	6433	4017	3347	3072	4217	3510
T/S-S-O (min-till)	1005	5032	7185	4601	2922	3637	4586	4064
T/S-S-S-O (no-till)	1540	5452	7618	5464	3876	3854	5203	4634
T/S-S-S-O (min-till)	1779	6053	12131	4766	3482	4090	6118	5384
T-S-O	*	*	3681	3353	3194	2284	3128	3128
LSD <sub>0.05</sub>	1323	2566	1331	693	1248	1108	663	---

<sup>†</sup>Average of years 2015–2018.

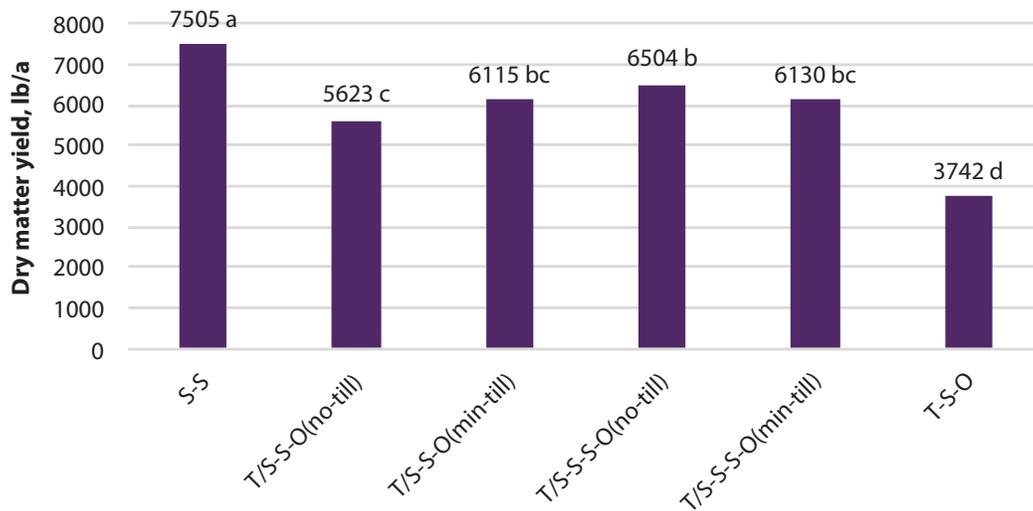
<sup>‡</sup>Average of years 2013–2018.

<sup>§</sup>T-S-O treatment started in 2015.

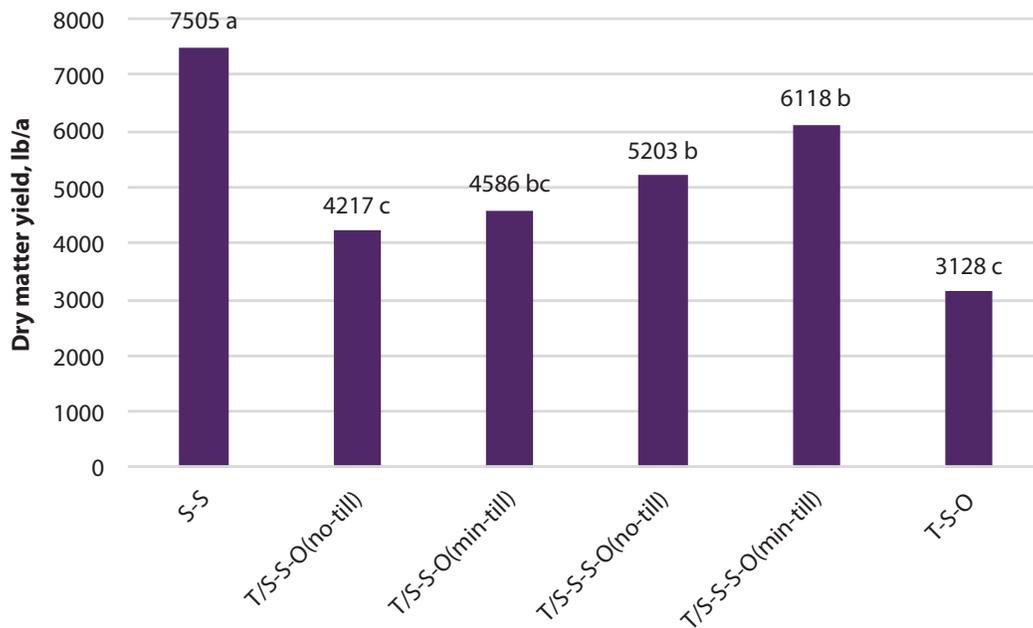
<sup>¶</sup>Means in columns separated by LSD in column are statistically different at  $P \leq 0.05$ .

S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

## CROPPING AND TILLAGE SYSTEMS



**Figure 1.** Forage dry matter annual yield for all crop rotations averaged across years from 2015 to 2018. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.



**Figure 2.** Forage dry matter yield per harvest for all crop rotations averaged across years from 2015 to 2018. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

## CROPPING AND TILLAGE SYSTEMS

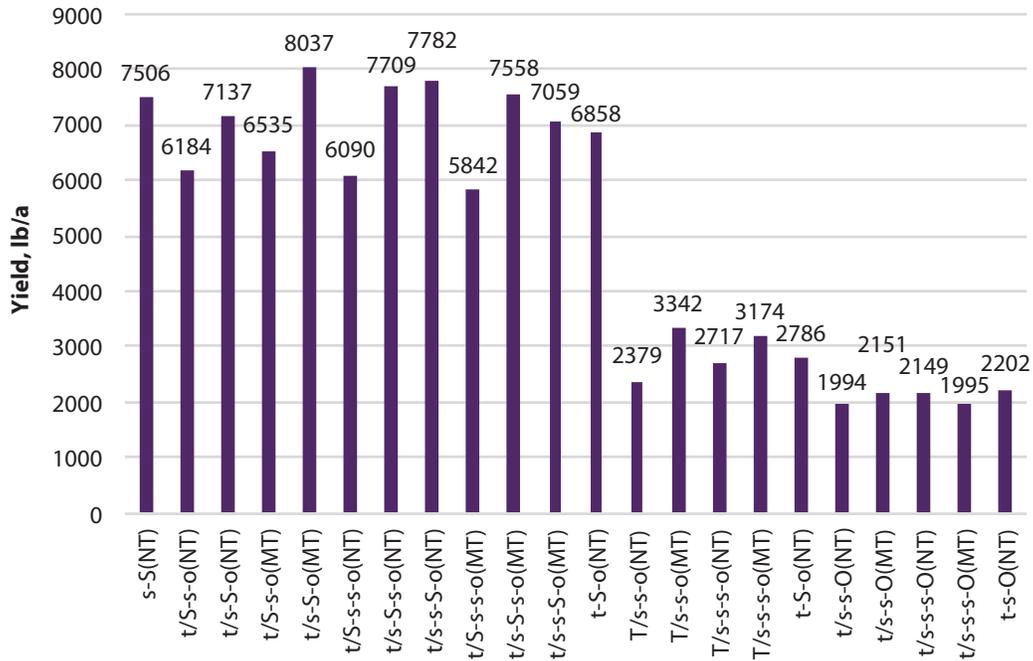


Figure 3. Forage dry matter yield for all crop rotations and phases averaged across years from 2013 to 2018. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

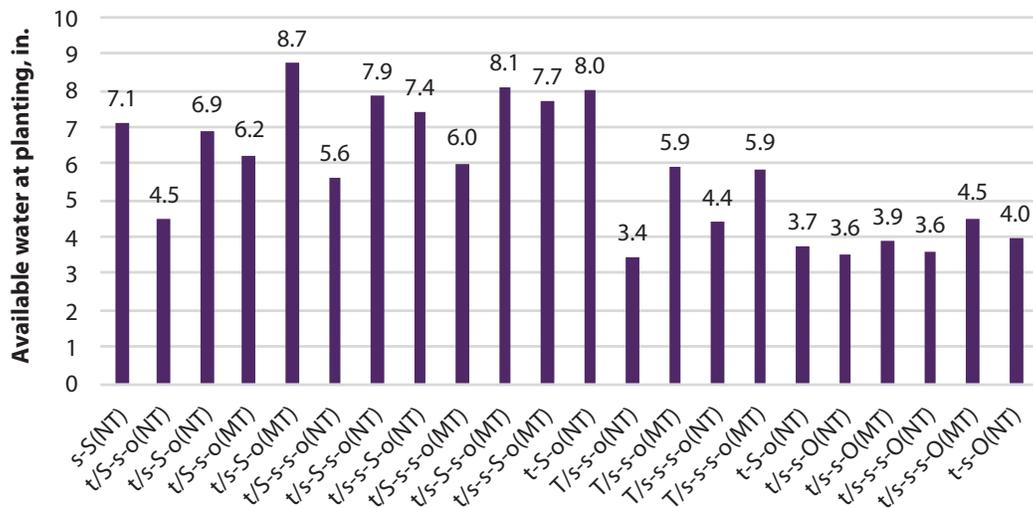


Figure 4. Plant available water in a 6-ft soil profile at planting for all crop rotations and phases averaged across years from 2013 to 2018. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

# CROPPING AND TILLAGE SYSTEMS

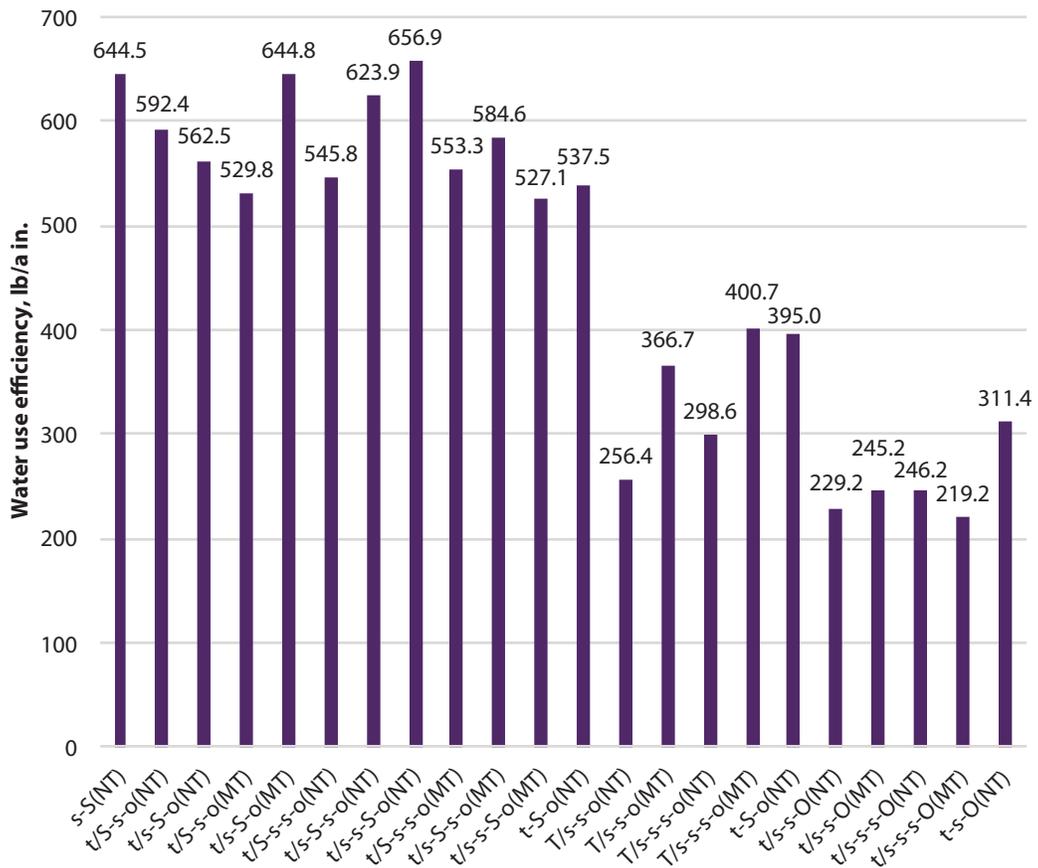
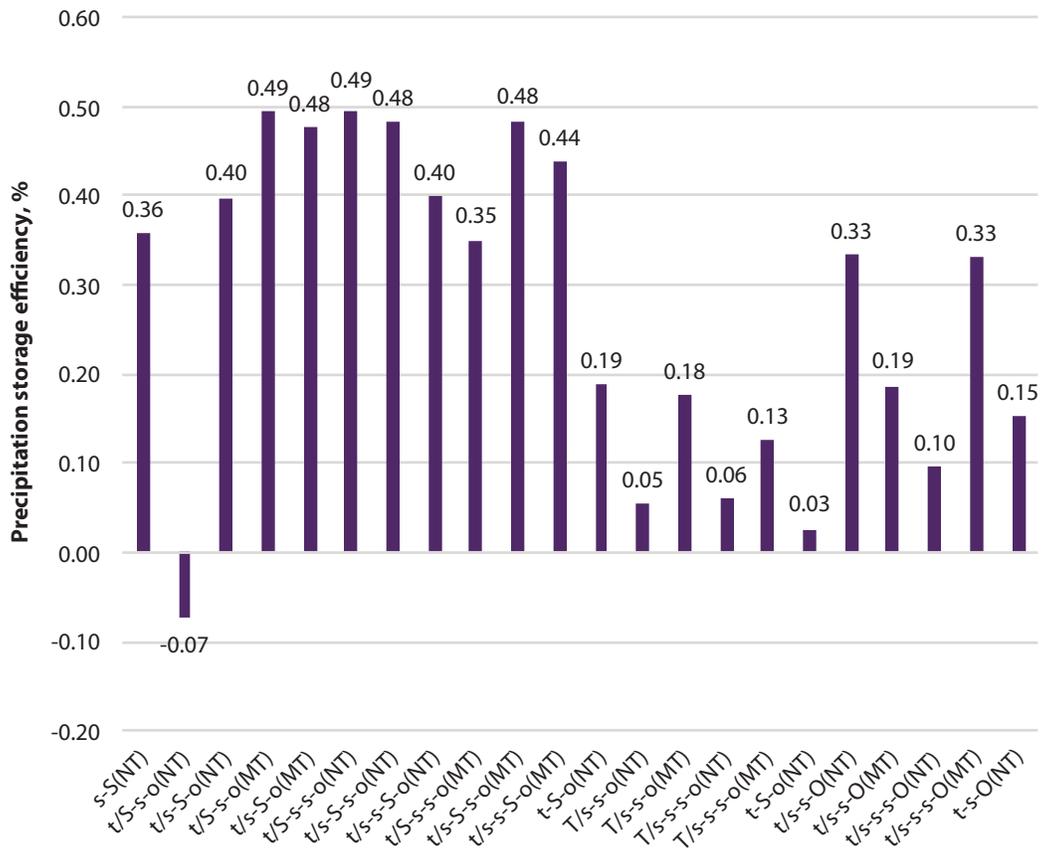


Figure 5. Water use efficiency (WUE) [forage dry matter yield/((ending-beginning soil water content) + growing season precipitation)] for all crop rotations and phases averaged across years from 2013 to 2018. Crop is identified by capitalization in X axis. S: Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

## CROPPING AND TILLAGE SYSTEMS



**Figure 6.** Precipitation storage efficiency (PSE) [precipitation/(ending-beginning soil water content)] for the fallow period preceding the crop for all crop rotations and phases averaged across years from 2013 to 2018. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

# 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. Preliminary results showed PAW and GSP explained 26% of the variability in forage sorghum yield. Winter triticale yield increased by 640 lb/a for every inch of water use (PAW plus GSP). However, spring triticale produced only 193 lb/a for every inch of water use. The low correlation with water use and spring triticale yield suggests other factors, such as temperature, affect spring forage production more than soil moisture.

## 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 could 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 2018, and spring triticale from 2012 through 2018.

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 at approximately the end of August. Forage yields were determined from a 3- × 30-ft area cut 3 in. high using a small plot Carter forage harvester for each plot. Forage yield was measured at each harvest. Gravimetric soil moisture content was measured at planting and harvest to a depth of 6 ft using 1-ft increments. Precipitation storage efficiency (percent of precipitation stored during the fallow period) was quantified for each fallow period, and crop water use efficiency (forage yield divided by soil water used plus precipitation) was determined for each crop harvest. Crop yield response to plant available water at planting was regressed to estimate yield. These yield data will eventually be used to develop a yield prediction model based on historical or expected weather conditions when sufficient years of data are obtained.

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

## Results and Discussion

### *Winter Triticale*

Winter triticale forage yield was correlated to PAW and GSP, although yield response was highly variable. Plant available water explained approximately 12% and GSP explained 2% of the variability in forage yield (Figures 1 and 2). Together, PAW and GSP explained 48% of the variability in forage yield (Figure 3). For every inch of water used (soil water plus GSP), yield was increased 640 lb/a. Averaged across the study period, yield was 3,400 lb/a.

### *Spring Triticale*

Spring triticale forage yield was significantly correlated to PAW and GSP, but yield response was highly variable. Plant available water explained approximately 5% and GSP explained 8% of the variability in forage yield (Figures 4 and 5). Combining PAW and GSP explained only 14% of the yield variability; suggesting something other than moisture, most likely temperature, greatly impacts yield (Figure 6). In years with cool spring temperatures, spring growth is promoted, but if temperatures become high, growth is stopped. For every inch of water used (soil water plus GSP), yield was increased 193 lb/a. Averaged across the study period, yield was 1,400 lb/a.

### *Forage Sorghum*

Forage sorghum yield was correlated to PAW but not GSP, and yield response was variable. Plant available water explained approximately 19% and GSP explained 7% of the variability in forage yield (Figures 7 and 8). Together, PAW and GSP explained 26% of the variability in forage yield (Figure 9). For every inch of water used (soil water plus GSP), yield was increased 445 lb/a. Averaged across the study period, yield was 5,700 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

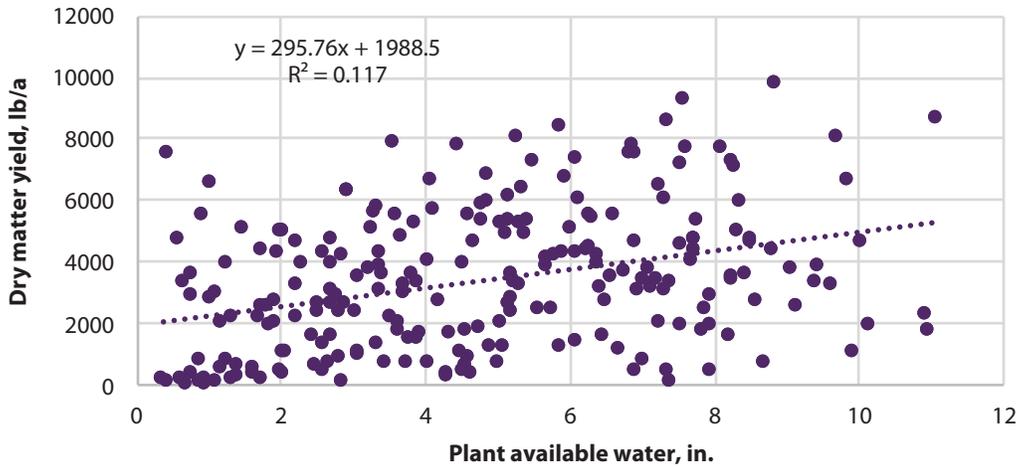


Figure 1. Winter triticale yield response to plant available water at planting.

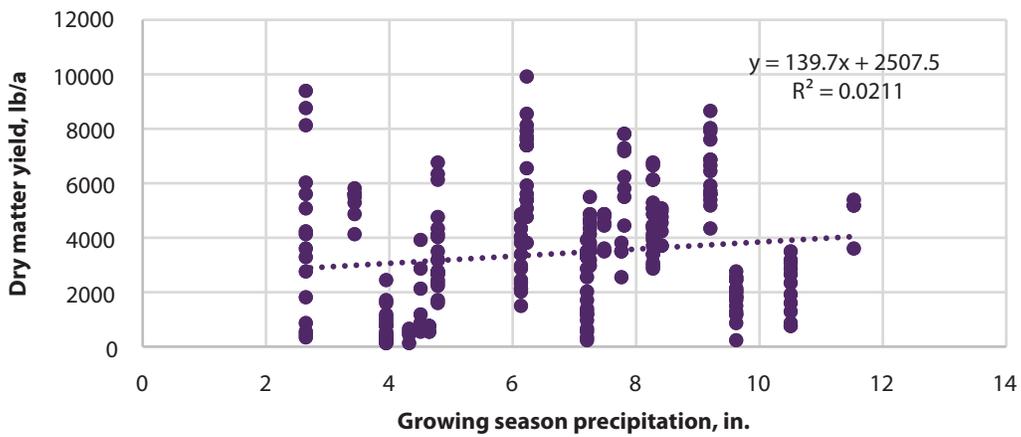


Figure 2. Winter triticale yield response to growing season precipitation.

# CROPPING AND TILLAGE SYSTEMS

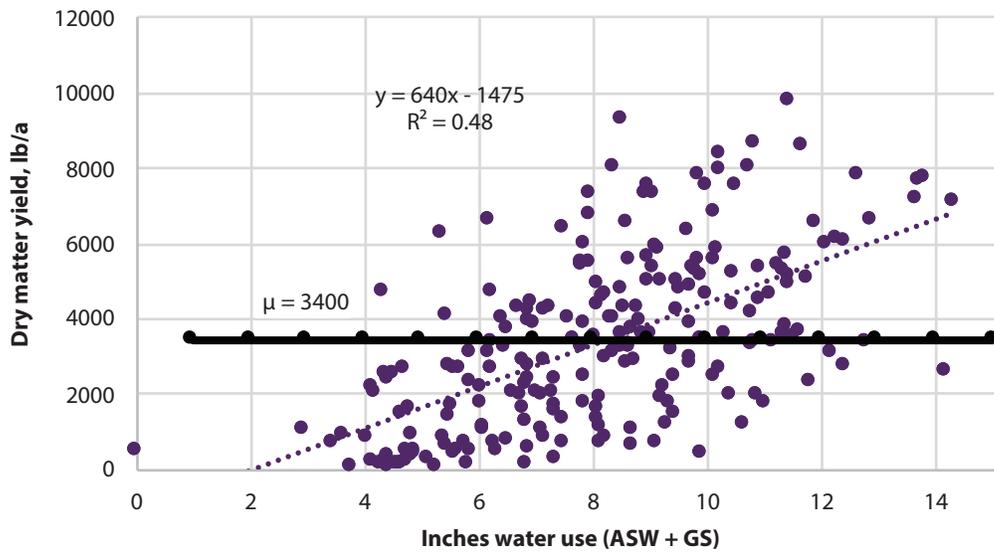


Figure 3. Winter triticale yield response to water use (available soil water (ASW) plus growing season (GS) precipitation) and average yield (bold line) across the study period.

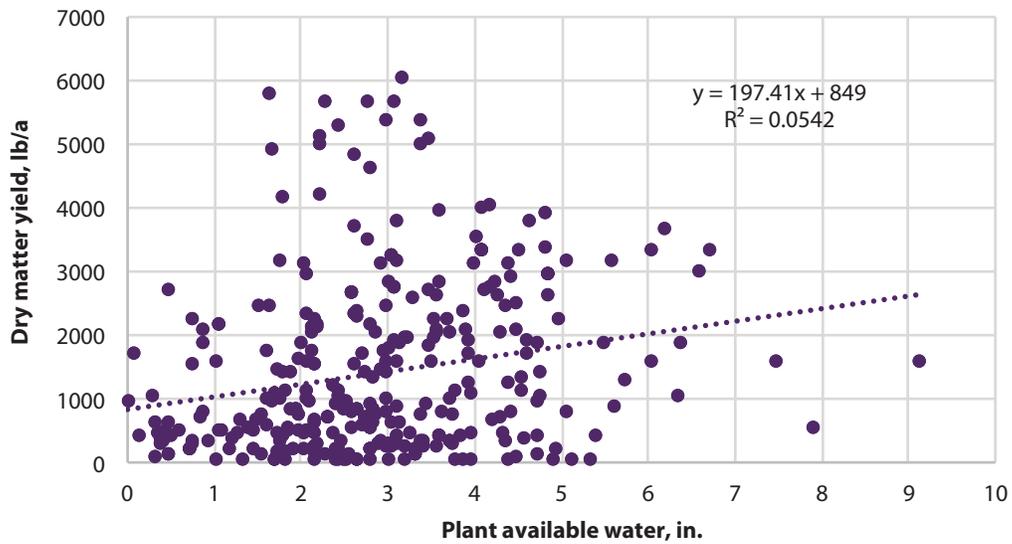


Figure 4. Spring triticale yield response to plant available water at planting.

# CROPPING AND TILLAGE SYSTEMS

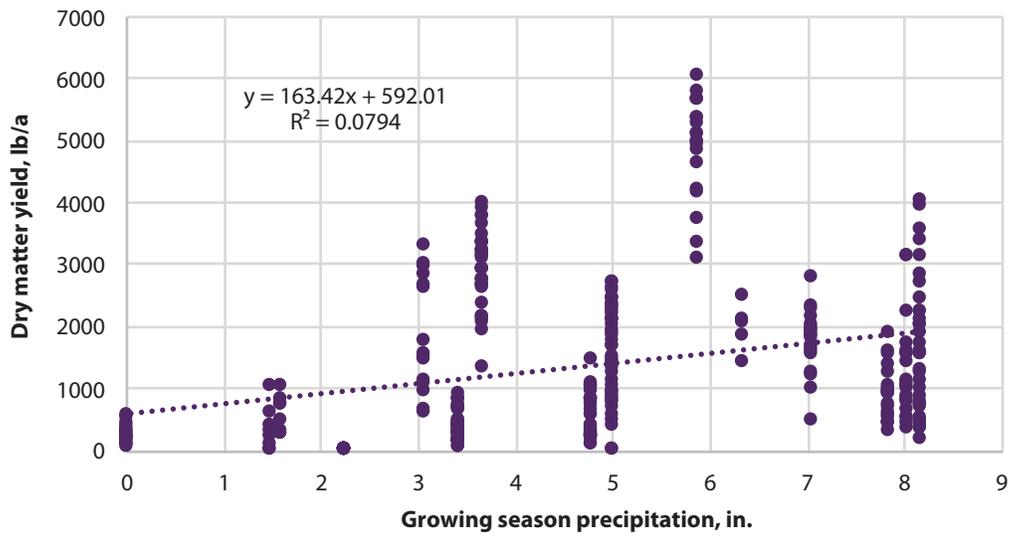


Figure 5. Spring triticale yield response to growing season precipitation.

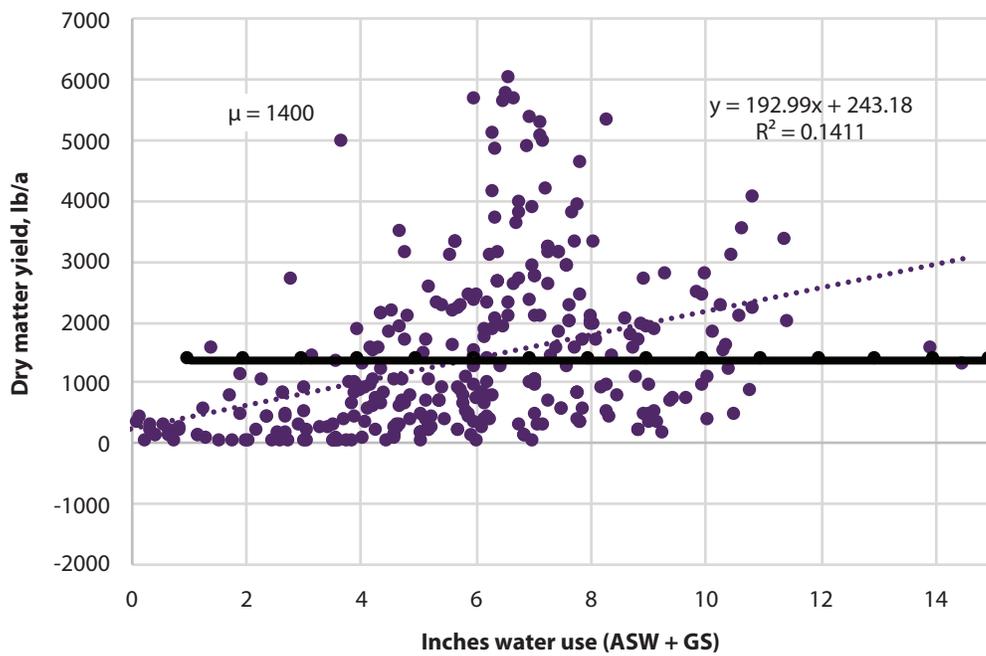


Figure 6. Spring triticale yield response to water use (available soil water (ASW) plus growing season (GS) precipitation) and average yield (bold line) across the study period.

# CROPPING AND TILLAGE SYSTEMS

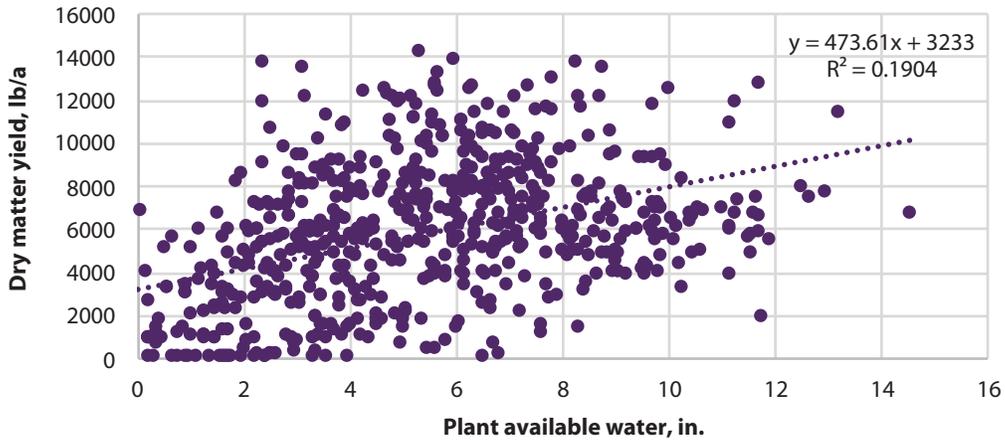


Figure 7. Forage sorghum yield response to plant available water at planting.

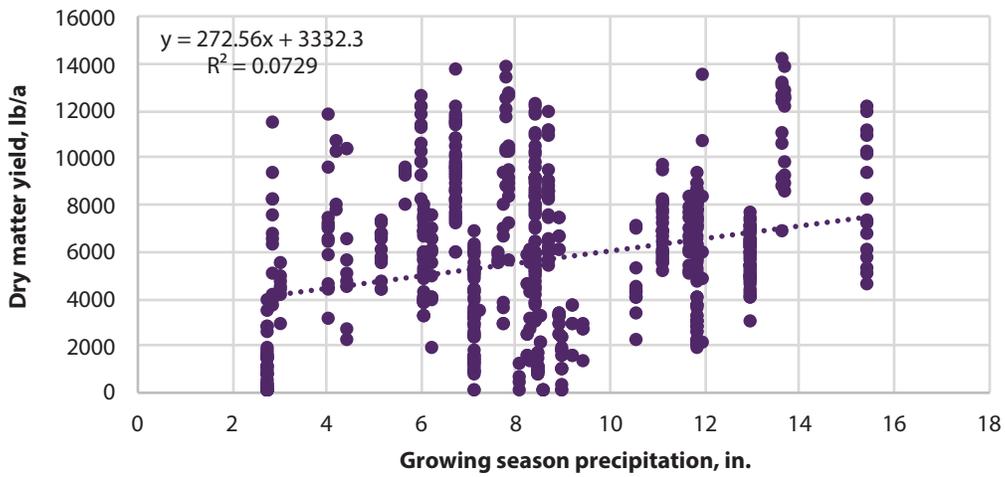


Figure 8. Forage sorghum yield response to growing season precipitation.

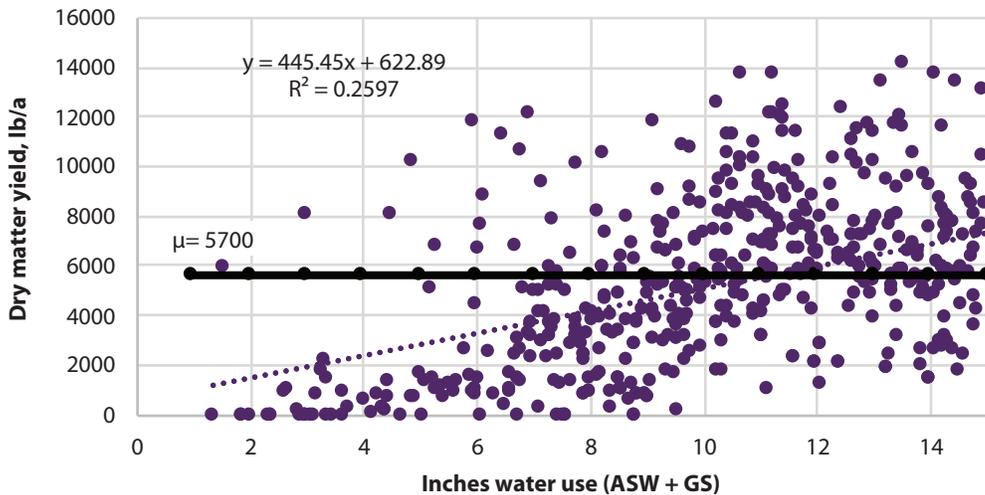


Figure 9. Forage sorghum yield response to water use (available soil water (ASW) plus growing season (GS) precipitation) and average yield (bold line) across the study period.

# Integrated Grain and Forage Rotations

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

## Summary

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

This study started in 2013, with crops grown in-phase beginning in 2014. Results showed grain crops were more sensitive to moisture stress than forage crops. Growing a double-crop forage sorghum after winter wheat reduced grain sorghum yield the second year, but did not reduce second-year forage sorghum yield. Growing a double-crop forage sorghum, followed by second-year forage sorghum, could intensify and increase profitability of the cropping system. Since other research has found cropping intensity should be reduced in dry years, caution should be used when planting double-crop forage sorghum by evaluating the soil moisture conditions and precipitation outlook after wheat harvest. The “flex-fallow” concept could be used to make a decision on whether to plant double-crop forage sorghum to increase the chance of improving cropping system profitability. This research showed forages are more tolerant to moisture stress than grain crops and the potential exists to increase cropping intensity by integrating forages into the crop rotation.

## Introduction

Interest in growing forages and reducing fallow has necessitated research on soil, water, and crop yields in intensified grain/forage rotations. Fallow stores moisture, which helps stabilize crop yields and reduces the risk of crop failure. However, only 25–30% of the precipitation received during the fallow period of a no-till wheat-sorghum-fallow rotation is stored. The remaining 75–70% precipitation is lost, primarily due to evaporation. Moisture storage in fallow is more efficient earlier in the fallow period, when the soil is dry, and during the winter months when the evaporation rate is lower. It may be possible to increase cropping intensity without reducing crop yields by using forage crops in the rotation. This study evaluated integrated grain/forage rotations compared to traditional grain-only crop rotations.

## Experimental Procedures

A study beginning in 2013 at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated various integrated grain and forage rotations compared to a no-till wheat-grain sorghum-fallow rotation. All phases of the rotation were present each year and in-phase by 2014. A total of 10 crop rotations were evaluated (Table 1). The study design was a split-plot randomized complete block design with four replications. Crop phase (wheat-sorghum-fallow) was the main plot and alternative crop choices were the split-plot. Each split-plot was 30-ft wide × 120-ft long.

“Flex-fallow” is a spring planting decision based on current soil moisture condition and seasonal outlook. Spring oats were planted when 12 inches or more of plant available water (PAW) was determined available by using a Paul Brown moisture probe, and seasonal precipitation forecasted outlook was neutral or favorable; otherwise the treatment was left fallow. The flex-fallow treatment was intended to take advantage of growing a crop during the fallow period in wet years and fallowing in dry years. A flex-fallow crop was planted in 2013, 2016, and 2019, but not in 2014, 2015, 2017, or 2018.

Each year, winter triticale was planted approximately October 1. Spring crops were planted as early as soil conditions allowed, ranging from the end of February through the middle of March. Wet spring conditions delayed planting in 2019. Spring forage crops were harvested approximately June 1. Forage sorghum was either planted around June 1 for full-season or following wheat harvest around July 1 for double-crop. Forage biomass yields were determined from a 3- × 120-ft area cut 3 in. high using a small plot Carter forage harvester. Winter wheat and grain sorghum were harvested with a small plot Wintersteiger combine from a 6.5- × 120-ft area at grain maturity.

Volumetric soil moisture content was measured at planting and harvest of winter wheat, grain sorghum, forage sorghum, spring oat, or fallow using a Giddings soil probe by 1-ft increments to a 6-ft soil depth. In addition, volumetric soil content was measured in the 0–3 in. soil depth at wheat planting to quantify moisture in the seed planting depth. Grain yield was corrected for moisture content, and test weight was measured using a grain analysis computer (GAC 2100, Dickey-John). Seed weight was determined from a 1,000-seed count using a seed counter computer (801, Seedburo). Grain samples were analyzed for nitrogen content.

## Results and Discussion

### *Winter Wheat*

Winter wheat yield, plant available moisture at planting, water use efficiency, and precipitation storage efficiency prior to planting were not affected by whether forage sorghum or grain sorghum were grown in place of one another in the rotation (Figure 1). Wheat yields were low and treatments averaged 14 bu/a or less from 2015 through 2018. Wheat yield was low in all years due to severe rabbit feeding and dry conditions. A flex-crop was grown in 2013, 2016, and 2019, but not 2014, 2015, 2017, or 2018. Dry conditions developed soon after planting a flex-crop in 2013, and growing a flex-crop in place of fallow reduced wheat yield 67% in 2014 and did not affect 2017 yield. Dry fall conditions and rabbit feeding killed the wheat crop in 2016 and there was no yield that year. Soil moisture was dry in the fall of 2017 and some of the wheat did not emerge until spring. Conditions were again very dry during the winter and spring of 2018.

Previous research found growing oats in place of fallow reduced wheat yields when wheat yield potential was less than 50 bu/a. For the years of this study, extreme dry weather and rabbit feeding masked any differences in wheat yield attributed to the treatments.

### *Grain Sorghum*

Grain sorghum yield was highly correlated with plant available moisture at planting, which explained 40% of the variability in grain yield (Figure 2). Including growing season precipitation in the model did not improve yield predictability (data not shown). Approximately 7.2 bushels were grown for every acre-inch of plant available water at planting. Plant available moisture was highest when forage sorghum was not double-cropped between wheat and grain sorghum (Figure 3). Higher wheat yields and residue levels improved the WUE of grain sorghum. Growing double-crop forage sorghum ahead of grain sorghum reduced grain sorghum yield 61% in 2014, 38% in 2015, 20% in 2016, 56% in 2017, and 20% in 2018. Averaged across years, growing a double-crop forage sorghum reduced the subsequent grain sorghum crop yield by 36%. Growing a forage sorghum crop after wheat reduced the amount of plant available water at planting and water use efficiency of the subsequent grain sorghum crop each year, but did not affect precipitation storage efficiency in the fallow period ahead of grain sorghum. Growing a forage sorghum crop reduced the test weight and seed weight of grain sorghum in 2015 and seed weight in 2017 and 2018.

### *Forage Sorghum*

Forage sorghum yield was also correlated with plant available moisture at planting, but not as much as grain sorghum. Plant available moisture at planting explained approximately 17% of the variability in forage yield (Figure 4). By including growing season precipitation in the model, 38% of the variability in forage yield was explained (Figure 5). Approximately 450 lb of forage was grown for every inch of plant available water (PAW) at planting.

Forage sorghum yields were not different across treatments in 2014, except double-crop FS in winter wheat/forage sorghum-forage sorghum-spring oat (ww/FS-fs-o) yielded 2,200 lb/a less than full-season forage sorghum in the same rotation of winter wheat/forage sorghum-forage sorghum-spring oat (ww/fs-FS-o) (Table 4). This lower yield was most likely due to less plant available water at planting, 1.3 versus 2.1 inches. In 2014, plant available water averaged 1.0 inch ahead of double-crop forage sorghum and 4.1 inches ahead of full season forage sorghum. Most of the annual precipitation in 2014 occurred later in the year (June-September), which likely helped improve the yield of double-crop forage sorghum relative to full-season forage sorghum. In 2014, double-crop forage sorghum yielded, on average, 17% less than full-season forage sorghum (3,300 versus 3,900 lb/a). In 2015, most of the precipitation occurred earlier in the year (May-August) than 2014, which helped increase wheat yields but also resulted in comparatively less moisture at planting time of double-crop forage sorghum, 1.6 versus 7.2 inches. As a result, 2015 double-crop forage sorghum yields were reduced 70% compared to full-season forage sorghum (2,400 versus 8,000 lb/a). In 2016, moisture conditions were favorable during the growing season (June-August), resulting in good forage yields across all treatments. There were 0.8 inches more PAW at planting of the full-season compared to double-crop forage sorghum. Double crop yields were reduced on average 43% compared to full-season forage sorghum (3,900 vs. 6,900 lb/a). In 2017, most of the precipitation occurred during the spring of the year, which increased moisture storage during the fallow period but little moisture during the growing season, resulting in low yields in the double-crop forage sorghum crop. Full season forage sorghum averaged 6,700 lb/a and double-crop averaged 1,000 lb/a. In 2018, most of the

precipitation fell during the second half of the growing season, resulting in good forage yields for both double and full-crop. Full season forage sorghum averaged 10,600 and double-crop averaged 8,200 lb/a. Between 2014 and 2018 full-season sorghum averaged 7,200 and double-crop averaged 4,000 lb/a.

Surprisingly, second-year forage sorghum yields following double-crop forage sorghum were similar to full-season forage sorghum following wheat with fallow between wheat harvest and sorghum planting (Figure 6). Yet forage sorghum planted after double-crop forage sorghum had an average of 3 inches less soil moisture compared to forage sorghum planted after wheat with a fallow period between crops. In dry years this difference in plant available soil water may result in yield differences, but it did not affect yield in this study. The yield plateau of a forage crop is lower than a grain crop, which might explain why there was no yield penalty for second-year forage sorghum grown after either fallow or double-crop forage sorghum. These results suggest that as long as the benefits of growing a double-crop forage sorghum crop exceeded costs, an extra forage sorghum crop could be grown in the rotation. A partial enterprise analysis of this phase of the rotation only, indicated double-crop forage sorghum yield needs to be at least 30% of full-season forage sorghum, or at least 2,000 lb/a, for a double-crop forage sorghum crop that is grazed to be profitable. The additional variable expenses of growing double-crop forage sorghum would be approximately \$25.00/a.

### *Spring Oat*

Spring oat yield was not affected by rotation treatment and yielded 564 lb/a in 2014, 1,927 lb/a in 2015, 1,877 lb/a in 2016, 1,456 lb/a in 2017, and 287 lb/a in 2018. Spring forage yields were low across years, averaging 1220 lb/a.

### *Conclusions*

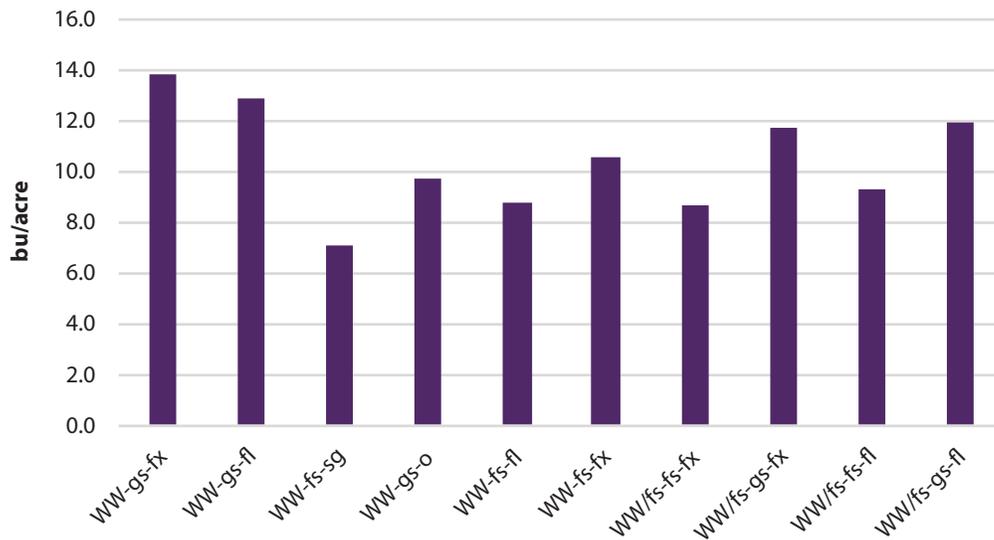
Wheat and spring oat yields were not affected by whether grain or forage sorghum were grown in place of each other in the crop rotation. Oats were grown in place of fallow in those years that indicated favorable moisture conditions. Wheat yields were reduced when oats were grown in place of fallow. Our previous fallow replacement research found wheat yield potential needed to be greater than 50 bushels for wheat yields to not be reduced by growing a crop in place of fallow. Wheat yield potential was very low in all years at 6 bu/a in 2014, 15 bu/a in 2015, failed to make grain in 2016, 8 bu/a in 2017, and 10 bu/a in 2018. The factors of rabbit feeding and low growing season precipitation caused very low wheat yield, and as a result, masked any yield difference that would be attributable to crops grown or fallow in the rotation.

Grain sorghum yield was more sensitive to moisture stress than forage sorghum. Growing a double-crop forage sorghum after wheat reduced grain yield 20–60% the second year but never reduced forage sorghum yield in the years of this study. However, with less summer precipitation, full-season forage sorghum yields might be more negatively impacted than they were in this study. Double-crop forage sorghum yields were more sensitive than full-season forage sorghum. Double-crop forage sorghum yields averaged 45% less than full-season, and in the driest growing season (2017) yields were reduced 85%. As long as double-crop forage sorghum is profitable, which we identified to be around 2,000 lb/a yield when grazed, it appears the cropping system can be intensified without negatively affecting second-year forage sorghum yield.

# CROPPING AND TILLAGE SYSTEMS

**Table 1. Grain and forage crop rotation treatments**

No.	Crop rotation	Abbreviation
1	Wheat-grain sorghum-flex-fallow	ww-gs-fx
2	Wheat-grain sorghum-fallow	ww-gs-fl
3	Wheat-forage sorghum-oat	ww-fs-o
4	Wheat-grain sorghum-oat	ww-gs-o
5	Wheat-forage sorghum-fallow	ww-fs-fl
6	Wheat-forage sorghum-flex-fallow	ww-fs-fx
7	Wheat/forage sorghum-forage sorghum-flex-fallow	ww/fs-fs-fx
8	Wheat/forage sorghum-grain sorghum-flex-fallow	ww/fs-gs-fx
9	Wheat/forage sorghum-forage sorghum-fallow	ww/fs-fs-fl
10	Wheat/forage sorghum-grain sorghum-fallow	ww/fs-gs-fl



**Figure 1. Wheat yield near Garden City, KS, between 2015 and 2018. See Table 1 for treatments.**

## CROPPING AND TILLAGE SYSTEMS

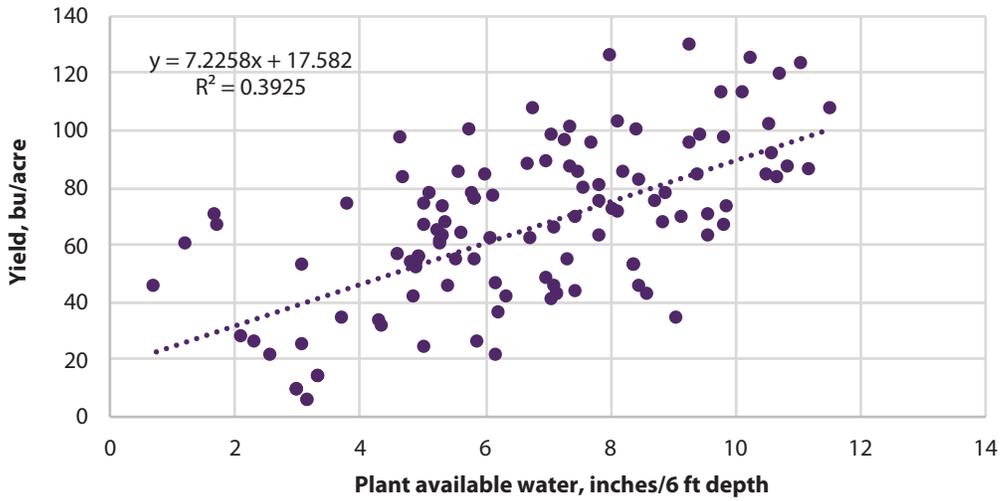


Figure 2. Grain sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2018.

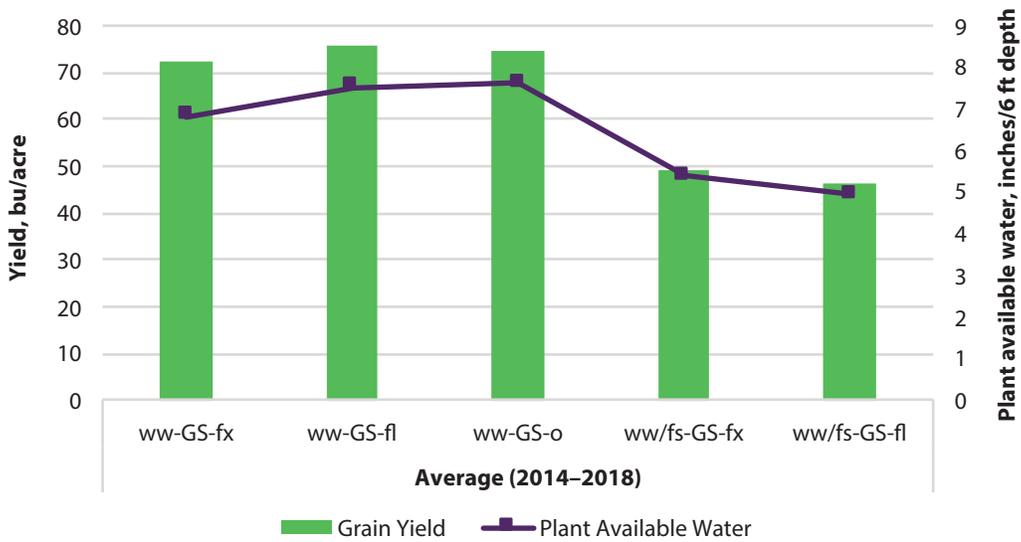


Figure 3. Grain sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2018. See Table 1 for treatments.

# CROPPING AND TILLAGE SYSTEMS

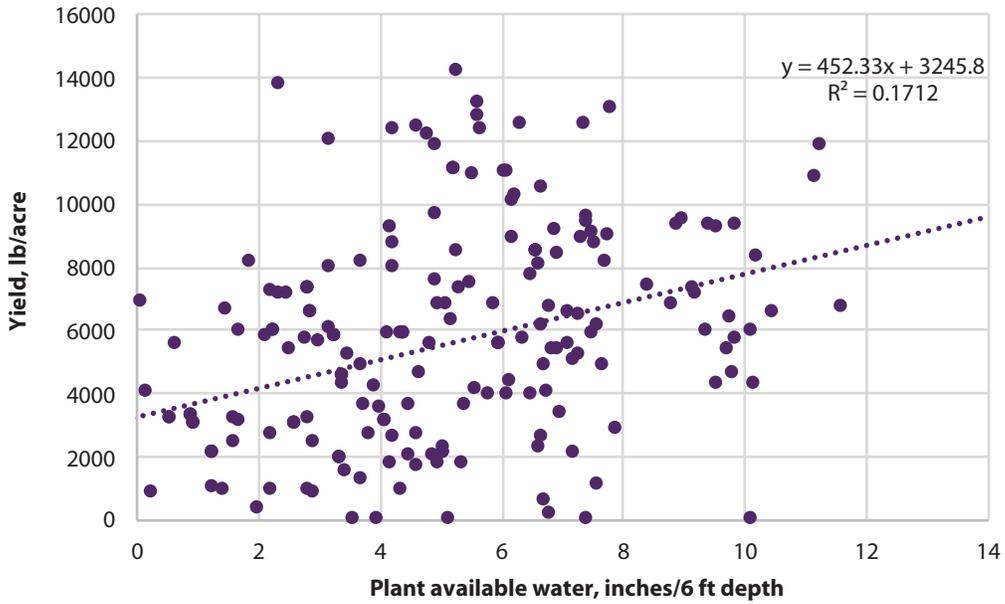


Figure 4. Forage sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2018.

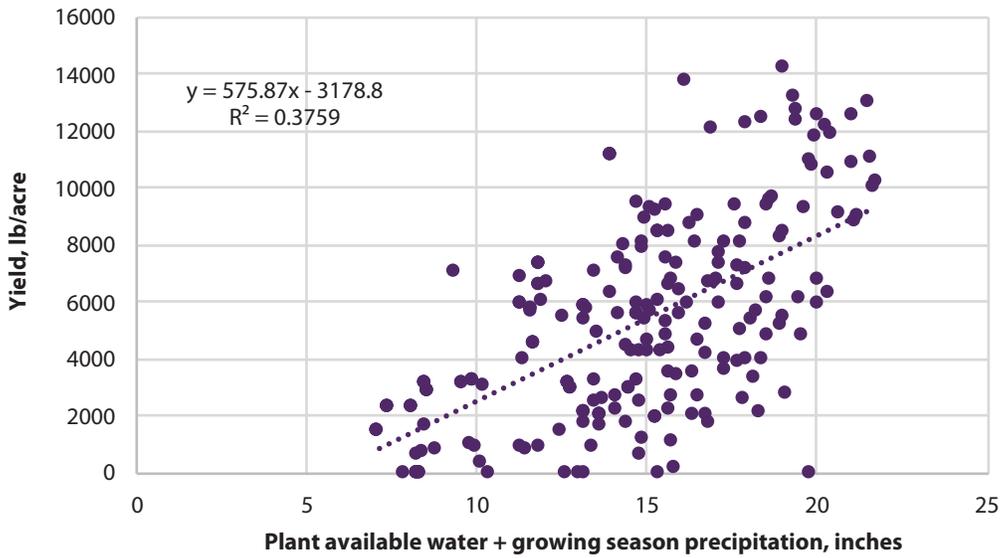
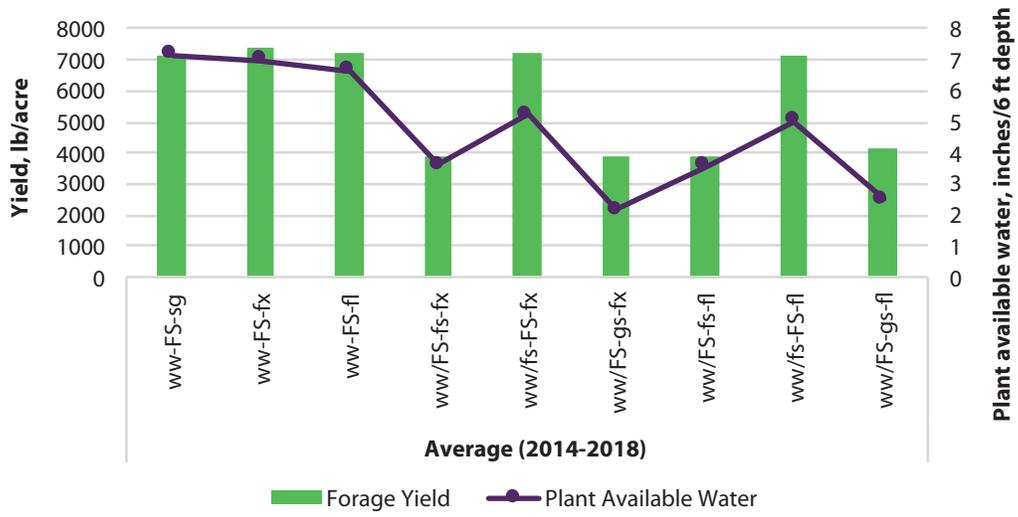


Figure 5. Forage sorghum yield response to plant available water at planting plus growing season precipitation near Garden City, KS, between 2014 and 2018.

## CROPPING AND TILLAGE SYSTEMS



**Figure 6. Forage sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2018. See Table 1 for treatments.**

# 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 at the Southwest Research-Extension Center near Tribune, KS, in 2012. The cropping systems were two annual systems (continuous corn [C-C] and continuous grain sorghum [GS-GS]) and two 2-year systems (corn- grain sorghum [C-GS] and corn-winter wheat [C-W]). In 2018, corn yields were similar for all rotations, although averaged across the past 6 years, corn yields were greater following wheat than following corn. There were no significant differences in grain sorghum yields in 2018, which was similar to the multi-year average. Wheat yields were near 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 May 3, 2018, and harvested on September 25, 2018. Grain sorghum was planted on June 4, 2018, and harvested on November 28, 2018. Wheat was planted on October 13, 2017, and harvested on July 6, 2018.

## Results and Discussion

Wheat yields in 2018 (45 bu/a) were slightly less than the long-term average (50 bu/a) (Tables 1 and 2). Precipitation was near normal from April through September followed by a wet October that delayed sorghum harvest. Corn yields in 2018 were above the long-term average with no differences among rotations. In contrast to previous years, grain sorghum yields were greater following sorghum than corn, but because of extreme variability the difference was not significant. The delayed harvest caused by above-normal late fall precipitation caused the grain sorghum to lodge, which may have reduced overall yields and increased variability. On average, corn yields are greatest following wheat and least following corn, with little difference 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 2018 (Table 3). Fallow efficiency was near zero or often negative because of wet soils at harvest in 2017. For wheat, available soil water at planting and harvest was greater than the 6-year average (Table 4). Averaged across the 6-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.

## Acknowledgment

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 2018**

Rotation	Corn	Wheat	Sorghum
	----- bu/a -----		
Continuous corn	214	---	---
Corn-wheat	232	45	---
Corn-sorghum	222	---	122
Continuous sorghum	---	---	142
LSD <sub>0.05</sub>	19	---	43
<hr/>			
ANOVA (P > F)			
System	0.141	--	0.235

LSD = least significant difference.

ANOVA = analysis of variance.

**Table 2. Grain yields of three crops under limited irrigation as affected by rotation across years 2013–2018**

Rotation	Corn	Wheat	Sorghum
	----- bu/a -----		
Continuous corn	175 b	---	---
Corn-wheat	196 a	50	---
Corn-sorghum	188 ab	---	139
Continuous sorghum	---	---	136
LSD <sub>0.05</sub>	15	---	11
<hr/>			
ANOVA (P > F)			
System	0.034	--	0.371

LSD = least significant difference.

ANOVA = analysis of variance.

## CROPPING AND TILLAGE SYSTEMS

**Table 3. Profile available soil water, crop water use, and fallow accumulation for crop rotations under limited irrigation, Tribune, KS, 2018**

Crop	Rotation	Available water			Crop water use	Fallow accumulation	Fallow efficiency
		Previous harvest	Planting	Harvest			
		----- inches -----					%
Corn	C-C	14.42	14.18	10.90	24.51	-0.24 b	-10
	C-W	14.02	14.81	11.53	24.51	0.79 a	5
	C-GS	14.50	13.94	10.74	24.43	-0.56 b	-24
LSD <sub>0.05</sub>		2.90	2.89	3.87	1.38	0.79	24
<u>ANOVA (P &gt; F)</u>							
System		0.909	0.760	0.873	0.987	0.014	0.064
Wheat	C-W	13.61	13.61	11.54	17.15	---	---
<u>ANOVA (P &gt; F)</u>							
System		---	---	---	---	---	---
Sorghum	C-GS	13.03	13.18	13.46	23.61	0.15	4
	GS-GS	13.42	13.40	13.35	23.95	-0.01	0
LSD <sub>0.05</sub>		1.53	1.85	1.61	0.77	0.75	18
<u>ANOVA (P &gt; F)</u>							
System		0.480	0.723	0.842	0.259	0.544	0.544

Note: All crops received ~10 inches of irrigation.

In season rainfall for corn (5/01 - 9/19) = 11.06 inches; sorghum (6/04 - 11/07) = 13.73 inches; and wheat (10/09/17 - 7/06/18) = 7.52 inches.

C = corn.

W = wheat.

GS = grain sorghum.

LSD = least significant difference.

ANOVA = analysis of variance.

## CROPPING AND TILLAGE SYSTEMS

**Table 4. Profile available soil water, crop water use, and fallow accumulation for crop rotations under limited irrigation across years, Tribune, KS, 2013–2018**

Crop	Rotation	Available water			Crop water use	Fallow accumulation	Fallow efficiency
		Previous harvest	Planting	Harvest			
		----- inches -----					%
Corn	C-C	11.88 a	13.92 a	12.23 a	26.37	2.04 b	21 b
	C-W	11.18 ab	14.04 a	12.28 a	26.44	2.86 a	19 b
	C-GS	10.45 b	12.42 b	10.76 b	26.34	1.97 b	38 a
LSD <sub>(0.05)</sub>		0.96	0.72	0.85	0.66	0.52	7
<u>ANOVA (P &gt; F)</u>							
System		0.016	0.001	0.001	0.951	0.002	0.001
Year		0.001	0.001	0.001	0.001	0.001	0.001
System × year		0.001	0.001	0.012	0.001	0.001	0.001
Wheat	C-W	11.87	11.87	11.43	19.60	---	---
<u>ANOVA (P &gt; F)</u>							
System		---	---	---	---	---	---
Year		0.001	0.001	0.001	0.001	---	---
System × year		---	---	---	---	---	---
Sorghum	C-GS	10.10	13.26	11.75	23.79	3.16	28
	GS-GS	10.18	12.94	11.53	23.69	2.76	31
LSD <sub>(0.05)</sub>		0.90	0.76	0.78	0.44	0.53	7
<u>ANOVA (P&gt;F)</u>							
System		0.865	0.391	0.558	0.653	0.135	0.395
Year		0.001	0.001	0.001	0.001	0.001	0.001
System × year		0.001	0.005	0.467	0.064	0.001	0.017

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 2014–2018. Wheat yields ranged across years from mid-20s to 80 bu/a at Tribune and less than 10 to near 60 bu/a at Garden City. Grain sorghum yields ranged from less than 50 to greater than 140 bu/a, depending upon year and location. In no year or location, were grain yields significantly affected by a single tillage operation. However, at Tribune, when averaged across the 5-year period, a single tillage after wheat harvest reduced grain sorghum yields compared to a complete no-till system. This indicates that if a single tillage operation is needed to control troublesome weeds, that grain yields will generally not be significantly affected. Furthermore, if 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 no-tillage in a wheat-sorghum-fallow (WSF) rotation. The reduced tillage systems generally used four or more tillage operations in the 3-yr rotation. With increased incidence of herbicide-resistant weeds, the use of a complete no-tillage system may not be economical and tillage may be needed for effective control. The objective of the research project is to determine the effect of a single tillage operation every 3 years on grain yields in a WSF rotation.

## 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 were initiated in 2012. The three tillage treatment intensities in this study are a single tillage in May or June during fallow, a single tillage after wheat harvest, and a complete no-tillage 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 57–58 bu/a in 2018 compared with 41–43 bu/a for the 5-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 2018 ranging from 115–130 bu/a (Table 2). Similar to wheat, there were no significant yield differences among tillage treatments in any year. However, averaged across years, NT produced greater yields than tillage post-wheat harvest.

At Garden City, wheat yields in 2018 were very low at 2–7 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. There were no significant yield differences among tillage treatments in any year or averaged across years. Grain sorghum yields in 2018 were good with all yields near 90 bu/a or greater (Table 4). Similar to wheat, there were no significant yield differences among tillage treatments in any year or averaged across years.

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 in a 3-yr WSF rotation generally had little effect on wheat or grain sorghum yields from 2014–2018 at Garden City or Tribune, KS.

### **Acknowledgment**

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

### **Reference**

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.

## CROPPING AND TILLAGE SYSTEMS

**Table 1. Grain yield response of dryland wheat to a single tillage operation (sweep plow) in a 3-year wheat-sorghum-fallow rotation grown from 2014–2018 near Tribune, KS**

Tillage	Year					Average
	2014	2015	2016	2017	2018	
	----- bu/a -----					
No-tillage	28	24	75	30	57	43
June in fallow	22	22	81	25	58	42
July post-harvest	23	21	77	27	57	41
ANOVA (P > F)						
Treatment	0.427	0.599	0.174	0.477	0.857	0.444
Year	---	---	---	---	---	0.001
Year × treatment	---	---	---	---	---	0.409

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 2014–2018 near Tribune, KS**

Tillage	Year					Average
	2014	2015	2016	2017	2018	
	----- bu/a -----					
No-tillage	77	133	129	147	130	123
June in fallow	84	114	129	145	123	119
July post-harvest	86	108	126	141	115	115
ANOVA (P > F)						
Treatment	0.573	0.104	0.280	0.567	0.065	0.046
Year	---	---	---	---	---	0.001
Year × treatment	---	---	---	---	---	0.096

ANOVA = analysis of variance.

## CROPPING AND TILLAGE SYSTEMS

**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 2014–2018 near Garden City, KS**

Tillage	Year					Average
	2014	2015	2016	2017	2018	
	----- bu/a -----					
No-tillage	8	34	55	20	4	24
June in fallow	6	35	60	19	3	25
July post-harvest	9	30	56	23	7	25
<b>ANOVA (P &gt; F)</b>						
Treatment	0.601	0.363	0.369	0.420	0.199	0.764
Year	---	---	---	---	---	0.001
Year × treatment	---	---	---	---	---	0.265

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 2014–2018 near Garden City, KS**

Tillage	Year					Average
	2014	2015	2016	2017	2018	
	----- bu/a -----					
No-tillage	58	63	116	51	98	77
June in fallow	57	62	121	46	88	75
July post-harvest	47	73	118	44	93	75
<b>ANOVA (P&gt;F)</b>						
Treatment	0.110	0.464	0.642	0.579	0.572	0.714
Year	---	---	---	---	---	0.001
Year × treatment	---	---	---	---	---	0.393

ANOVA = analysis of variance.

# Large-Scale Dryland Cropping Systems

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

## Summary

This study was conducted from 2008–2018 at the Kansas State University Southwest Research-Extension Center near Tribune, KS. The purpose of the study was to identify whether more intensive cropping systems can enhance and stabilize production in rainfed cropping systems to optimize economic crop production, more efficiently capture and utilize scarce precipitation, and maintain or enhance soil resources and environmental quality. The crop rotations evaluated were continuous grain sorghum (SS), wheat-fallow (WF), wheat-corn-fallow (WCF), wheat-sorghum-fallow (WSF), wheat-corn-sorghum-fallow (WCSF), and wheat-sorghum-corn-fallow (WSCF). All rotations were grown using no-tillage practices except for WF, which was grown using reduced-tillage. The efficiency of precipitation capture was not greater with more intensive rotations. Length of rotation did not affect wheat yields. Corn and grain sorghum yields were about 50% greater when following wheat than when following corn or grain sorghum. Grain sorghum yields were about 50% 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 11-year study period and was near normal (+/- 15%) in 7 out of 11 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 was greater with WF than all other wheat rotations (Table 1). The fallow efficiencies of the 3- and 4-year 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-year rotations.

Fallow accumulation prior to corn planting and profile available soil water at planting was greater following wheat (WCF or WCSF) than following grain sorghum (WSCF) (Table 1). However, the fallow period following wheat was longer, resulting in low fallow efficiencies (~17%) following wheat and only 20% 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 (15–20%).

Wheat yields were above normal in 2018 (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 11 years, cropping system had little effect on wheat yields.

Grain sorghum yields were very good in 2018 with yields greater than 100 bu/a when following wheat (Figure 3). Sorghum following corn produced 20 bu/a less yield than following wheat, and continuous sorghum yields were 20 bu/a less than following corn. Average grain sorghum yields following wheat were approximately 50% greater than following corn or sorghum.

In contrast to sorghum, corn yields were poor in 2018 (Figure 4) with all rotations yielding 40 bu/a or less. Corn yields following wheat in either the 3- or 4-year 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 50% 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 > 80 bu/a (Figure 5). These yields were about 50% 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 also about 50% greater than following sorghum.

## Acknowledgments

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

## CROPPING AND TILLAGE SYSTEMS

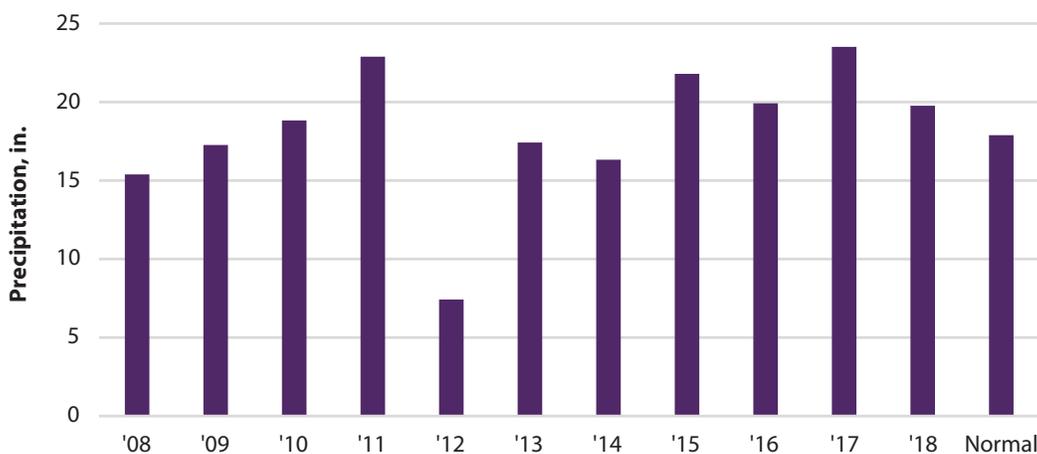
**Table 1. Fallow accumulation, fallow efficiency, profile (8 ft) available soil water at planting, and crop water use by wheat, corn, and grain sorghum in several crop rotations, Tribune, KS, 2008–2018**

Crop	Rotation	Fallow accumulation	Fallow efficiency	Profile ASW at planting <sup>2</sup>	Crop water use
		inch	%	inch	inch
Wheat	W <sup>f</sup>	6.95 a	28 a	10.04 a	18.28 a
	W <sup>sf</sup>	3.09 bc	19 b	6.46 b	14.17 b
	W <sup>cf</sup>	2.65 c	15 c	6.32 b	14.11 b
	W <sup>scf</sup>	3.35 b	19 b	6.81 b	14.42 b
	W <sup>csf</sup>	3.21 b	18 b	6.46 b	14.21 b
LSD <sub>0.05</sub>		0.52	3	0.61	0.53
Corn	wC <sup>f</sup>	2.37 a	17 b	5.82 a	13.87 a
	wC <sup>sf</sup>	2.39 a	17 b	5.87 a	13.85 a
	wsC <sup>f</sup>	1.47 b	20 a	4.85 b	13.02 b
LSD <sub>0.05</sub>		0.36	3	0.57	0.36
Grain sorghum	wS <sup>f</sup>	2.27 b	15 b	5.80 b	13.40 b
	wS <sup>cf</sup>	2.84 a	18 a	6.40 a	13.78 a
	wcS <sup>f</sup>	1.33 d	15 b	5.02 c	12.78 c
	SS	1.85 c	20 a	5.21 c	12.80 c
LSD <sub>0.05</sub>		0.34	3	0.56	0.34

<sup>1</sup>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.

<sup>2</sup>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 (2008–2018) and normal precipitation (1981–2010, last bar), Tribune, KS.**

## CROPPING AND TILLAGE SYSTEMS

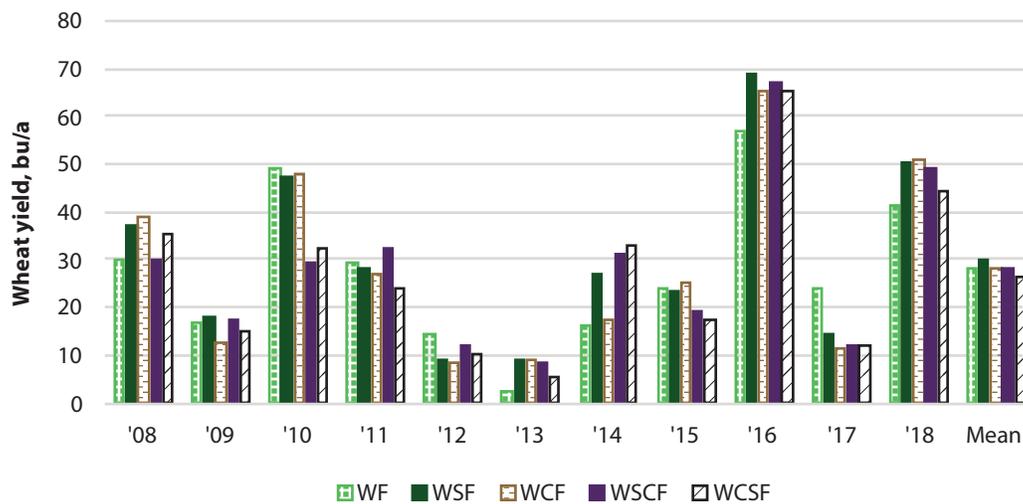


Figure 2. Wheat yields by cropping system, 2008–2018. Last set of columns are treatment means. Wheat-fallow (WF), wheat-sorghum-fallow (WSF), wheat-corn-fallow (WCF), wheat-corn-sorghum-fallow (WCSF), and wheat-sorghum-corn-fallow (WSCF).

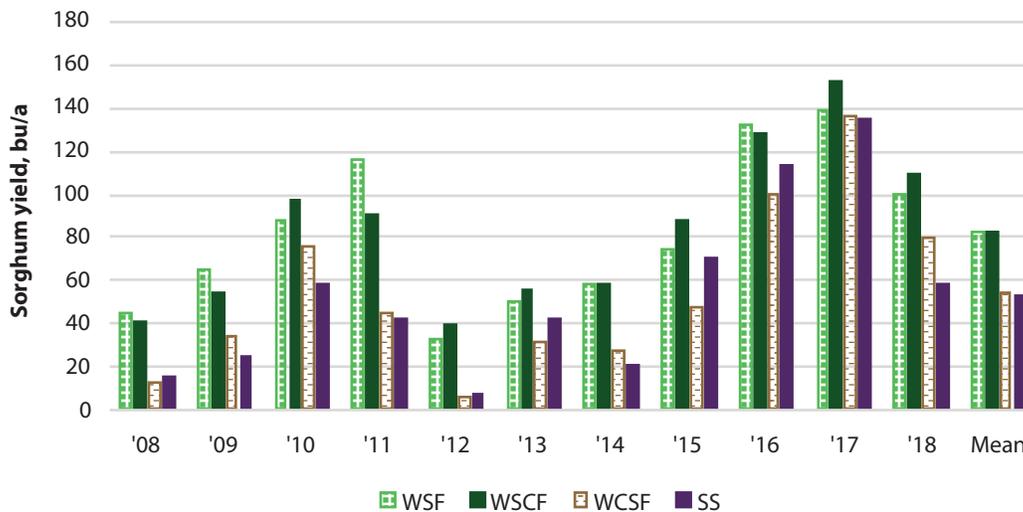
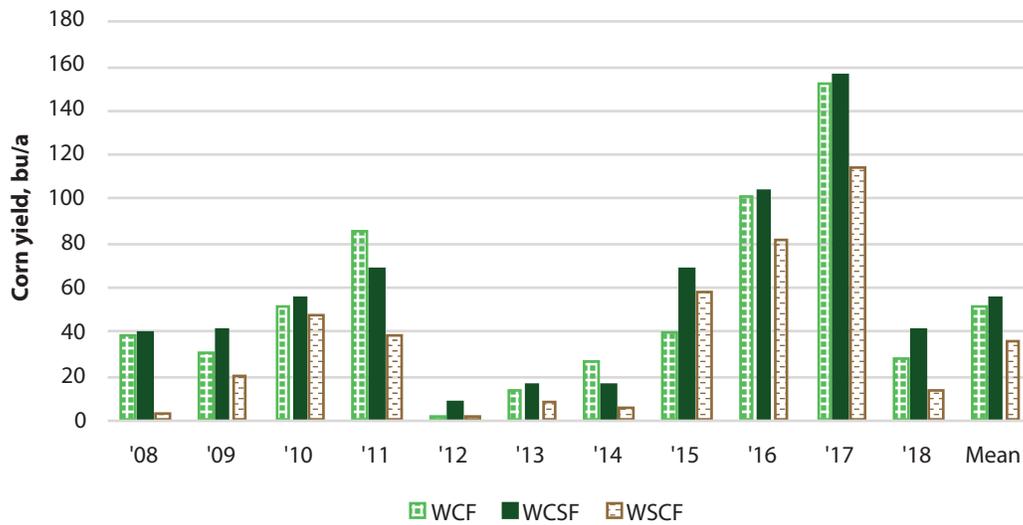
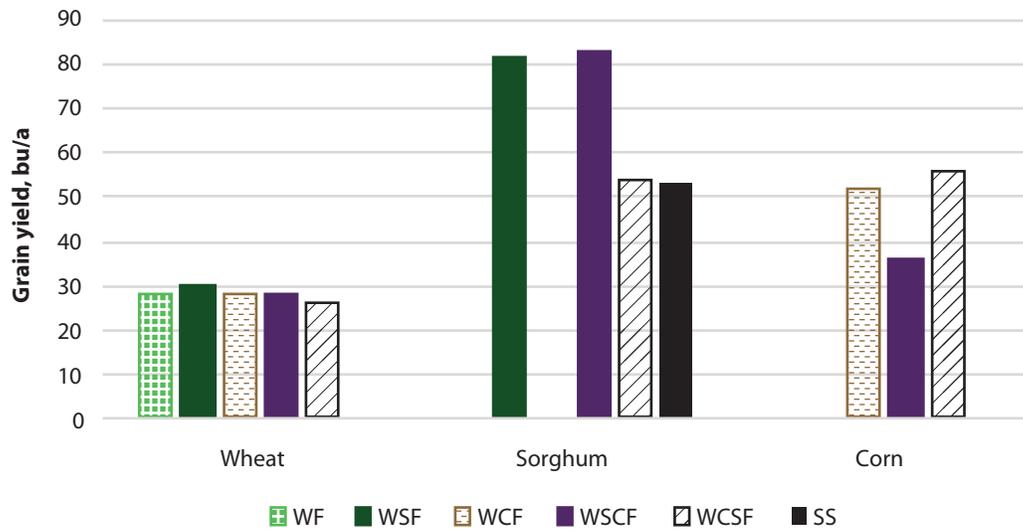


Figure 3. Grain sorghum yields by cropping system, 2008–2018. Last set of columns are treatment means. Wheat-sorghum-fallow (WSF), wheat-sorghum-corn-fallow (WSCF), wheat-corn-sorghum-fallow (WCSF), and continuous grain sorghum (SS).

## CROPPING AND TILLAGE SYSTEMS



**Figure 4.** Corn yields by cropping system, 2008–2018. 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, 2008–2018. 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 2018, 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 18-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 18 years, NT wheat yields were 5 bu/a greater than RT and 8 bu/a greater than CT. Grain sorghum yields in 2018 were twice as great in long-term NT compared to short-term NT with the lowest yields with CT. Averaged across the past 18 years, sorghum yields with long-term NT have been 58% greater than with short-term NT (76 vs. 48 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 2018, available soil water at wheat planting was greater with NT than RT and least with CT. Averaged across the 18-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 2018, 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 2018 were greater than the long-term average (Table 1). Since 2001, wheat yields have been depressed in 11 of 18 years, primarily because of lack of precipitation, winterkill (2015), and disease (2017). Reduced tillage and NT increased wheat yields. On average, wheat yields were 8 bu/a higher for NT (26 bu/a) than CT (18 bu/a). Wheat yields for RT were 3 bu/a greater than CT even though both systems had tillage prior to wheat. Yields of NT were significantly less than CT or RT in only 1 of the 18 years.

Grain sorghum yields in 2018 were greater than the long-term average (Table 2). Sorghum yields were twice as great with NT than RT (116 vs. 57 bu/a) while CT yields were the least (35 bu/a). The yield benefit from reducing tillage is greater for grain sorghum than wheat. Grain sorghum yields for RT averaged 18 bu/a more than CT, whereas NT averaged 28 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 18 years, sorghum yields with long-term NT have been 58% greater than with short-term NT (76 vs. 48 bu/a).

### **Acknowledgment**

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

## CROPPING AND TILLAGE SYSTEMS

**Table 1. Wheat response to tillage in a wheat-sorghum-fallow rotation, Tribune, KS, 2001–2018**

Year	Tillage			LSD (0.05)	ANOVA ( $P > F$ )		
	Conventional	Reduced	No-tillage		Tillage	Year	Tillage × year
	----- bu/a -----						
2001	17	40	31	8	0.002		
2002	0	0	0	---	---		
2003	22	15	30	7	0.007		
2004	1	2	4	2	0.001		
2005	32	32	39	12	0.360		
2006	0	2	16	6	0.001		
2007	26	36	51	15	0.017		
2008	21	19	9	14	0.142		
2009	8	10	22	9	0.018		
2010	29	35	50	8	0.002		
2011	22	20	20	7	0.649		
2012	0	1	5	1	0.001		
2013	0	0	0	---	---		
2014	10	11	18	12	0.336		
2015	10	9	9	9	0.966		
2016	72	85	82	18	0.239		
2017	13	12	12	9	0.970		
2018	46	48	64	4	0.001		
Mean	18 c	21 b	26 a	2	0.001	0.001	0.001

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

## CROPPING AND TILLAGE SYSTEMS

**Table 2. Grain sorghum response to tillage in a wheat-sorghum-fallow rotation, Tribune, KS, 2001–2018**

Year	Tillage			LSD (0.05)	ANOVA ( $P > F$ )		
	Conventional	Reduced	No-tillage		Tillage	Year	Tillage × year
	----- bu/a -----						
2001	6	43	64	7	0.001		
2002	0	0	0	---	---		
2003	7	7	37	8	0.001		
2004	44	67	118	14	0.001		
2005	28	38	61	35	0.130		
2006	4	3	29	10	0.001		
2007	26	43	62	42	0.196		
2008	16	25	40	20	0.071		
2009	19	5	72	31	0.004		
2010	10	26	84	9	0.001		
2011	37	78	113	10	0.001		
2012	0	0	0	---	---		
2013	37	51	78	32	0.053		
2014	38	72	94	28	0.008		
2015	56	60	102	55	0.153		
2016	55	124	139	47	0.010		
2017	121	163	159	33	0.038		
2018	35	57	116	33	0.003		
Mean	30c	48b	76a	5	0.001	0.001	0.001

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

## CROPPING AND TILLAGE SYSTEMS

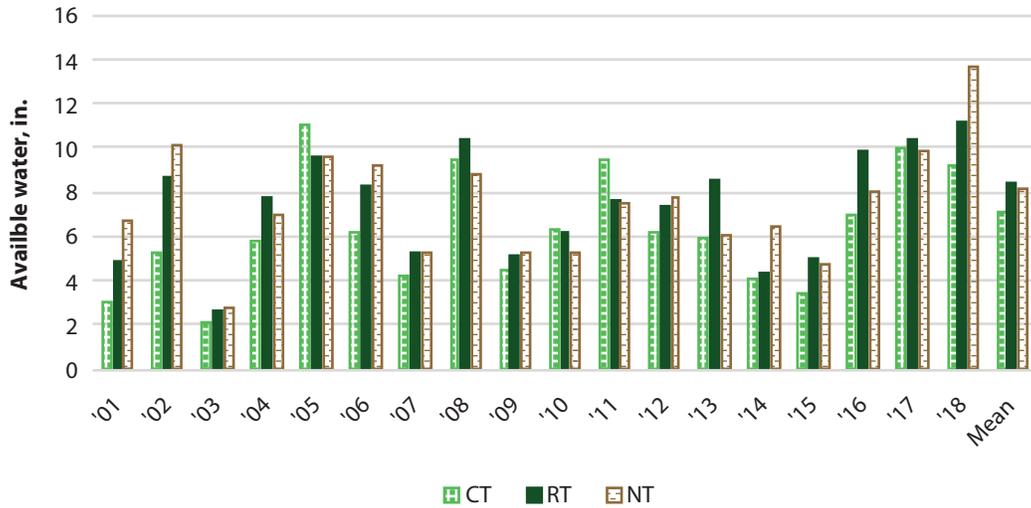


Figure 1. Available soil water in 8-ft profile at planting of wheat in a wheat-sorghum-fallow rotation as affected by tillage intensity, Tribune, KS, 2001–2018. The last set of bars (Mean) is the average across years. CT = conventional tillage. RT = reduced tillage. NT = no-tillage.

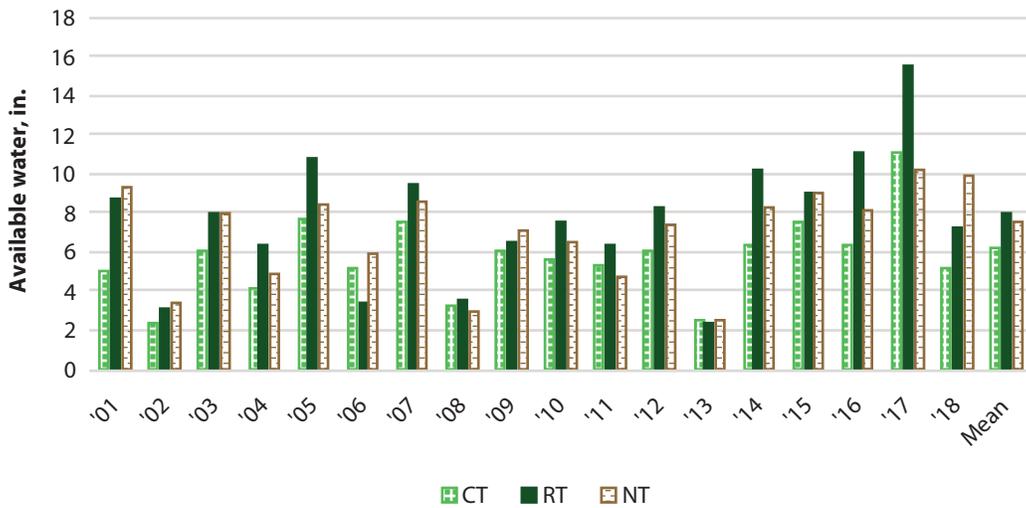


Figure 2. Available soil water in 8-ft profile at planting of grain sorghum in a wheat-sorghum-fallow rotation as affected by tillage intensity, Tribune, KS, 2001–2018. The last set of bars (Mean) is the average across years. CT = conventional tillage. RT = reduced tillage. NT = no-tillage.

# 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 in. less for the second sorghum crop compared with sorghum following wheat. 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 ~63% 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 2018, available soil water was greater for wheat following sorghum and for wheat following wheat compared to the long-term average. Soil water was similar following fallow after either one or two sorghum crops and averaged about 9 in. across the 22-year study period. Water at planting of the second wheat crop in a WWSF rotation was generally less than at planting of the first wheat crop,

except in 1997 and 2003. Soil water for the second wheat crop averaged more than 3 in. (or about 40%) less than that for the first wheat crop in the rotation. Continuous wheat averaged 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 was greater than the long-term average. Soil water was similar following fallow after either one or two wheat crops and averaged about 8 in. over 23 years. Water at planting of the second sorghum crop in a WSSF rotation was generally less than that at planting of the first sorghum crop. Averaged across the entire study period, the first sorghum crop had about 1.3 in. more available water at planting than the second crop.

### *Grain Yields*

In 2018, wheat yields after fallow were greater than the long-term average while wheat yields after wheat were less than the long-term average (Table 1). Averaged across 22 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 most years, continuous wheat yields have been similar to recrop wheat yields, but in several years (2003, 2007, 2009, and 2014), recrop wheat yields were considerably greater than continuous wheat yields. However, in 2018, continuous wheat yields were considerably less than recrop wheat yields (6 vs. 24 bu/a).

Sorghum yields in 2018 for all rotations were higher than the long-term average yields. This is the fourth year in a row of above average sorghum yields. Sorghum yields following wheat were 37–50 bu/a greater than the long-term average (Table 2). Sorghum yields were similar following one or two wheat crops, which is consistent with the long-term average. The second sorghum crop yields were 51% of the first sorghum crop in 2018, which is less than the long-term average of about 63%.

## CROPPING AND TILLAGE SYSTEMS

**Table 1. Wheat response to dryland crop rotation, Tribune, KS, 1997–2018**

Year	Rotation				LSD 0.05	ANOVA (P > F)		
	W <sub>ssf</sub> <sup>1</sup>	W <sub>wsf</sub>	w <sub>Wsf</sub>	WW		Rotation	Year	Year × rotation
	----- bu/a -----							
1997	57	55	48	43	8	0.017		
1998	70	64	63	60	12	0.391		
1999	74	80	41	43	14	0.001		
2000	46	35	18	18	10	0.001		
2001	22	29	27	34	14	0.335		
2002	0	0	0	0	---	---		
2003	29	27	66	30	14	0.001		
2004	5.7	6.1	0.4	0.5	1.6	0.001		
2005	45	40	41	44	10	0.690		
2006	28	26	7	2	8	0.001		
2007	75	61	63	41	14	0.004		
2008	40	40	5	6	5	0.001		
2009	37	39	50	24	15	0.029		
2010	63	60	29	23	9	0.001		
2011	25	22	25	17	8	0.152		
2012	14	20	10	9	15	0.380		
2013	0	0	0	0	---	---		
2014	51	45	31	12	18	0.004		
2015	49	36	24	24	12	0.001		
2016	78	77	58	52	12	0.001		
2017	20	20	4	6	4	0.001		
2018	52	51	24	6	4	0.001		
Mean	40 a	38 b	29 c	23 d	2	0.001	0.001	0.001

<sup>1</sup>W = wheat. S = sorghum. Capital letters denote current year's crop.

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

ANOVA = analysis of variance.

LSD = least significant difference.

## CROPPING AND TILLAGE SYSTEMS

**Table 2. Grain sorghum response to crop rotation, Tribune, KS, 1996–2018**

Year	Rotation				ANOVA (P>F)		
	wSsf <sup>1</sup>	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		
Mean	88a	55b	87a	4	0.001	0.001	0.001

<sup>1</sup>W = wheat. S = sorghum. Capital letters denote current year's crop.

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

ANOVA = analysis of variance.

LSD = least significant difference.

## CROPPING AND TILLAGE SYSTEMS

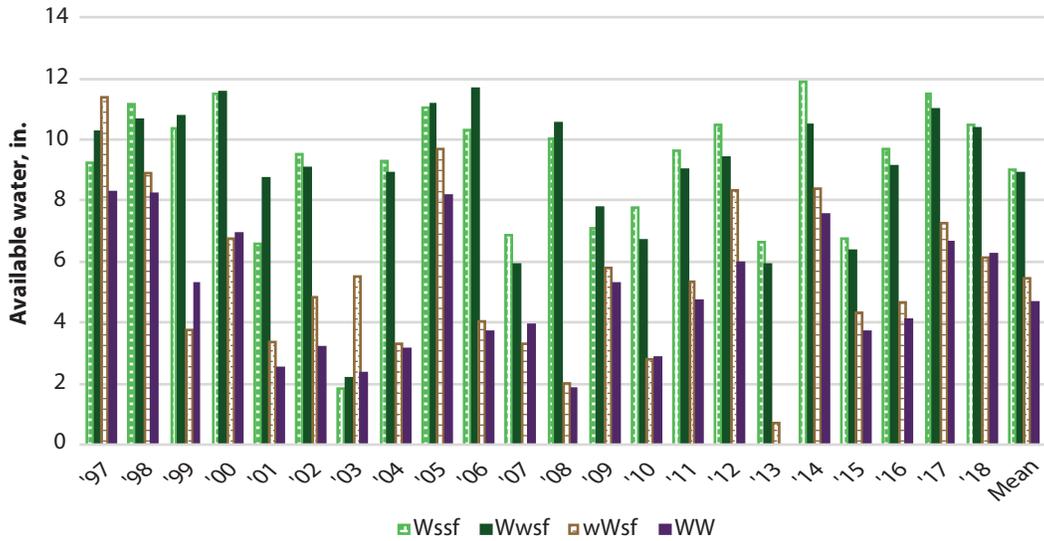


Figure 1. Available soil water in 6-ft profile at planting of wheat in several rotations at Tribune, KS, 1997–2018. Capital letter denotes current crop in rotation (W, wheat; S, sorghum). The last set of bars (Mean) is the average across years. Wheat-sorghum-sorghum-fallow (WSSF), wheat-wheat-sorghum-fallow (WWSF), and continuous wheat (WW).

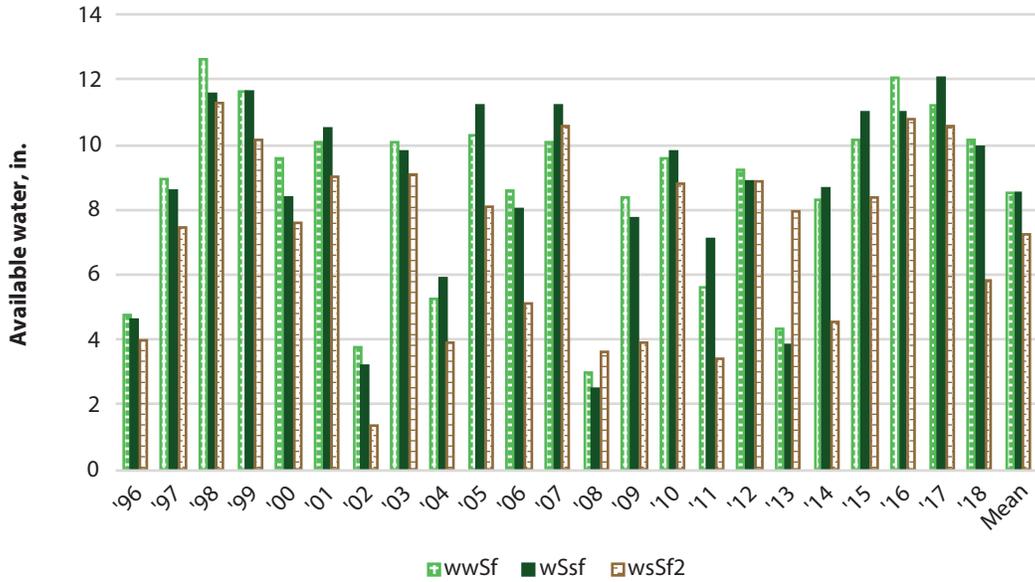


Figure 2. Available soil water in 6-ft profile at planting of sorghum in several rotations at Tribune, KS, 1996–2018. Capital letter denotes current crop in rotation (W, wheat; S, sorghum). The last set of bars (Mean) is the average across years. Wheat-sorghum-sorghum-fallow (WSSF) and wheat-wheat-sorghum-fallow (WWSF).

# Seeding Rate for Dryland Wheat

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

## Summary

Four winter wheat varieties (PlainsGold Byrd, Limagrain T158, Syngenta TAM 111, and WestBred Winterhawk) were planted at five seeding rates (30, 45, 60, 75, and 90 lb/a) in the fall of 2014, 2015, 2016, and 2017 at Colby, Garden City, and Tribune, KS. The objective of the study is to identify appropriate seeding rates for dryland winter wheat in western Kansas. Averaged across varieties, a seeding rate of 60 lb/a seemed to be adequate at all locations in 2015. However, with higher yields in 2016, a higher seeding rate (75 lb/a) was beneficial. Although yields were less in 2017 than 2016, a seeding rate of 75 lb/a generally produced the highest yields. In 2018, yield increased with increased seeding rate. The wheat variety T158 was the highest yielding (or in the highest group) at all locations in 2015. Other varieties may have been affected by differential response to stripe rust and winter injury resulting in lower yields. In 2016, the highest yielding variety varied by location. TAM 114 was in the highest yielding variety at each location in 2017. In 2018, Winterhawk was the lowest yielding variety. Variety selection and growing season appears to have more effect on wheat yields than seeding rate. A seeding rate of 30 or 45 lb/a, and often 60 lb/a, resulted in lower yields than the 75 or 90 lb/a rate. Yield response to seeding rate, and optimal seeding rate for any site-year was similar across varieties.

## Introduction

The purpose of this project is to determine appropriate seeding rates for dryland winter wheat in western Kansas, and to determine if the optimal seeding rate is dependent on variety. A preliminary study conducted in 2014 found no yield benefit from increasing seeding rates from 30 to 75 lb of seed/a for 4 wheat varieties at Tribune, while a similar study at Garden City suffered severe hail damage causing yields to be less than 10 bu/a. The objective is to evaluate seeding rates on grain yield of several popular wheat varieties representing a range of genetic backgrounds and tillering ability under dryland conditions at three sites in western Kansas.

## Experimental Procedures

- Four winter wheat varieties—Byrd, T158, TAM111 or TAM114, and Winterhawk
- Five seeding rates—30, 45, 60, 75, and 90 lb/a
- 2015 seed size (seed/lb) was Byrd (15,839), T158 (15,479), TAM 111 (17,627), and Winterhawk (12,921)

## Results and Discussion

Growing season precipitation was below normal for Garden City all years, but normal to above normal for Tribune and Colby. In addition, precipitation was infrequent and variable across the growing seasons. In 2015, precipitation was high in May (6.38 in. at Garden City, 6.16 in. at Tribune, and 6.42 in. at Colby) making up for a dry winter and early spring. For 2016, rainfall was above normal for Tribune, slightly below normal for Garden City, and below normal at Colby. April was wet with 5.16 in. at Tribune,

4.59 in. at Garden City, and 5.64 in. at Colby. In 2017, precipitation was above average at Tribune in April (4.67 in.) and May (5.00 in.); however, wheat streak mosaic virus reduced grain yield. At Garden City conditions were very dry in the fall of 2016 (0.3 in. between October and January), and the majority of the precipitation (6.58 in.) occurred in March and April. At Colby, conditions were extremely dry at seeding time followed by above normal precipitation in the late spring. A blizzard event on April 30 to May 1, 2017, resulted in the wheat being completely laid flat at the boot stage at Tribune and Colby with 14–20 inches of snow on top.

In 2015, averaged across seeding rates at Tribune, T158 and Winterhawk produced the greatest yields with TAM 111 producing the lowest yields (Table 3). At Colby and Garden City in 2015, T158 produced significantly higher yields than all other varieties. Stripe rust was prevalent in the 2015 growing season. Resistance ratings from the Kansas State University Department of Plant Pathology (publication MF991, Wheat Variety Disease and Insect Ratings 2016, E.D. De Wolf, R. Lollato, and R.J. Whitworth), with a scale of 1 being resistant to 10 being susceptible, were 8, 2, 8, and 6 for Byrd, T158, TAM111, and Winterhawk, respectively. Stripe rust infestation and associated yield reductions at Colby (and other locations) were consistent with these ratings.

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

Wheat yields were very good at all locations in 2016 (Table 4). The response to variety and seeding rate varied greatly across locations. Averaged across seeding rates, Byrd produced the greatest yields at Tribune while it produced the lowest yields at Garden City. Winterhawk and T158 were the lowest yielding at Tribune while they were the highest yielding at Garden City and Colby. There was a significant positive yield response to increased seeding rate at Tribune and Colby but no significant response to seeding rate at Garden City.

Wheat yields were increased by increased seeding rates at all locations in 2017 (Table 5). Wheat yields were the lowest at Tribune (significant wheat streak mosaic virus damage) and greatest at Colby. TAM 114 was in the highest yielding group at all locations. The ranking of the other varieties depended upon location. The dry fall conditions in 2016 at Garden City likely reduced tiller development, resulting in reduced wheat yields at seeding rates less than 60 lb/a. Relative differences in growth stage among varieties at the time of the late spring blizzard may have affected their yield potential, however, this was very difficult to assess.

Wheat yields increased by increasing seeding rates at all locations in 2018 (Table 6). Wheat yields were lowest at Garden City and highest at Colby. Yields by variety were generally mixed with the exception of Winterhawk being the lowest yielding variety at all three locations. As seeding rate increased from 30 to 90 lb/a, yields increased by 7, 7, and 16 bu/a at Garden City, Tribune, and Colby, respectively.

Averaged across years (2015–2018), T158 was the highest yielding variety at Garden City and Colby (Table 6). Byrd was the highest yielding variety at Tribune, but the lowest yielding at the other two locations. At all locations, grain yields were increased

by increased seeding rate. When averaged across all locations and years, yields were increased by 8 bu/a from increasing seeding rate from 30 to 60 lb/a and an additional 3 bu/a when seeding rate was increased to 90 lb/a. There was not a significant variety  $\times$  seeding rate interaction as all varieties responded positively to increased seeding rate.

In 14 site-years of this study, a variety  $\times$  seeding rate interaction has only been observed in 2 site-years. At those two site-years (Garden City and Tribune, 2015), increasing seeding rates resulted in increased yield for stripe rust-susceptible varieties. We hypothesize that higher seeding rates in the stripe rust-susceptible varieties partially compensated for lower per plant grain yield due to reduction of productive leaf area due to stripe rust. In general, the data collected in this study would not support the need for variety-specific seeding rate recommendations.

*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.*

## CROPPING AND TILLAGE SYSTEMS

**Table 1. Site conditions and factors at three locations of winter wheat seeding rate trials, 2015–2018**

Site	Year	Planting date	Harvest date	Growing season precipitation <sup>1</sup>	Fertilizer		
					Starter (N-P-K)	Pre-plant	Topdress
				in.	lb/a	----- lb N/a -----	
Colby	2015	10/20/2014	7/04/2015	14.03	---	---	90
	2016	10/14/2015	7/10/2016	12.36	---	90	---
	2017	10/10/2016	7/01/2017	16.05	---	60	---
	2018	10/11/2017	7/03/2018	12.54	---	---	90
Garden City	2015	10/09/2014	6/29/2015	12.18	5.5-26-0	---	30
	2016	10/09/2015	6/22/2016	11.31	5.5-26-0	---	100
	2017	10/14/2016	7/06/2017	11.14	5.5-26-0	---	80
	2018	10/12/2017	7/02/2018	7.96	5.5-26-0	---	40
Tribune	2015	9/26/2014	6/30/2015	12.83	6-20-0	---	60
	2016	10/13/2015	7/04/2016	14.32	5-16-0	---	80
	2017	10/05/2016	6/28/2017	14.96	7-23-0	---	80
	2018	10/12/2017	7/01/2018	7.99	7-24-0	---	100

<sup>1</sup>October – June.

N = nitrogen. P = phosphorus. K = potassium.

## CROPPING AND TILLAGE SYSTEMS

**Table 2. Herbicide application at three locations of winter wheat seeding rate trials, 2015–2018**

Site	Year	Herbicides
Colby	2015	Ally Extra (0.5 oz/a)
	2016	Huskie (15 oz/a) + dicamba (2 oz/a) + Zidua (2 oz/a)
	2017	Rave (4 oz/a)
	2018	Rave (4 oz/a)
Garden City	2015	Starane Ultra (0.4 pt/a) + MCPA (0.75 pt/a) + Ally (0.1 oz/a) + NIS (0.25% v/v)
	2016	Starane Ultra (0.4 pt/a) + MCPA (0.75 pt/a) + Ally (0.1 oz/a) + NIS (0.25% v/v)
	2017	Starane Ultra (0.4 pt/a) + MCPA (0.75 pt/a) + Ally (0.1 oz/a) + NIS (0.25% v/v)
	2018	Starane Ultra (0.4 pt/a) + MCPA (0.75 pt/a) + Ally (0.1 oz/a) + NIS (0.25% v/v)
Tribune	2015	Dicamba (4 oz/a) + Ally (0.1 oz/a) + NIS (0.25% v/v)
	2016	Dicamba (4 oz/a) + Ally (0.1 oz/a) + NIS (0.25% v/v)
	2017	Dicamba (4 oz/a) + Ally (0.1 oz/a) + NIS (0.25% v/v)
	2018	Dicamba (4 oz/a) + Ally (0.1 oz/a) + NIS (0.25% v/v)

## CROPPING AND TILLAGE SYSTEMS

**Table 3. Dryland wheat response to variety and seeding rate at three locations in 2015**

Variety	Seeding rate	Grain yield			
		Tribune	Garden City	Colby	Average
	lb/a	bu/a			
Byrd	30	47	38	23	36
	45	52	42	25	40
	60	60	50	27	46
	75	53	51	29	45
	90	58	53	28	46
T158	30	58	72	45	59
	45	60	71	53	61
	60	64	79	56	67
	75	69	71	53	65
	90	71	65	55	64
TAM 111	30	39	34	20	31
	45	40	40	25	35
	60	43	44	28	39
	75	46	50	32	43
	90	44	52	34	43
Winterhawk	30	60	31	21	37
	45	66	41	25	44
	60	68	42	29	47
	75	64	51	34	50
	90	67	50	35	51

*continued*

## CROPPING AND TILLAGE SYSTEMS

**Table 3. Dryland wheat response to variety and seeding rate at three locations in 2015**

Variety	Seeding rate lb/a	Grain yield			Average
		Tribune	Garden City	Colby	
		----- bu/a -----			
<b>ANOVA (P&gt;F)</b>					
Variety		0.001	0.001	0.001	0.001
Seeding rate		0.001	0.001	0.001	0.001
Variety × seeding rate		0.046	0.001	0.731	0.124
Location					0.001
Location × variety					0.001
Location × seeding rate					0.743
Location × variety × seeding rate					0.001
<b>MEANS<sup>1</sup></b>					
Variety					
Byrd		54 b	47 b	26 b	43 c
T158		64 a	72 a	53 a	63 a
TAM 111		42 c	44 bc	28 b	38 d
Winterhawk		65 a	43 c	29 b	46 b
LSD <sub>0.05</sub>		2	3	3	2
Seeding rate (lb/a)					
30		51 c	44 c	27 c	41 c
45		55 b	49 b	32 b	45 b
60		59 a	54 a	35 ab	49 a
75		58 a	56 a	37 a	50 a
90		60 a	55 a	38 a	51 a
LSD <sub>0.05</sub>		3	4	4	2

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

ANOVA = analysis of variance.

LSD = least significant difference.

## CROPPING AND TILLAGE SYSTEMS

**Table 4. Dryland wheat response to variety and seeding rate at three locations in 2016**

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

*continued*

## CROPPING AND TILLAGE SYSTEMS

**Table 4. Dryland wheat response to variety and seeding rate at three locations in 2016**

Variety	Seeding rate lb/a	Grain yield			Average
		Tribune	Garden City	Colby	
		----- bu/a -----			
<b>ANOVA (P&gt;F)</b>					
Variety		0.001	0.001	0.029	0.001
Seeding rate		0.001	0.205	0.001	0.001
Variety × seeding rate		0.361	0.999	0.190	0.584
Location					0.015
Location × variety					0.001
Location × seeding rate					0.058
Location × variety × seeding rate					0.594
<b>MEANS<sup>1</sup></b>					
Variety					
Byrd		81 a	78 d	102 b	90 c
T158		68 c	111 a	110 a	96 a
TAM 111		71 b	92 c	102 b	88 c
Winterhawk		68 c	101 b	106 ab	91 b
LSD <sub>0.05</sub>		2	5	6	3
Seeding rate (lb/a)					
30		63 d	92	95 c	84 d
45		68 c	95	102 b	88 c
60		72 b	94	107 ab	91 b
75		76 a	98	112 a	95 a
90		78 a	98	111 a	96 a
LSD <sub>0.05</sub>		2	6	6	3

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

ANOVA = analysis of variance.

LSD = least significant difference.

## CROPPING AND TILLAGE SYSTEMS

**Table 5. Dryland wheat response to variety and seeding rate at three locations in 2017**

Variety	Seeding rate	Grain yield			
		Tribune	Garden City	Colby	Average
	lb/a	bu/a			
Byrd	30	26	25	47	33
	45	32	33	49	38
	60	29	36	53	40
	75	36	39	52	42
	90	38	35	56	43
T158	30	24	33	67	41
	45	29	40	71	47
	60	29	36	67	44
	75	34	43	75	51
	90	33	48	79	53
TAM 114	30	30	35	70	45
	45	30	41	72	48
	60	33	45	77	52
	75	37	47	72	52
	90	37	44	78	53
Winterhawk	30	24	26	62	37
	45	25	27	69	40
	60	31	38	65	45
	75	32	41	71	48
	90	34	41	74	50

*continued*

## CROPPING AND TILLAGE SYSTEMS

**Table 5. Dryland wheat response to variety and seeding rate at three locations in 2017**

Variety	Seeding rate lb/a	Grain yield			Average
		Tribune	Garden City	Colby	
----- bu/a -----					
<b>ANOVA (P&gt;F)</b>					
Variety		0.014	0.001	0.001	0.001
Seeding rate		0.001	0.001	0.001	0.001
Variety × seeding rate		0.910	0.376	0.400	0.259
Location					0.001
Location × variety					0.001
Location × seeding rate					0.249
Location × variety × seeding rate					0.763
<b>MEANS<sup>1</sup></b>					
Variety					
Byrd		32 ab	34 b	51 c	39 d
T158		30 bc	40 a	72 a	47 b
TAM 114		33 a	42 a	74 a	50 a
Winterhawk		29 c	34 b	68 b	44 c
LSD <sub>0.05</sub>		3	4	3	2
Seeding rate (lb/a)					
30		26 c	30 c	61 c	39 c
45		29 bc	35 b	65 b	43 b
60		31 b	39 ab	66 b	45 b
75		35 a	43 a	67 b	48 a
90		36 a	42 a	72 a	50 a
LSD <sub>0.05</sub>		3	4	4	2

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

ANOVA = analysis of variance.

LSD = least significant difference.

## CROPPING AND TILLAGE SYSTEMS

**Table 6. Dryland wheat response to variety and seeding rate at three locations in 2018**

Variety	Seeding rate	Grain yield			
		Tribune	Garden City	Colby	Average
	lb/a	bu/a			
Byrd	30	49	34	67	50
	45	55	31	71	52
	60	58	36	76	56
	75	57	40	76	58
	90	56	36	79	57
T158	30	47	28	63	46
	45	47	28	76	50
	60	51	35	78	54
	75	54	39	81	58
	90	54	40	85	60
TAM 114	30	47	33	70	50
	45	48	35	71	52
	60	50	42	79	57
	75	52	37	76	55
	90	56	40	87	61
Winterhawk	30	43	27	55	41
	45	45	29	58	44
	60	48	30	61	47
	75	45	33	67	48
	90	47	33	70	50

*continued*

## CROPPING AND TILLAGE SYSTEMS

**Table 6. Dryland wheat response to variety and seeding rate at three locations in 2018**

Variety	Seeding rate lb/a	Grain yield			Average
		Tribune	Garden City	Colby	
----- bu/a -----					
<b>ANOVA (P&gt;F)</b>					
Variety		0.001	0.001	0.001	0.001
Seeding rate		0.005	0.001	0.001	0.001
Variety × seeding rate		0.907	0.119	0.075	0.125
Location					0.001
Location × variety					0.001
Location × seeding rate					0.002
Location × variety × seeding rate					0.642
<b>MEANS<sup>1</sup></b>					
Variety					
Byrd		55 a	35 ab	74 b	55 a
T158		51 b	34 b	76 a	54 a
TAM 114		51 b	38 a	76 a	55 a
Winterhawk		46 c	30 c	62 c	46 b
LSD <sub>0.05</sub>		3	2	3	2
Seeding rate (lb/a)					
30		46 c	30 b	64 d	47 d
45		49 bc	31 b	69 c	50 c
60		52 ab	36 a	73 b	54 b
75		52 ab	37 a	75 b	55 b
90		53 a	37 a	80 a	57 a
LSD <sub>0.05</sub>		4	3	3	2

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

ANOVA = analysis of variance.

LSD = least significant difference.

## CROPPING AND TILLAGE SYSTEMS

**Table 7. Average dryland wheat response to variety and seeding rate at three locations from 2015–2018**

Variety	Seeding rate	Grain yield				
		Tribune	Garden City	Colby	Average	
	lb/a	bu/a				
Byrd	30	48	44	56	49	
	45	54	46	61	54	
	60	57	49	65	57	
	75	58	52	68	60	
	90	61	51	67	59	
T158	30	47	60	69	59	
	45	51	62	79	64	
	60	53	65	77	65	
	75	58	67	80	68	
	90	58	67	84	69	
TAM 111/114	30	5	44	48	64	52
	45	46	52	65	54	
	60	50	55	73	59	
	75	52	57	72	60	
	90	54	58	77	63	
Winterhawk	30	48	45	58	50	
	45	50	49	63	54	
	60	54	53	67	58	
	75	53	57	71	60	
	90	56	57	73	62	

*continued*

## CROPPING AND TILLAGE SYSTEMS

**Table 7. Average dryland wheat response to variety and seeding rate at three locations from 2015–2018**

Variety	Seeding rate lb/a	Grain yield			Average
		Tribune	Garden City	Colby	
		----- bu/a -----			
<b>ANOVA (P&gt;F)</b>					
Variety		0.001	0.001	0.001	0.001
Seeding rate		0.001	0.001	0.001	0.001
Variety × seeding rate		0.270	0.916	0.064	0.468
Year		0.001	0.001	0.001	0.001
Year × variety		0.001	0.001	0.001	0.001
Year × seeding rate		0.020	0.223	0.091	0.476
Year × variety × seeding rate		0.855	0.044	0.313	0.160
Location					0.001
Location × variety					0.001
Location × seeding rate					0.187
Location × variety × seeding rate					0.209
Year × location					0.001
Year × location × variety					0.001
Year × location × seeding rate					0.007
Year × location × variety × seeding rate					0.192
<b>MEANS<sup>1</sup></b>					
Variety					
Byrd		55 a	48 d	63 d	56 c
T158		53 b	64 a	78 a	65 a
TAM 111/114		49 d	54 b	70 b	58 b
Winterhawk		52 c	52 c	66 c	57 c
LSD <sub>0.05</sub>		1	2	2	1
Seeding rate (lb/a)					
30		47 e	49 d	62 e	52 e
45		50 d	52 c	67 d	56 d
60		53 c	56 b	70 c	60 c
75		55 b	58 a	73 b	62 b
90		57 a	58 a	75 a	63 a
LSD <sub>0.05</sub>		2	2	2	1

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

ANOVA = analysis of variance.

LSD = least significant difference.

# Wheat Stubble Height on Subsequent Corn and Grain Sorghum Crops

*A. Schlegel and L. Haag*

## Summary

A field study initiated in 2006 at the Southwest Research-Extension Center near Tribune, KS, was designed to evaluate the effects of three wheat stubble heights on subsequent grain yields of corn and grain sorghum. Corn and sorghum yields in 2018 were greater than the long-term average. When averaged from 2007 through 2018, corn grain yields were 9 bu/a greater when planted into either high or strip-cut stubble than into low-cut stubble. Average grain sorghum yields were 6 bu/a greater in high-cut stubble than low-cut stubble. Similarly, water use efficiency was greater for high or strip-cut stubble for corn and high-cut stubble for grain sorghum than for low-cut stubble. Harvesting wheat shorter than necessary causes a yield penalty for the subsequent row crops, especially dryland corn.

## Introduction

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

## Experimental Procedures

This study was conducted at the Southwest Research-Extension Center dryland station near Tribune, KS. From 2007 through 2018, 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 2018, these heights were 16, 8, and 24 in. (cut after 2017 wheat harvest). In 2018, corn and grain sorghum were seeded at rates of 15,000 seeds/a and 45,000 seeds/a, respectively. Nitrogen was applied to all plots at a rate of 80 lb/a. Starter fertilizer (10-34-0 nitrogen-phosphorus-potassium (N-P-K)) was surface-dribbled off-row at a rate of 7 gal/a. Plots were 40 × 60 ft, with treatments arranged in a randomized complete block design with six replications. Two rows from the center of each plot were harvested with a plot combine for yield and yield component analysis. Soil water mea-

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

## Results and Discussion

The 2018 growing season was drier than normal through March but near or above normal for the remainder of the year, with above normal precipitation for the year (19.81 inch in 2019 vs. normal of 17.90 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 2007 to 2018, corn yields were 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 2018 were not affected by stubble height (Table 3). When averaged across years from 2007 through 2018, 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, 2018**

Stubble height	Yield	Plant population	Ear population	Biomass	Residue	1,000-seed weight	Kernels	WUE <sup>1</sup>
	bu/a	----- 10 <sup>3</sup> /a -----	----- 10 <sup>3</sup> /a -----	----- lb/a -----	----- lb/a -----	oz	no./ear	lb/in.
Low	104	13.6	13.6	11645 b	6720	13.89	492	386
High	112	13.5	13.9	12548 ab	7233	14.28	506	395
Strip	114	13.9	14.5	13231 a	7850	14.08	501	404
LSD <sub>0.05</sub>	15	0.7	1.0	1199	1178	0.57	46	44
ANOVA (P > F)								
Stubble height	0.340	0.407	0.202	0.043	0.152	0.344	0.815	0.672

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

LSD = least significant difference.

ANOVA = analysis of variance.

## CROPPING AND TILLAGE SYSTEMS

**Table 2. Average corn yield, biomass, and yield components as affected by stubble height, Tribune, KS, 2007–2018**

Stubble height	Yield bu/a	Plant	Ear	Biomass	Residue	1,000-seed	Kernels	WUE <sup>1</sup> lb/in.
		population	population			weight		
Low	83 b	13.9	13.8	9982 b	6061 b	11.06	516	307 b
High	92 a	13.9	14.1	10866 a	6511 ab	11.38	508	341 a
Strip	92 a	14.0	14.3	11069 a	6696 a	11.29	536	342 a
LSD <sub>0.05</sub>	5	0.4	0.5	584	516	0.26	71	18
<b>ANOVA (P &gt; F)</b>								
Year	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Stubble height	0.001	0.920	0.238	0.001	0.047	0.056	0.733	0.001
Year × stubble height	0.993	0.996	0.982	0.371	0.118	0.868	0.955	0.955

<sup>1</sup>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, 2018**

Stubble height	Yield bu/a	Head	Biomass	Residue	1,000-seed	Kernels	WUE <sup>1</sup> lb/in.
		population			weight		
Low	116	64.0	12554	6847	1.01	1624	438
High	124	67.9	12339	6251	1.00	1652	453
Strip	125	67.6	11090	4942	0.98	1701	453
LSD <sub>0.05</sub>	10	4.0	1748	1533	0.06	168	37
<b>ANOVA (P &gt; F)</b>							
Stubble height	0.146	0.099	0.182	0.052	0.619	0.607	0.590

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

LSD = least significant difference.

ANOVA = analysis of variance.

## CROPPING AND TILLAGE SYSTEMS

**Table 4. Average sorghum yield, biomass, and yield components as affected by stubble height, Tribune, KS, 2007–2018**

Stubble height	Yield	Head pop- ulation	Biomass <sup>2</sup>	Residue <sup>2</sup>	1,000-seed weight	Kernels	WUE <sup>1</sup>
	bu/a	10 <sup>3</sup> /a	----- lb/a -----		oz	no./head	lb/in.
Low	103 b	56.0	11155	6128	0.90	1887	398 b
High	109 a	57.8	11681	6404	0.90	1944	425 a
Strip	105 ab	57.1	11188	6026	0.89	1879	412 ab
LSD <sub>0.05</sub>	4	2.1	510	460	0.02	101	18
<b>ANOVA (P &gt; F)</b>							
Year	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Stubble height	0.039	0.222	0.077	0.248	0.116	0.384	0.015
Year × stubble height	0.996	0.911	0.985	0.891	0.749	0.018	0.964

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

<sup>2</sup>2015 values not included in average - no samples collected.

LSD = least significant difference.

ANOVA = analysis of variance.

# Mobile Drip Irrigation for Water Limited Crop Production: Initial Results

*J. Aguilar, T. Oker, and I. Kisekka*

## Summary

The farmers within the Ogallala aquifer desire to extend the usable life of this aquifer despite experiencing diminishing well capacities, thus the quest for more efficient irrigation application technologies. Mobile drip irrigation (MDI), which integrates drip lines onto a mechanical irrigation system such as a center pivot, has attracted their attention lately. The concept is that by applying water along crop rows, it was hypothesized that MDI could eliminate water losses due to spray droplet evaporation, wind drift, and reduce soil evaporation due to limited surface wetting especially before canopy closure. A study was conducted with the following objectives: 1) compare soil water evaporation under MDI and in-canopy spray nozzles (low elevation spray application (LESA)); 2) evaluate soil water redistribution under MDI at 60-inch drip line lateral spacing; and 3) compare corn grain yield, and water productivity under MDI and LESA at two well capacities (300 and 600 gpm). The experimental design was randomized complete block with four replications and two treatments (MDI and LESA). Nozzle performance was evaluated using the Spot-on flow measurement device. Soil water evaporation was measured using 4-inch mini-lysimeters placed between corn rows. The effect of a 60-inch lateral spacing on soil water redistribution was measured using neutron attenuation to a depth of 8 feet. Corn yield was determined from harvesting two 40-foot corn rows in the center of each plot. Measured and design nozzle flow rates were similar indicating the irrigation system was performing as designed. Results indicate that soil water evaporation was lower under MDI compared to LESA by an average of 35%. Soil water was greatest at the mid-point between two drip line laterals spaced 60 inches apart at a depth of approximately 20–24 inches. These results indicate drip line spacing of 60 inches is adequate for silt loam soils of southwest Kansas. The effect of irrigation application method (MDI versus spray nozzles [LESA]) on yield at high (600 gpm) and low (300 gpm) well capacities was not statistically significant at the 5% level ( $P > 0.05$ ). The effect of application method on water productivity and irrigation water use efficiency was also not significant. The lack of significant differences in yield could be attributed to the above normal rainfall received during the 2015 growing season (18 inches from May to September). However, it is worth noting that the effect of application method on end-of-season soil water was statistically significant under low well capacity (300 gpm) with mobile drip irrigation having more soil water compared to spray nozzles.

## Introduction

Economies of many rural communities in the Central Plains rely heavily on irrigated agriculture. Diminishing well capacities coupled with the desire to extend the usable life of the Ogallala aquifer have stimulated the quest for efficient irrigation application technologies. Mobile drip irrigation (MDI) which integrates drip line onto a mechanical irrigation system such as a center pivot has attracted attention lately. The concept is not new but with some tweaks from the previous design and the affordability of new materials (e.g. pressure compensating emitters on the drip line), MDI is back in the

market. By applying water along crop rows, it hypothesized that MDI could eliminate water losses due to spray droplet evaporation, wind drift, and reduce soil evaporation due to limited surface wetting especially before canopy closure. However, there were questions raised, particularly during the 2015 Southwest Research-Extension Center Advisory Committee meeting in Garden City, KS, about the use of MDI as it relates to ease of conversion, effect of friction on longevity of the dripline, emitter clogging, rodent damage, and agrochemical application. The SWREC Advisory Committee is composed of crop consultants, one farmer from every county in southwest Kansas, and agriculture and natural resource county extension agents in southwest Kansas. This group was very supportive of testing this technology side by side with existing older technology.

### Experimental Procedures

The experimental design was randomized complete block with four replications (each center pivot span was a replication having MDI and LESA [spray nozzles]). Mobile drip irrigation and in-canopy spray nozzles were compared at high (600 gpm) and low (300 gpm) well capacities to mimic a range of pumping capacities experienced by producers (Figure 1). Nozzle performance was evaluated using the Spot-on device (Figure 2). By applying water along crop rows, it was hypothesized that MDI could reduce soil water evaporation due to reduced surface wetting. Soil water evaporation was measured using 4-inch mini-lysimeters placed between corn rows (Figure 3) in the MDI and LESA research plots. The effect of a 60-inch lateral spacing on soil water redistribution was measured using neutron attenuation to a depth of 8 feet in a transect of five neutron probe access tubes (Figure 4). Corn yield was determined from harvesting two 40-foot corn rows in the center of each plot. Seasonal crop water use was determined from a soil water balance and used in calculating water use efficiency (WUE, also known as water productivity).

### Results and Discussion

Measured mean flow rate,  $\bar{q}$ , for MDI was  $1.03 \pm 0.08 \text{ m}^3/\text{s}$ , which is equivalent to the manufacturer's value (3.7 L/h), indicating that the driplines were functioning as designed. The uniformity coefficient,  $UC$ , of MDI was 93.8%. The uniformity coefficient,  $CU_H$ , for LESA was 83.8%, which was less than that of MDI by 8.9%. Measured and design nozzle flow rates for each span are shown in Table 2, which generally implies the system was uniformly applying water and was performing according to design.

Results indicate that soil water evaporation was lower under MDI compared to LESA on average by 35% (Figure 5). Soil water was greatest at the mid-point between two drip line laterals spaced 60 inches apart at a depth of approximately 20–24 inches (Figure 6). These results indicate that drip line spacing of 60 inches is adequate for silt loam soils of southwest Kansas. The effect of irrigation application method (MDI versus spray nozzles [LESA]) on yield at a high (600 gpm) and low (300 gpm) well capacities was not statistically significant at the 5% level (Figures 8 and 10). For the 600 and 300 gpm studies, the  $P$ -values were  $P = 0.37$  and  $0.67$ , respectively. The effect of application method on water productivity and irrigation water use efficiency was also not significant at high and low well capacities (Figures 9 and 11). The lack of significant differences in yield could be attributed to the high rainfall received during the 2015 growing season (18 inches from May to September). Figure 7 shows the 2015 growing season

## CROPPING AND TILLAGE SYSTEMS

rainfall in comparison to long-term averages. However, it is worth noting that the effect of application method on end-of-season soil water was statistically significant under low well capacity (300 gpm). Plots with mobile drip irrigation have more end-season soil water compared to spray nozzles (Figure 13).

Based on the initial two years of data, it appears that there is lower soil water evaporation under MDI compared to LESA (in-canopy spray nozzles). The spacing of 60 inches also appears adequate for MDI on silt loam soils. Results have shown that there is no significant difference in yield during the two years of corn growing seasons. Accordingly, there was no significant difference in water productivity and irrigation water use efficiency at the same well capacity between the application technologies, but water use efficiency (WUE) was higher at low well capacity (300 gpm) compared to WUE at 600 gpm. It was interesting to note that the end-of-season soil water was significantly higher under MDI for low well capacity (300 gpm) for 2015, but this was not evident in 2016.

**Table 1. Measured and design spray nozzle flow rates for selected nozzles in span 1 at the Kansas State University Southwest Research-Extension Center, near Garden City, KS**

No.	Span	Sprinkler	Design value	Measured value		Mean
				07/09/2015	06/30/2015	
----- gpm -----						
1	1	3	0.57	0.56	0.53	0.55
2	1	5	0.68	0.66	0.64	0.65
3	1	6	0.68	0.65	0.64	0.65
4	1	8	0.68	0.77	0.72	0.75

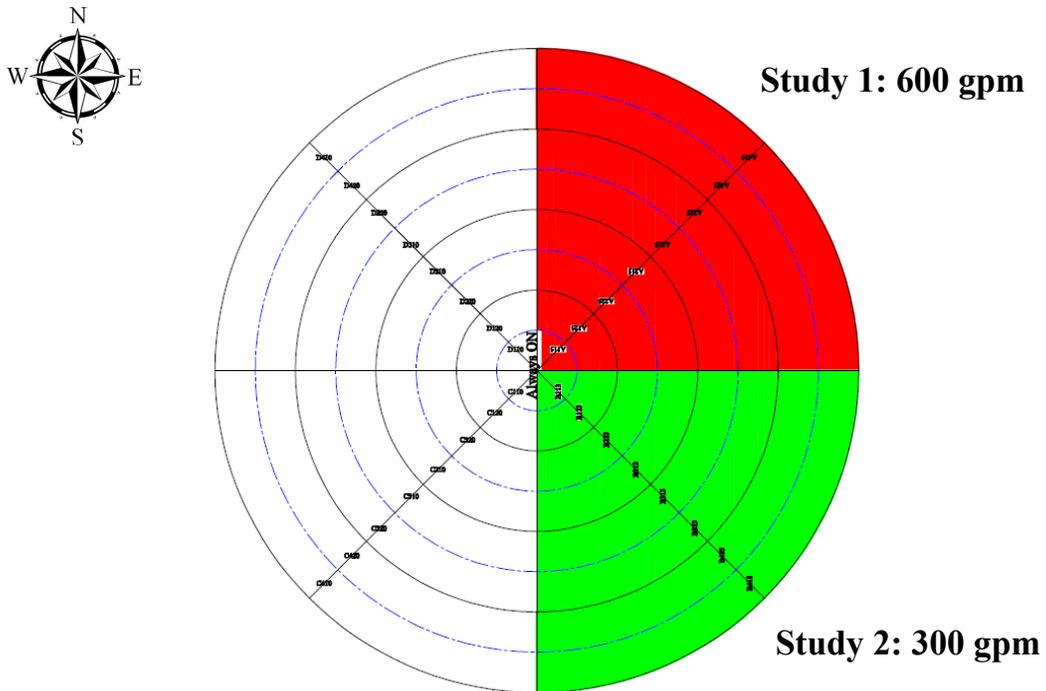


Figure 1. Experimental layout of two studies comparing mobile drip irrigation (MDI) and in-canopy spray nozzles at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.

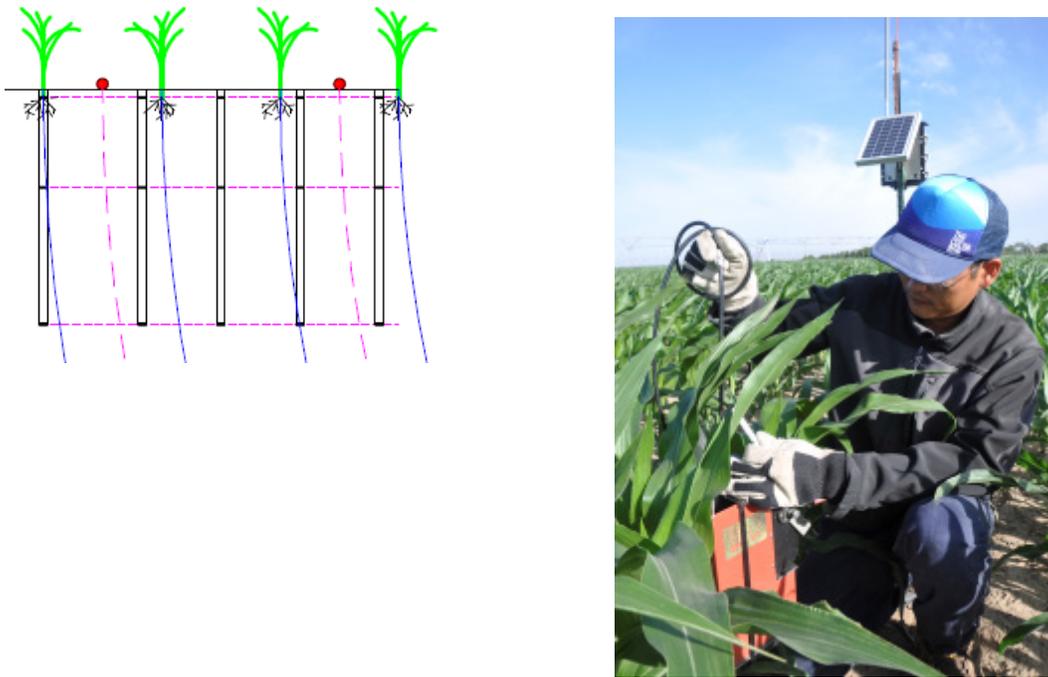


Figure 2. Measuring spray nozzle flow rate using a Spot-on device to compare with design flow rates at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.



**Figure 3. Measuring soil water evaporation using mini-lysimeter under spray nozzles and mobile drip irrigation at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.**

## CROPPING AND TILLAGE SYSTEMS

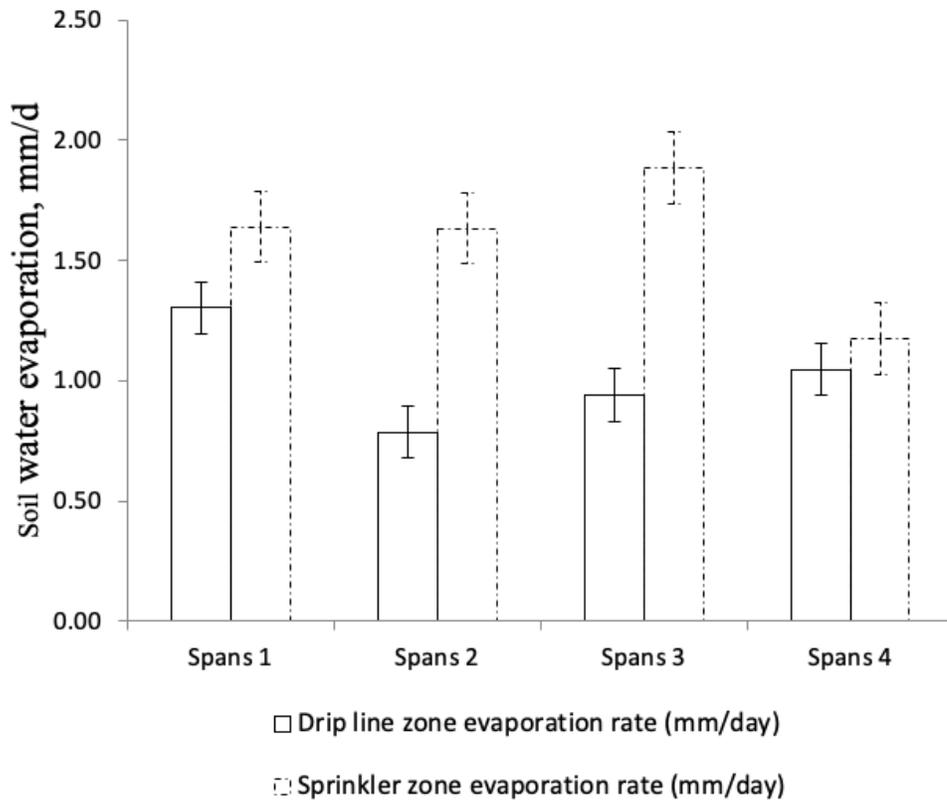


**Figure 4.** Soil water measurement using a neutron probe to determine soil water redistribution and crop water use at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.

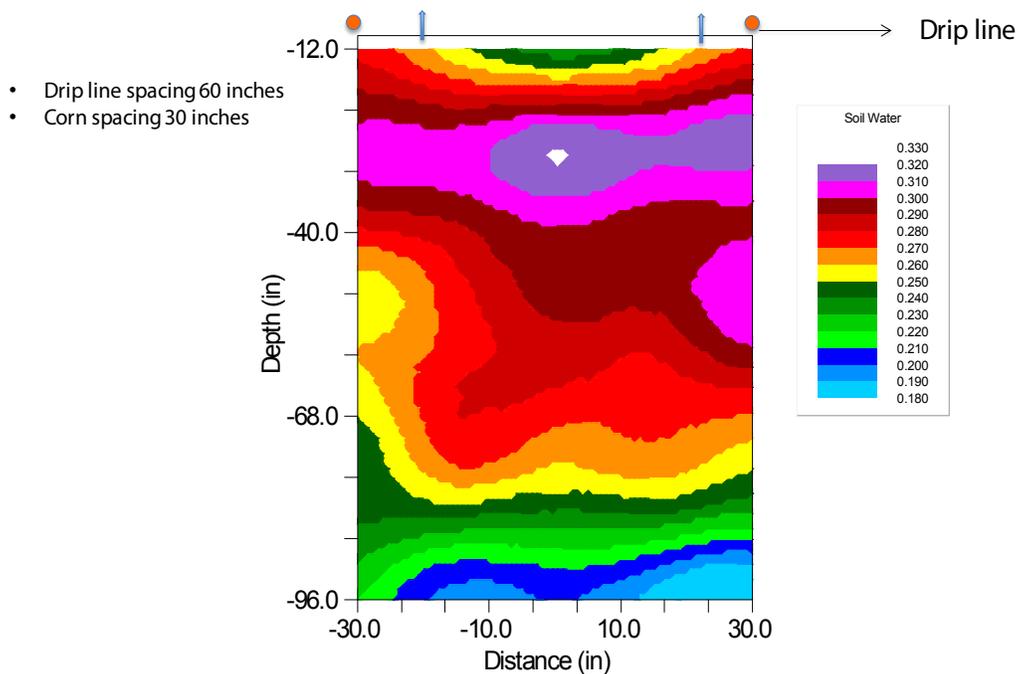


**Figure 5.** Shelling corn to determine yield at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.

## CROPPING AND TILLAGE SYSTEMS

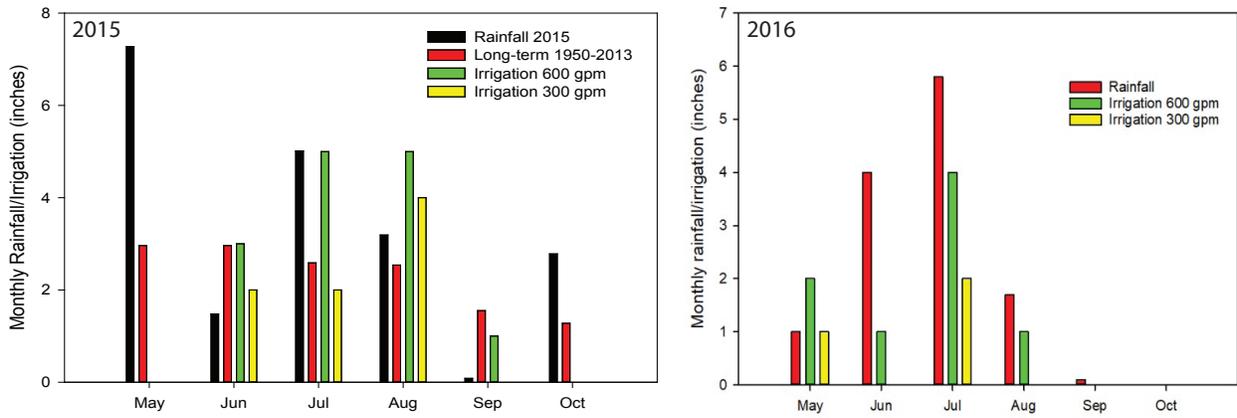


**Figure 6.** Comparing soil water evaporation under MDI and spray nozzles during the 2015 corn growing season at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.

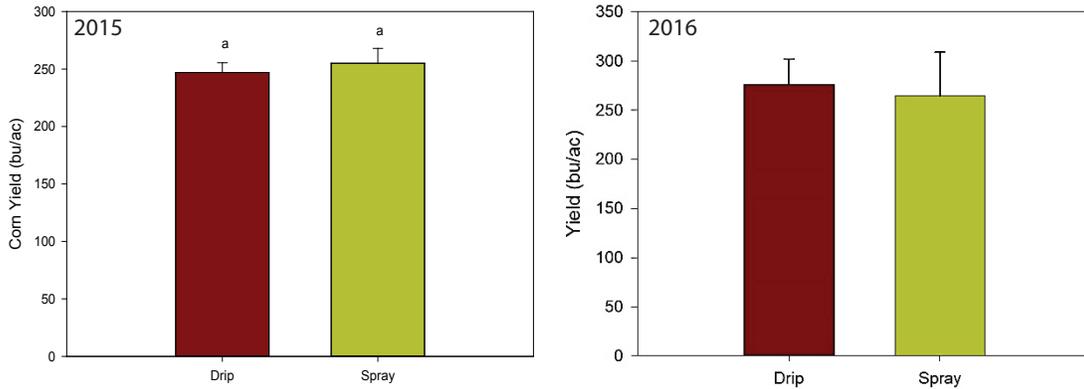


**Figure 7.** Soil water at different points within the root zone under mobile drip irrigation, drip line lateral spacing is 60 inches, data are from transect of five neutron probes access tubes and surface created using Kriging.

# CROPPING AND TILLAGE SYSTEMS

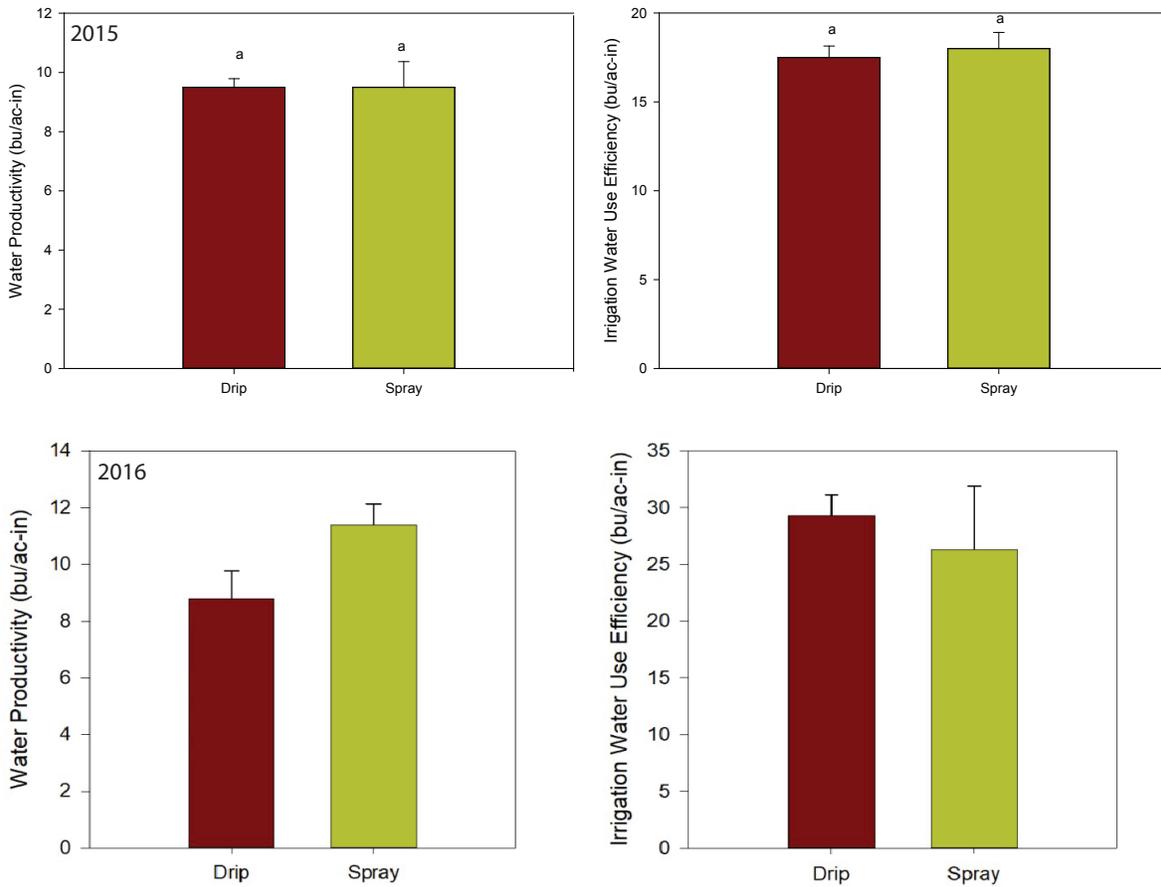


**Figure 8. Growing season (May to September) rainfall, long term average, monthly irrigation applications for the 300 and 600 gpm studies at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.**

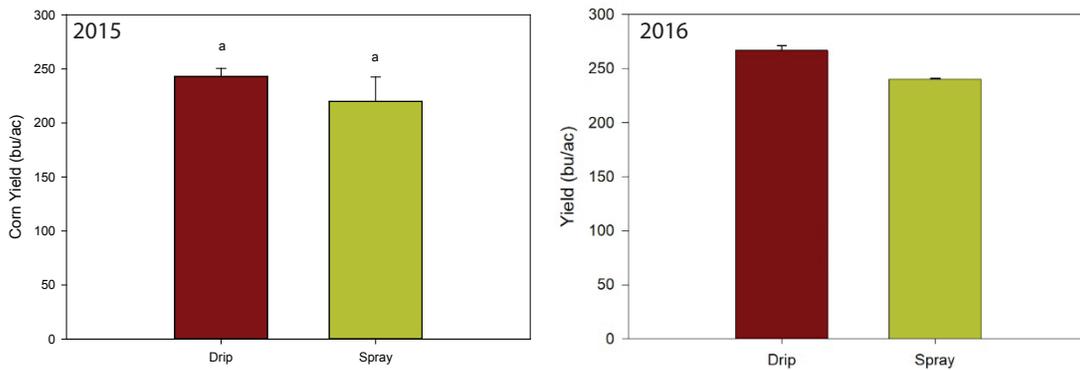


**Figure 9. Corn grain yield under mobile drip irrigation and spray nozzles for well capacity of 600 gpm during the 2015 and 2016 growing seasons at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.**

# CROPPING AND TILLAGE SYSTEMS

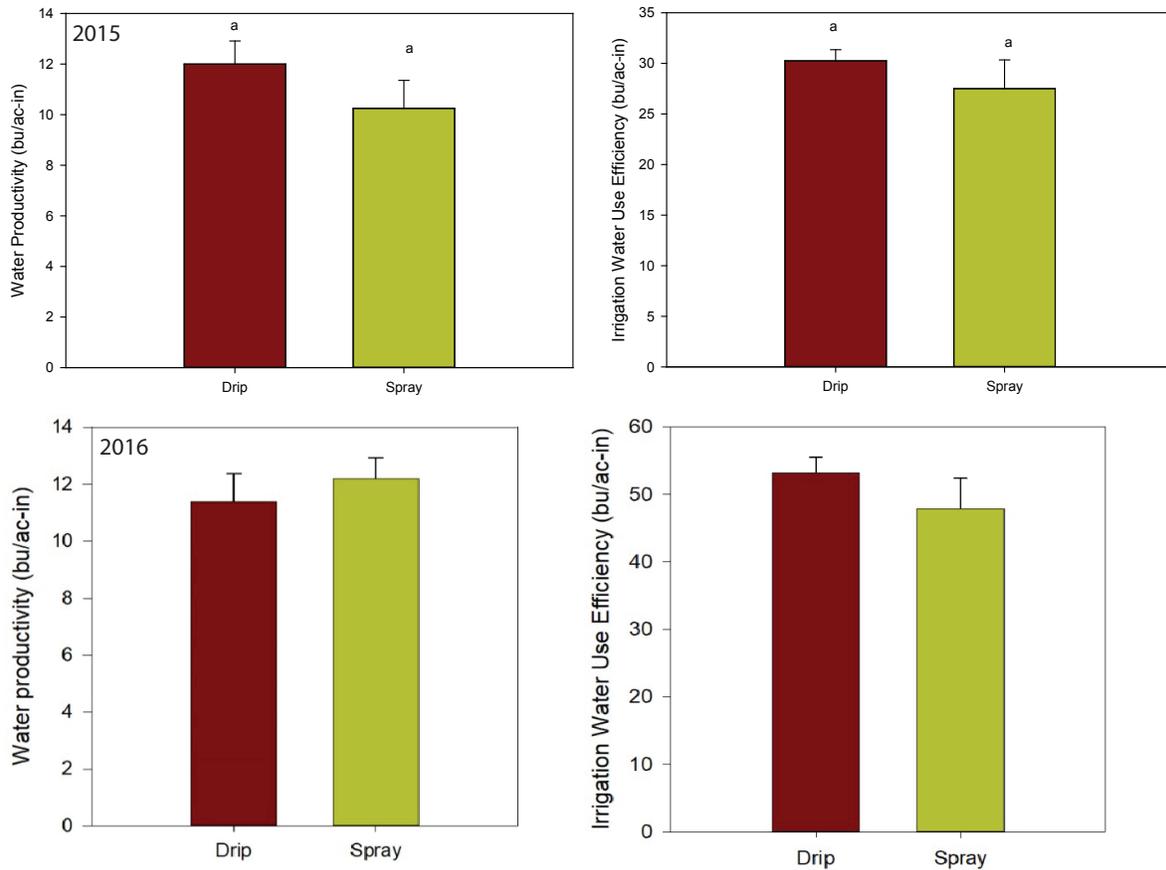


**Figure 10. Water productivity and irrigation water use efficiency of mobile drip irrigation and spray nozzles for well capacity of 600 gpm during the 2015 and 2016 growing seasons at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.**

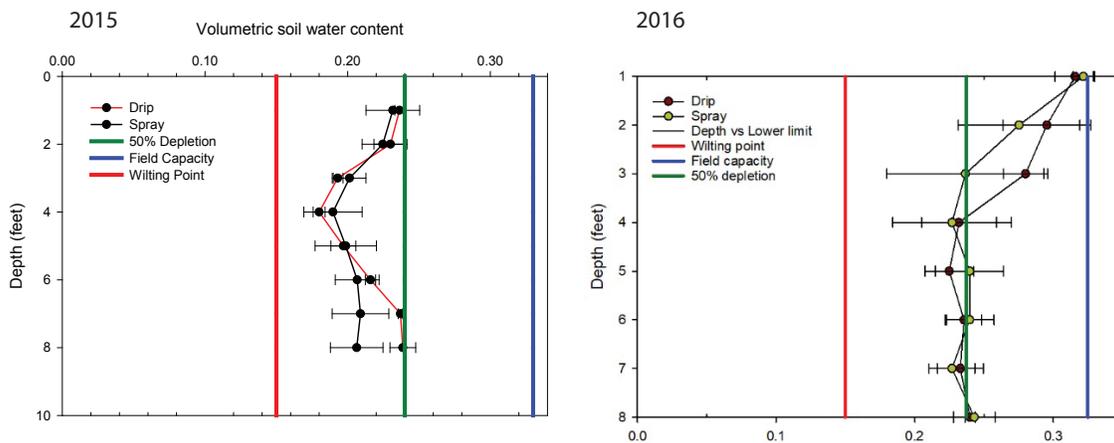


**Figure 11. Corn grain yield under mobile drip irrigation and spray nozzles for well capacity of 300 gpm during the 2015 and 2016 growing seasons at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.**

# CROPPING AND TILLAGE SYSTEMS

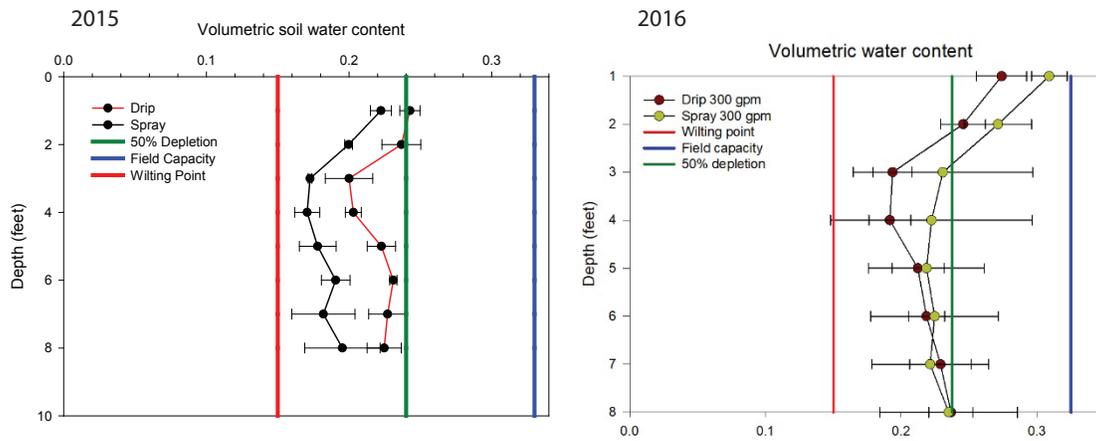


**Figure 12. Water productivity and irrigation water use efficiency of mobile drip irrigation and spray nozzles for well capacity of 600 gpm during the 2015 and 2016 growing season at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.**



**Figure 13. End-of-season soil water measurements under mobile drip irrigation and spray nozzles for well capacity of 600 gpm during the 2015 and 2016 growing seasons at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.**

# CROPPING AND TILLAGE SYSTEMS



**Figure 14. End-of-season soil water measurements under mobile drip irrigation and spray nozzles for well capacity of 300 gpm during the 2015 and 2016 growing seasons at the Kansas State University Southwest Research-Extension Center, near Garden City, KS.**

# 2018 Kansas Summer Annual Forage Hay and Silage Variety Trial

*J. Holman, A. Obour, A. Esser, J. Lingenfelter, T. Roberts, and S. Maxwell*

## Summary

In 2018, summer annual forage variety trials were conducted across Kansas near Garden City, Hays, and Scandia. All sites evaluated hay and silage entries. Companies were able to enter varieties into any possible combinations of research sites, so not all sites had all varieties. Across the sites, a total of 77 hay varieties and 87 silage varieties were evaluated.

## Introduction

Annually there are approximately 35,000,000 acres of hay and haylage harvested in the U.S. for a total of 96,000,000 dry matter tons of production. Yields in Kansas averaged 2.77 tons of dry matter per acre. Of this total, about 13,600,000 acres were alfalfa, which averaged 3.76 dry matter tons per acre, and all other crops averaged 2.13 dry matter tons/a.

In Kansas, there were 2,400,000 acres of hay and haylage harvested with an average yield of 2.24 dry matter tons per acre. Of this total, 650,000 acres were alfalfa with an average yield of 3.72 dry matter tons per acre, and 1,770,000 acres were crops other than alfalfa with an average yield of 1.69 dry matter tons/a. Kansas ranked 6th in the U.S. for hay and haylage production, which largely supports the state dairy (ranked 19th in the U.S. and valued at \$483,000,000) and cattle (feedlot, background, and cow/calf) industries (ranked second in the U.S. and valued at \$10,200,000,000). Dairy and beef cattle represented 58% of the total agricultural product of Kansas. Hay and grain commodities that support these two industries are critical for the state.

## Study Objectives

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

## Procedures

The Summer Annual Forage Variety Test was conducted near Garden City, Hays, and Scandia, KS. All of the sites evaluated hay and silage entries. Companies were able to enter varieties into any possible combinations of research sites, so not all sites had all varieties. In the hay test, there were 23 entries at Garden City, 15 at Hays, 9 at Mound Valley, and 11 at Scandia. In the silage test, there were 33 entries at Garden City, 29 at Hays, and 25 at Scandia (Table 1). Across the sites, a total of 77 hay varieties and 87 silage varieties were evaluated. Information on the varieties is shown in Tables 2 and 3.

Management guidelines were provided to cooperators; however, previous growing experience influenced final management decisions. All trials were planted in small research plots (approximately 225 ft<sup>2</sup>) with three replications. Cultural practices (Table 4), growing season temperature, and precipitation (Figures 1-4) are provided for each site. Results are listed alphabetically by seed supplier. Forage samples were dried, ground, and analyzed for nutrient contents using NIR (near infrared reflectance) by SDK Laboratories in Hutchinson, KS. Nutrient contents measured were acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro true dry matter digestibility after 48 hours (IVTDMD@48hr), lignin, % of NDF digestible after 48 hours (NDFD@48hr), nitrogen free NDF (NDFn), net energy for gain (NEG), net energy for lactation (NEL), net energy for maintenance (NEM), non-fibrous carbohydrates (NFC), crude protein, relative forage quality (RFQ), total digestible nutrients (TDN), and starch (silage only).

### ***2018 Growing Conditions***

Temperature and precipitation (Figures 1-4) for each site is shown. Thick black lines on the temperature graphs represent long-term average high and low temperatures (°F) for the location. The upper thin line represents actual daily high temperatures, and the lower thin line represents actual daily low temperatures. On the precipitation graph, the line labeled “normal” represents long-term average precipitation (1981-2010), and the line labeled “2018” represents actual precipitation.

In general, the 2018 growing season saw near normal temperatures, dry spring conditions, coupled with above average moisture during the remainder of the growing season. Garden City and Hays ended the growing season with twice the normal accumulative precipitation, and Scandia ended with near normal precipitation.

## **Results and Discussion**

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

### ***Hay Test***

At Garden City, ADV S6504, AS6402, Nutrimaxx II BMR, and Super Sugar DM were in the top LSD (least significant difference at  $P \leq 0.05$ ) group in the first cutting (Table 5). In the second cutting, more separation occurred between entries. Canex, Millex32, Nutri King BMR, Sweet Forever BMR, and Sweet Six BMR were in the highest yielding LSD group. Combined across cuttings, F75FS13, Sumac, Canex, Canex BMR 210, Millex32, ADV S6504, AS6402, SP4555 BMR, Fullgraze II BMR, Grazex BMR 801, Nutrimaxx II BMR, Nutri King BMR, Super Sugar DM, Sweet Forever BMR, and Sweet Six BMR were in the top LSD group.

At Hays, 374x66, AL374x66, F75FS13, Sumac, ADV S6504, AS6402, Lincoln, 1st Choice BMR, Cadan 99B, High Yield BMR, High Yield Conventional, Danny Boy BMR, Fullgraze II, Fullgraze II BMR, Nutrimaxx II BMR, Mega Green BMR, Nutri King BMR, Super Sugar DM, and Sweet Six BMR had the greatest yield in the top LSD

group in the first cutting (Table 6). There was no second cutting due to little regrowth caused by soil water ponding and frost in early October.

At Scandia, F75FS13, Rox Orange, ADV S6504, AS6402, Fullgraze II, Bruiser BMR, Nutri King BMR, Super Sugar DM, Sweet Forever BMR, and Sweet Six BMR were in the top LSD group in the first cutting (Table 7). There was no second cutting due to little regrowth caused by soil water ponding and frost in early October.

### *Silage Test*

At Garden City, ADV XF033, AF8301, 705F, Super Sile 20, and Super Sile 30 were in the top LSD group for silage (Table 8).

At Hays, ADV XF033, Silo Mor II BMR, F74FS23 BMR, F76FS77 BMR, Super Sile 20, Super Sile 30, KS Orange, Canex BMR 600, Silex BMR 540, Packer, 4 Ever Green, EXP 10002 BMR, EXP 10218, EXP 10222 BMR, EXP 10225 BMR, EXP 10226 BMR, EXP 10227 BMR, GW 2120, and GW 400 BMR were in the top LSD group for silage (Table 9).

At Scandia, ADV XF033 and Super Sile 30 were in the top LSD group for silage (Table 10).

### *Recommendation*

Inestimable differences in soil type, weather, and environmental conditions play a part in increasing experimental error, therefore one should use more than one location and one year of data to make an informed variety selection decision. Please refer to previous years' forage reports to see how a variety performed across years.

### **Acknowledgments**

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

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

Location	Hay	Silage
Garden City	23	33
Hays	36	29
Scandia	18	25
Total	77	87

Table 2. 2018 Hay entries

Year	Company	Variety	Type	BMR	Dwarf	Male sterile	Dry stalk	Photoperiod sensitive	Maturity	Greenbug resistance
2018	Agrilead	AL374x66	FS	N	Y	N	N	N	E	N
2018	Agrilead	374x66	FS	N	Y	N	N	N	E	N
2018	Alta Seeds	AS6402	SS	Y	Y	N	N	N	ML	NA
2018	Alta Seeds	ADV S6504	SS	Y	N	N	N	Y	PS	NA
2018	American Hybrids	Brighton	SS	N	N	N	Y	N	M	N
2018	American Hybrids	Lincoln	SS	Y	N	N	N	N	M	N
2018	American Hybrids	Sugar Sweet	SS	N	N	N	Y	N	M	N
2018	American Hybrids	Navion	SS	Y	N	N	N	N	ML	N
2018	Arrow Seed	1st Choice BMR	SS	Y	N	N	N	N	E	N
2018	Browning Seed	Cadan 99B	SS	N	N	N	Y	N	ML	N
2018	Browning Seed	Sweet Sioux BMR	SS	Y	N	N	N	N	ML	N
2018	Chromatin Inc.	Millex32	MT	N	N	N	N	N	E	NA
2018	Chromatin Inc.	SP4555 BMR	SS	Y	N	N	N	N	M	NA
2018	Chromatin Inc.	SP4105 BMR	SS	Y	Y	N	N	Y	PS	NA
2018	CHS Seed Resources	High Yield Conventional	SS	N	N	N	N	N	L	NA
2018	CHS Seed Resources	High Yield BMR	SS	Y	N	N	N	N	L	NA
2018	CHS Seed Resources	High Yield BMR Dwarf	SS	Y	Y	N	N	N	ME	NA
2018	CHS Seed Resources	PearlPlus BMR	MT	Y	N	N	N	N	ML	NA
2018	CHS Seed Resources	High Yield BMR PS	SS	Y	N	N	N	Y	PS	NA
2018	Dyna-Gro Seed	PearlMil	MT	N	N	N	N	N	M	N

*continued*

**Table 2. 2018 Hay entries**

Year	Company	Variety	Type	BMR	Dwarf	Male sterile	Dry stalk	Photoperiod sensitive	Maturity	Greenbug resistance
2018	Dyna-Gro Seed	F75FS13	FS	N	N	N	N	N	M	N
2018	Dyna-Gro Seed	Fullgraze BMR	SS	Y	N	N	N	N	MF	N
2018	Dyna-Gro Seed	Fullgraze II	SS	N	N	N	N	N	MF	N
2018	Dyna-Gro Seed	Fullgraze II BMR	SS	Y	N	N	N	N	MF	N
2018	Dyna-Gro Seed	Danny Bo BMR	SS	Y	N	N	N	Y	PS	N
2018	KSU (check)	Rox Orange	FS	N	N	N	N	N	M	N
2018	KSU (check)	Early Sumac	FS	N	N	N	N	N	M	N
2018	KSU (check)	Mixed Cane	FS	NA	NA	NA	NA	NA	NA	NA
2018	Sharp Bros Seed	Canex	FS	N	N	Y	N	N	ME	N
2018	Sharp Bros Seed	Canex BMR 210	FS	Y	N	N	N	N	ME	N
2018	Sharp Bros Seed	Grazex BMR 801	SS	Y	N	Y	N	N	ME	N
2018	Star Seed	Nutrimaxx II BMR	SS	Y	N	N	N	N	L	NA
2018	Star Seed	Bruiser BMR	SS	Y	N	N	N	N	ME	NA
2018	Walter Moss Seed	Mega Green	SS	N	N	N	N	Y	PS	Y
2018	Walter Moss Seed	Mega Green BMR	SS	Y	N	N	N	Y	PS	Y
2018	Ward Seed	Sweet Six BMR	SS	Y	N	N	Y	N	E	NA
2018	Ward Seed	Super Sugar DM	SS	N	N	N	N	N	L	NA
2018	Ward Seed	Nutri King BMR	SS	Y	N	N	N	N	ME	NA
2018	Ward Seed	Sweet Forever BMR	SS	Y	N	N	N	Y	PS	NA

Hybrid information was provided by seed companies.

Abbreviations: Forage sorghum (FS), sorghum sudan (SS), sorghum (S), brown mid-rib (BMR), photoperiod sensitive (PS), not applicable (NA).

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

**Table 3. 2018 Silage Entries**

Company	Variety	Type	BMR	Dwarf	Male sterile	Dry stalk	Photoperiod sensitive	Maturity	Greenbug resistance	1000 seed weight, grams
Agrilead	AL374x66	FS	N	N	Y	N	N	E	N	26.98
Agrilead	374x66	FS	N	N	Y	N	N	E	N	26.96
Alta Seeds	AF7401	FS	Y	Y	N	N	N	ML	NA	23.35
Alta Seeds	ADV XF372	FS	Y	Y	N	N	N	M	NA	25.55
Alta Seeds	AF8301	FS	N	N	N	N	N	M	NA	31.83
Alta Seeds	ADV XF033	FS	N	N	N	N	N	M	NA	36.54
Arrow Seed	Silo Mor II BMR	FS	Y	N	N	N	N	ML	N	29.41
Chromatin Inc.	NK300	FS	N	N	N	N	N	ME	N	32.79
Chromatin Inc.	SP2876 BMR	FS	Y	N	N	N	N	M	N	28.53
Chromatin Inc.	SP3808SB BMR	FS	Y	Y	N	N	N	F	NA	26.25
Chromatin Inc.	SP4555 BMR	SS	Y	N	N	N	N	M	NA	30.55
Dyna-Gro Seed	705F	FS	N	N	N	N	N	EM	N	31.33
Dyna-Gro Seed	Super Sile 30	FS	N	N	N	N	N	EM	N	29.08
Dyna-Gro Seed	F74FS23 BMR	FS	Y	N	N	N	N	M	N	32.38
Dyna-Gro Seed	F76FS77 BMR	FS	Y	Y	N	N	N	ML	C	32.51
Dyna-Gro Seed	FX18340	FS	N	N	N	N	N	ML	N	32.67
Dyna-Gro Seed	Super Sile 20	FS	N	N	N	N	N	ML	N	23.35

*continued*

**Table 3. 2018 Silage Entries**

Company	Variety	Type	BMR	Dwarf	Male sterile	Dry stalk	Photoperiod sensitive	Maturity	Greenbug resistance	1000 seed weight, grams
KSU (check)	KS Orange	FS	N	N	N	N	N	M	N	18.40
Sharp Bros Seed	Canex BMR 210	FS	Y	N	N	N	N	M	N	26.20
Sharp Bros Seed	Canex BMR 600	FS	Y	N	Y	N	N	ML	N	27.95
Sharp Bros Seed	Silex BMR 540	FS	Y	Y	N	N	N	ML	N	28.78
Star Seed	Packer	FS	N	N	N	N	N	ML	NA	27.32
Star Seed	Brutus BMR	FS	N	N	N	N	N	ML	NA	29.53
Walter Moss Seed	4 Ever Green	FS	N	N	N	N	Y	PS	Y	27.44
Ward Seed	Silo Pro BMR	FS	Y	Y	Y	N	N	M	Y	29.61
Ward Seed	GW 400 BMR	FS	Y	N	Y	N	N	ME	Y	24.98
Ward Seed	GW 475 BMR	FS	Y	N	Y	Y	N	E	Y	29.92
Ward Seed	GW 2120	FS	N	N	Y	N	N	M	Y	24.96
Ward Seed	EXP 10218	FS	N	Y	N	N	N	L	Y	29.09
Ward Seed	EXP 10002 BMR	FS	Y	Y	N	Y	N	M	Y	20.73
Ward Seed	EXP 10222 BMR	FS	Y	Y	N	Y	N	M	Y	25.00
Ward Seed	EXP 10225 BMR	FS	Y	Y	N	Y	N	M	Y	30.98
Ward Seed	EXP 10226 BMR	FS	Y	Y	N	Y	N	M	Y	25.40
Ward Seed	EXP 10227 BMR	FS	Y	Y	N	Y	N	ME	Y	29.68
Ward Seed	EXP 10228 BMR	FS	Y	Y	N	Y	N	ME	Y	25.79

Hybrid information was provided by seed companies.

Abbreviations: Forage sorghum (FS), sorghum sudan (SS), sorghum (S), brown mid-rib (BMR), photoperiod sensitive (PS), not applicable (NA).

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

**Table 4. Irrigation, planting, harvesting, and fertilizing details for hay and silage variety tests near Garden City, Hays, and Scandia, KS, in 2018**

Location	Irrigation	Planting date	1st harvest date(s)	2nd harvest	Seeding rate	Harvest area	Fertilizer	
				date			lb N/a	lb P <sub>2</sub> O <sub>5</sub> /a
	in.				lb/a	ft <sup>2</sup>		
Hay test								
Garden City	9.17	5-Jun	2-Aug / 14-Aug / 27-Aug	2-Nov	20	360		0
Hays	---	15-Jun	28-Aug / 18-Sep / 25-Sep	---	15	90	50	30
Scandia	---	14-Jun	28-Aug	---	30	60	50	0
Silage test								
					Seeds/a			
Garden City	9.17	4-Jun	14-Sep / 27-Sep	---	100000	225	180	0
Hays	---	15-Jun	18-Sep / 2-Oct / 16-Oct	---	50000	25	50	30
Scandia	---	14-Jun	17-Sep / 24-Sep / 27-Sep	---	80800	67.5	50	

**Table 5a. Hay performance test near Garden City  
2018 Garden City, Kansas Hay Performance Test, Finney County**

Brand	Name	Performance					
		1st cutting	2nd cutting	Total yield	1st cutting	2nd cutting	1st height
		----- lb DM/a -----			----- % moisture -----		in.
Forage sorghum							
Dyna-Gro Seed	F75FS13	8251	3835	<b>12086</b>	0.83	0.47	94
KSU (check)	Early Sumac	7931	4093	<b>12024</b>	0.84	0.48	79
KSU (check)	Mixed Cane	7202	4109	11310	0.84	0.46	84
KSU (check)	Rox Orange	6471	2166	8637	0.85	0.42	69
Sharp Bros Seed	Canex	7323	<b>4987</b>	<b>12309</b>	0.86	0.59	100
Sharp Bros Seed	Canex BMR 210	9341	3239	<b>12580</b>	0.84	0.47	93
Millet							
Chromatin Inc.	Millex32	7128	<b>4866</b>	<b>11995</b>	0.86	0.34	88
Dyna-Gro Seed	PearlMil	7163	3823	10986	0.83	0.30	85
Sorghum sudan							
Alta Seeds	ADV S6504	<b>10483</b>	1852	<b>12335</b>	0.85	0.35	77
Alta Seeds	AS6402	<b>10700</b>	1292	<b>11992</b>	0.80	0.32	73
Chromatin Inc.	SP4105 BMR	10260	1065	11325	0.85	0.37	69
Chromatin Inc.	SP4555 BMR	6598	<b>5548</b>	<b>12146</b>	0.87	0.60	97
Dyna-Gro Seed	Danny Boy BMR	6090	<b>5451</b>	11542	0.88	0.63	99
Dyna-Gro Seed	Fullgraze BMR	9411	1123	10534	0.83	0.34	83
Dyna-Gro Seed	Fullgraze II	7361	3614	10974	0.86	0.51	101
Dyna-Gro Seed	Fullgraze II BMR	10135	2545	<b>12680</b>	0.81	0.46	90
Sharp Bros Seed	Grazex BMR 801	8852	4203	<b>13055</b>	0.83	0.41	109
Star Seed	Bruiser BMR	7968	3298	11266	0.84	0.47	79
Star Seed	Nutrimaxx II BMR	<b>12243</b>	1271	<b>13514</b>	0.83	0.43	99
Ward Seed	Nutri King BMR	7321	<b>5455</b>	<b>12775</b>	0.86	0.57	87
Ward Seed	Super Sugar DM	<b>11479</b>	2475	<b>13954</b>	0.81	0.38	99
Ward Seed	Sweet Forever BMR	6054	<b>5673</b>	<b>11727</b>	0.85	0.54	98
Ward Seed	Sweet Six BMR	7531	<b>5941</b>	<b>13473</b>	0.86	0.57	96
	Average	8404	3562	11966	0.84	0.46	89.09
	LSD (0.05)	1776	1352	2305			

**Table 5b. Hay performance test near Garden City  
2018 Garden City, Kansas Hay Performance Test, Finney County**

Brand	Name	Forage quality											Crude protein	RFQ	TDN
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC				
----- % -----															
Forage sorghum															
Dyna-Gro Seed	F75FS13	39.56	61.62	72.77	8.24	54.33	57.31	0.22	0.52	0.55	18.60	10.23	93.82	51.85	
KSU (check)	Early Sumac	37.91	60.10	71.40	8.38	50.93	55.89	0.24	0.53	0.56	21.72	9.75	97.54	52.68	
KSU (check)	Mixed Cane	39.32	63.48	70.07	8.37	51.13	59.03	0.21	0.51	0.54	17.63	10.74	92.74	51.05	
KSU (check)	Rox Orange	38.24	61.65	72.80	7.55	55.77	57.34	0.26	0.55	0.58	21.95	8.45	98.82	54.25	
Sharp Bros Seed	Canex	38.69	61.16	72.77	8.13	54.07	56.88	0.24	0.54	0.57	21.08	9.90	99.57	53.35	
Sharp Bros Seed	Canex BMR 210	38.39	61.59	74.10	8.27	56.63	57.28	0.24	0.54	0.57	19.34	9.90	100.14	53.36	
Millet															
Chromatin Inc.	Millex32	41.60	64.39	71.37	9.31	54.67	59.88	0.21	0.51	0.53	14.26	12.44	87.17	50.50	
Dyna-Gro Seed	PearlMil	39.46	62.79	73.80	8.41	58.03	58.40	0.24	0.53	0.56	16.83	11.36	95.13	52.81	
Sorghum sudan															
Alta Seeds	ADV S6504	43.19	66.82	70.90	8.23	54.77	62.15	0.19	0.49	0.52	15.18	8.69	79.23	49.17	
Alta Seeds	AS6402	42.18	65.24	70.20	8.36	51.73	60.67	0.19	0.49	0.52	15.26	10.47	82.90	49.12	
Chromatin Inc.	SP4105 BMR	41.67	64.13	71.20	8.32	53.33	59.64	0.19	0.49	0.52	15.77	9.76	83.53	49.38	
Chromatin Inc.	SP4555 BMR	38.89	59.99	74.23	8.09	55.53	55.79	0.22	0.52	0.55	17.16	11.70	94.11	51.48	
Dyna-Gro Seed	Danny Boy BMR	41.17	62.42	76.73	8.14	62.43	58.05	0.24	0.53	0.57	14.49	12.27	95.92	53.02	
Dyna-Gro Seed	Fullgraze BMR	40.70	63.56	73.20	8.47	55.33	59.11	0.22	0.52	0.55	19.75	8.38	88.60	51.63	
Dyna-Gro Seed	Fullgraze II	40.27	65.07	68.27	9.14	50.50	60.52	0.19	0.49	0.52	16.29	9.40	84.32	49.17	
Dyna-Gro Seed	Fullgraze II BMR	42.76	67.71	67.43	8.07	49.73	62.97	0.18	0.48	0.51	16.69	7.73	75.13	48.48	
Sharp Bros Seed	Grazex BMR 801	42.66	65.98	67.53	9.43	49.57	61.36	0.18	0.49	0.51	15.08	10.30	80.39	48.65	
Star Seed	Bruiser BMR	38.37	62.47	75.63	7.82	60.47	58.09	0.26	0.55	0.59	18.40	9.89	104.13	54.56	
Star Seed	Nutrimaxx II BMR	42.01	63.13	71.80	9.47	51.13	58.71	0.18	0.49	0.51	18.60	8.97	80.62	48.80	
Ward Seed	Nutri King BMR	38.37	60.12	76.57	7.56	60.10	55.91	0.24	0.54	0.57	16.47	12.18	100.73	53.11	
Ward Seed	Super Sugar DM	40.82	63.26	68.93	8.90	48.93	58.83	0.20	0.50	0.53	20.71	8.43	84.34	50.31	
Ward Seed	Sweet Forever BMR	40.64	62.46	70.97	9.09	52.07	58.08	0.21	0.51	0.54	17.84	10.99	90.08	50.86	
Ward Seed	Sweet Six BMR	40.28	62.43	74.77	7.99	58.57	58.06	0.24	0.53	0.57	17.04	10.94	97.68	53.02	
	Average	40.31	63.53	72.06	8.42	54.34	58.69	0.22	0.52	0.54	17.66	10.12	90.72	51.33	

Values in bold are in the top LSD group.

Acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro true dry matter digestibility after 48 hours (IVTDMD@48hr), % of NDF digestible after 48 hours (NDFD@48hr), nitrogen free NDF (NDFn), net energy for gain (NEG), net energy for lactation (NEL), net energy for maintenance (NEM), non-fibrous carbohydrates (NFC), relative forage quality (RFQ), total digestible nutrients (TDN).

**Table 6a. Hay performance test near Hays  
2018 Hays, Kansas Forage Hay Performance Test, Ellis County**

Brand	Name	Performance		
		1st cutting lb DM/a	1st cutting % moisture	1st height in.
Forage sorghum				
Agrilead	374x66	<b>10211</b>	0.74	84
Agrilead	AL374x66	<b>8635</b>	0.72	89
Dyna-Gro Seed	F75FS13	<b>9609</b>	0.72	88
KSU (check)	Early Sumac	<b>9520</b>	0.75	101
KSU (check)	Mixed Cane	6311	0.74	99
KSU (check)	Rox Orange	7958	0.76	88
Sharp Bros Seed	Canex	7185	0.74	95
Sharp Bros Seed	Canex BMR 210	7100	0.72	95
Millet				
CHS Seed Resources	PearlPlus BMR	5189	0.71	50
Dyna-Gro Seed	PearlMil	3466	0.70	72
Sorghum sudan				
Alta Seeds	ADV S6504	<b>9862</b>	0.72	87
Alta Seeds	AS6402	<b>8983</b>	0.67	74
American Hybrids	Brighton	8529	0.68	112
American Hybrids	Lincoln	<b>8915</b>	0.71	88
American Hybrids	Navion	8515	0.69	85
American Hybrids	Sugar Sweet	8412	0.69	106
Arrow Seed	1st Choice BMR	<b>8771</b>	0.73	89
Browning Seed	Cadan 99B	<b>8897</b>	0.69	111
Browning Seed	Sweet Sioux BMR	6932	0.74	89

*continued*

**Table 6a. Hay performance test near Hays  
2018 Hays, Kansas Forage Hay Performance Test, Ellis County**

Brand	Name	Performance		
		1st cutting lb DM/a	1st cutting % moisture	1st height in.
CHS Seed Resources	High Yield BMR	<b>8970</b>	0.67	88
CHS Seed Resources	High Yield BMR Dwarf	5395	0.71	83
CHS Seed Resources	High Yield BMR PS	8573	0.71	89
CHS Seed Resources	High Yield Conventional	<b>10727</b>	0.66	98
Dyna-Gro Seed	Danny Boy BMR	<b>8835</b>	0.69	90
Dyna-Gro Seed	Fullgraze BMR	7414	0.70	89
Dyna-Gro Seed	Fullgraze II	<b>10758</b>	0.66	100
Dyna-Gro Seed	Fullgraze II BMR	<b>10398</b>	0.65	77
Sharp Bros Seed	Grazex BMR 801	7841	0.65	98
Star Seed	Bruiser BMR	6370	0.72	88
Star Seed	Nutrimaxx II BMR	<b>9196</b>	0.71	109
Walter Moss Seed	Mega Green	8319	0.68	86
Walter Moss Seed	Mega Green BMR	<b>9678</b>	0.71	86
Ward Seed	Nutri King BMR	<b>9947</b>	0.70	100
Ward Seed	Super Sugar DM	<b>10646</b>	0.68	103
Ward Seed	Sweet Forever BMR	7997	0.68	89
Ward Seed	Sweet Six BMR	<b>8935</b>	0.68	91
	Average	8417	0.70	90.66
	LSD (0.05)	2183		

**Table 6b. Hay performance test near Hays  
2018 Hays, Kansas Forage Hay Performance Test, Ellis County**

Brand	Name	Forage quality												
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ	TDN
----- % -----														
Forage sorghum														
Agrilead	374x66	40.10	62.83	72.90	6.72	55.10	58.43	0.26	0.55	0.58	22.48	7.99	96.68	54.36
Agrilead	AL374x66	40.11	62.58	72.40	6.51	54.57	58.20	0.25	0.55	0.58	22.12	8.34	96.88	53.97
Dyna-Gro Seed	F75FS13	39.32	61.88	73.77	6.27	55.63	57.55	0.28	0.57	0.61	25.82	6.81	98.13	55.96
KSU (check)	Early Sumac	39.51	61.24	74.30	6.44	56.43	56.96	0.28	0.57	0.61	25.90	7.01	99.58	56.13
KSU (check)	Mixed Cane	40.33	63.31	73.20	6.47	56.00	58.88	0.26	0.55	0.59	23.72	6.50	92.38	54.72
KSU (check)	Rox Orange	40.82	63.28	72.93	6.27	56.00	58.85	0.25	0.54	0.57	20.91	8.20	94.91	53.62
Sharp Bros Seed	Canex	38.23	60.32	74.07	6.60	54.90	56.10	0.28	0.57	0.61	26.48	7.37	101.02	56.02
Sharp Bros Seed	Canex BMR 210	35.95	57.93	79.77	6.31	62.90	53.87	0.34	0.62	0.67	29.80	7.16	118.74	60.47
Millet														
CHS Seed Resources	PearlPlus BMR	37.76	58.73	75.83	6.19	58.43	54.62	0.27	0.56	0.59	22.62	8.84	103.03	54.92
Dyna-Gro Seed	PearlMil	40.08	59.20	73.47	6.55	53.70	55.06	0.24	0.53	0.56	25.05	6.42	86.79	52.84
Sorghum sudan														
Alta Seeds	ADV S6504	40.59	63.07	73.00	6.39	56.17	58.66	0.25	0.54	0.58	22.55	6.33	89.60	53.88
Alta Seeds	AS6402	39.32	61.01	75.00	6.19	58.20	56.74	0.28	0.57	0.60	24.72	6.17	94.50	55.91
American Hybrids	Brighton	39.87	64.15	69.27	6.95	49.77	59.66	0.24	0.53	0.57	22.87	7.46	90.56	52.92
American Hybrids	Lincoln	36.55	59.05	76.63	5.78	58.43	54.91	0.29	0.58	0.62	25.45	8.51	110.51	57.09
American Hybrids	Navion	39.54	59.70	73.37	6.41	53.90	55.52	0.25	0.54	0.57	23.25	7.39	92.86	53.59
American Hybrids	Sugar Sweet	39.70	61.93	71.83	7.15	52.20	57.59	0.27	0.56	0.59	26.34	6.87	94.78	55.14
Arrow Seed	1st Choice BMR	38.54	61.45	75.47	6.19	58.17	57.15	0.28	0.57	0.61	22.37	8.93	107.03	56.06
Browning Seed	Cadan 99B	40.48	64.42	70.17	7.27	51.57	59.91	0.24	0.54	0.57	22.49	7.13	88.69	53.03
Browning Seed	Sweet Sioux BMR	39.35	61.25	73.77	6.39	55.30	56.96	0.25	0.54	0.57	21.17	8.93	97.41	53.53

*continued*

**Table 6b. Hay performance test near Hays  
2018 Hays, Kansas Forage Hay Performance Test, Ellis County**

Brand	Name	Forage quality												
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ	TDN
CHS Seed Resources	High Yield BMR	37.60	59.35	77.03	5.86	60.17	55.19	0.31	0.59	0.64	27.16	6.23	105.11	58.29
CHS Seed Resources	High Yield BMR Dwarf	39.34	62.49	76.17	6.12	61.23	58.11	0.29	0.58	0.62	24.75	5.88	97.57	56.74
CHS Seed Resources	High Yield BMR PS	38.54	61.11	77.80	6.01	62.63	56.84	0.32	0.60	0.65	30.34	3.59	91.00	59.29
CHS Seed Resources	High Yield Conventional	42.49	63.21	69.23	7.51	49.60	58.79	0.23	0.53	0.56	25.16	4.84	75.41	52.27
Dyna-Gro Seed	Danny Boy BMR	39.37	60.39	75.83	5.78	58.60	56.16	0.27	0.56	0.60	22.91	7.84	100.53	55.17
Dyna-Gro Seed	Fullgraze BMR	40.11	62.89	73.53	6.89	55.60	58.48	0.27	0.56	0.60	25.30	5.84	91.93	55.38
Dyna-Gro Seed	Fullgraze II	41.64	65.46	68.80	7.05	51.80	60.88	0.24	0.54	0.57	23.44	5.41	81.01	53.22
Dyna-Gro Seed	Fullgraze II BMR	40.98	63.96	71.97	6.81	55.77	59.48	0.27	0.56	0.60	27.10	3.39	76.06	55.16
Sharp Bros Seed	Grazex BMR 801	40.47	62.97	70.73	7.37	51.40	58.56	0.25	0.54	0.57	24.09	7.09	88.22	53.59
Star Seed	Bruiser BMR	37.05	60.38	77.33	5.57	60.60	56.15	0.30	0.58	0.62	22.95	9.40	114.45	57.39
Star Seed	Nutrimaxx II BMR	40.23	62.19	75.13	6.57	58.03	57.83	0.28	0.57	0.61	25.76	5.77	93.40	56.03
Walter Moss Seed	Mega Green	40.15	61.20	69.87	7.78	49.13	56.92	0.23	0.53	0.56	26.81	5.12	80.36	52.60
Walter Moss Seed	Mega Green BMR	40.81	62.41	72.50	6.96	54.33	58.04	0.24	0.53	0.56	23.18	5.86	81.55	52.84
Ward Seed	Nutri King BMR	37.70	60.44	76.87	6.12	60.43	56.21	0.29	0.58	0.62	23.39	8.94	108.61	56.92
Ward Seed	Super Sugar DM	39.24	60.68	73.40	6.78	54.93	56.44	0.28	0.57	0.60	25.13	7.70	100.33	55.79
Ward Seed	Sweet Forever BMR	42.06	63.78	70.47	7.21	52.07	59.32	0.24	0.54	0.57	23.46	6.57	85.99	53.08
Ward Seed	Sweet Six BMR	38.19	61.65	74.93	6.04	57.53	57.33	0.28	0.56	0.60	22.69	8.79	103.10	55.71
	<b>Average</b>	<b>39.50</b>	<b>61.72</b>	<b>73.69</b>	<b>6.54</b>	<b>55.87</b>	<b>57.40</b>	<b>0.27</b>	<b>0.56</b>	<b>0.59</b>	<b>24.44</b>	<b>6.96</b>	<b>95.24</b>	<b>55.10</b>

Values in bold are in the top LSD group.

Acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro true dry matter digestibility after 48 hours (IVTDMD@48hr), % of NDF digestible after 48 hours (NDFD@48hr), nitrogen free NDF (NDFn), net energy for gain (NEG), net energy for lactation (NEL), net energy for maintenance (NEM), non-fibrous carbohydrates (NFC), relative forage quality (RFQ), total digestible nutrients (TDN).

**Table 7a. Hay performance test near Scandia  
2018 Scandia, Kansas Forage Hay Performance Test, Republic County**

Brand	Name	Performance		
		1st cutting lb DM/a	1st cutting % moisture	1st height in.
Forage sorghum				
Dyna-Gro Seed	F75FS13	<b>8624</b>	0.83	108
KSU (check)	Early Sumac	5630	0.82	94
KSU (check)	Mixed Cane	6353	0.82	102
KSU (check)	Rox Orange	<b>6816</b>	0.82	91
Sorghum sudan				
Alta Seeds	ADV S6504	<b>7510</b>	0.85	112
Alta Seeds	AS6402	<b>6844</b>	0.81	89
Arrow Seed	1st Choice BMR	6364	0.83	107
Dyna-Gro Seed	Danny Boy BMR	5169	0.82	112
Dyna-Gro Seed	Fullgraze BMR	6313	0.84	107
Dyna-Gro Seed	Fullgraze II	<b>7545</b>	0.80	124
Dyna-Gro Seed	Fullgraze II BMR	6438	0.84	112
Star Seed	Bruiser BMR	<b>6965</b>	0.83	104
Star Seed	Nutrimaxx II BMR	6178	0.83	110
Ward Seed	Nutri King BMR	<b>7631</b>	0.81	101
Ward Seed	Super Sugar DM	<b>7763</b>	0.80	117
Ward Seed	Sweet Forever BMR	<b>7541</b>	0.77	110
Ward Seed	Sweet Six BMR	<b>7977</b>	0.78	107
	Average	6921	0.82	106
	LSD (0.05)	2166		

**Table 7b. Hay performance test near Scandia  
2018 Scandia, Kansas Forage Hay Performance Test, Republic County**

Brand	Name	Forage quality											Crude protein	RFQ	TDN
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC				
----- % -----															
Forage sorghum															
Dyna-Gro Seed	F75FS13	41.21	64.96	69.70	7.69	51.53	60.41	0.24	0.53	0.56	20.31	8.55	91.71	52.70	
KSU (check)	Early Sumac	37.37	60.45	73.23	6.93	53.50	56.22	0.28	0.57	0.60	23.67	10.12	110.02	55.75	
KSU (check)	Mixed Cane	40.50	65.61	69.20	7.88	51.40	61.02	0.24	0.53	0.57	19.86	8.94	94.75	52.90	
KSU (check)	Rox Orange	38.14	61.64	73.07	7.14	55.07	57.33	0.27	0.56	0.60	22.02	9.81	106.81	55.25	
Sorghum sudan															
Alta Seeds	ADV S6504	41.05	65.40	72.77	7.12	56.97	60.82	0.23	0.53	0.56	14.92	9.77	91.28	52.13	
Alta Seeds	AS6402	40.24	64.17	75.50	6.75	61.43	59.68	0.27	0.56	0.59	14.86	11.52	104.02	54.94	
Arrow Seed	1st Choice BMR	40.09	64.66	75.00	7.10	59.57	60.14	0.27	0.56	0.60	18.31	9.45	104.02	55.29	
Dyna-Gro Seed	Danny Boy BMR	40.97	64.67	73.80	7.66	58.67	60.14	0.24	0.54	0.57	14.50	11.34	97.31	53.19	
Dyna-Gro Seed	Fullgraze BMR	42.52	67.22	72.60	8.03	57.33	62.51	0.23	0.53	0.56	16.14	8.62	88.79	52.44	
Dyna-Gro Seed	Fullgraze II	45.34	71.71	61.23	9.78	43.77	66.69	0.15	0.46	0.48	14.39	7.87	67.78	46.24	
Dyna-Gro Seed	Fullgraze II BMR	43.77	70.03	68.67	7.96	54.50	65.13	0.21	0.51	0.53	12.85	9.19	82.85	50.43	
Star Seed	Bruiser BMR	41.33	67.23	73.50	7.77	58.73	62.53	0.25	0.55	0.58	16.28	9.22	97.69	54.02	
Star Seed	Nutrimaxx II BMR	41.43	65.38	72.70	7.92	55.70	60.80	0.22	0.52	0.55	16.04	9.70	89.70	51.54	
Ward Seed	Nutri King BMR	39.22	62.80	74.90	6.79	58.83	58.41	0.27	0.56	0.59	17.96	10.94	106.20	55.03	
Ward Seed	Super Sugar DM	42.01	66.49	69.50	8.10	52.60	61.83	0.23	0.53	0.56	17.34	9.63	91.52	52.37	
Ward Seed	Sweet Forever BMR	42.71	65.08	67.70	8.76	48.17	60.52	0.22	0.52	0.55	21.20	8.11	85.53	51.46	
Ward Seed	Sweet Six BMR	40.20	64.81	71.50	7.24	54.53	60.27	0.24	0.54	0.57	17.58	10.12	97.99	53.25	
	Average	41.07	65.43	71.45	7.68	54.84	60.85	0.24	0.53	0.56	17.54	9.58	94.59	52.88	

Values in bold are in the top LSD group.

Acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro true dry matter digestibility after 48 hours (IVTDMD@48hr), % of NDF digestible after 48 hours (NDFD@48hr), nitrogen free NDF (NDFn), net energy for gain (NEG), net energy for lactation (NEL), net energy for maintenance (NEM), non-fibrous carbohydrates (NFC), relative forage quality (RFQ), total digestible nutrients (TDN).

**Table 8a. Silage performance test near Garden City  
2018 Garden City, Kansas Silage Performance Test, Finney County**

Brand	Variety	Performance							
		Yield lb DM/a	Harvest moisture %	Stand	Vigor	Flowering date	Days to harvest	Height in.	Lodging %
Agrilead	374x66	13265	0.74	10	9	8/24/18	102	114	0
Agrilead	AL374x66	14978	0.74	10	9	8/24/18	102	112	0
Alta Seeds	ADV XF033	<b>17134</b>	0.71	10	9	9/14/18	115	92	0
Alta Seeds	ADV XF372	11745	0.76	10	9	9/14/18	115	75	0
Alta Seeds	AF7401	13504	0.75	10	9	9/14/18	115	79	0
Alta Seeds	AF8301	<b>16421</b>	0.72	10	9	9/14/18	115	91	0
Chromatin Inc.	NK300	14320	0.72	10	9	9/14/18	115	87	0
Chromatin Inc.	SP2876 BMR	14192	0.76	10	9	8/24/18	102	120	0
Chromatin Inc.	SP3808SB BMR	12905	0.76	10	9	9/14/18	115	104	3
Chromatin Inc.	SP4555 BMR	13062	0.75	10	9	8/24/18	102	111	0
Dyna-Gro Seed	705F	<b>16419</b>	0.73	10	9	9/14/18	115	90	0
Dyna-Gro Seed	F74FS23 BMR	14897	0.73	9	9	9/14/18	115	117	0
Dyna-Gro Seed	F76FS77 BMR	13494	0.75	10	8	9/14/18	115	76	0
Dyna-Gro Seed	FX18340	13395	0.76	10	9	8/24/18	102	120	0
Dyna-Gro Seed	Super Sile 20	<b>16898</b>	0.74	10	8	9/14/18	115	118	0
Dyna-Gro Seed	Super Sile 30	<b>17097</b>	0.74	10	9	9/14/18	115	113	2
KSU (check)	KS Orange	12649	0.71	9	9	8/24/18	102	127	0

*continued*

**Table 8a. Silage performance test near Garden City  
2018 Garden City, Kansas Silage Performance Test, Finney County**

Brand	Variety	Performance							
		Yield lb DM/a	Harvest moisture %	Stand	Vigor	Flowering date	Days to harvest	Height in.	Lodging %
Sharp Bros Seed	Canex BMR 210	11911	0.76	9	9	8/24/18	102	113	0
Sharp Bros Seed	Canex BMR 600	15077	0.75	9	9	9/14/18	115	122	8
Sharp Bros Seed	Silex BMR 540	13962	0.74	10	9	9/14/18	115	95	0
Star Seed	Brutus BMR	13897	0.74	9	9	9/14/18	115	97	2
Star Seed	Packer	15005	0.73	9	9	9/14/18	115	95	0
Ward Seed	EXP 10002 BMR	13150	0.73	9	9	8/24/18	102	111	0
Ward Seed	EXP 10218	15021	0.77	9	9	9/14/18	115	107	0
Ward Seed	EXP 10222 BMR	13914	0.72	10	9	9/14/18	115	107	0
Ward Seed	EXP 10225 BMR	13784	0.69	10	9	9/14/18	115	117	3
Ward Seed	EXP 10226 BMR	12213	0.71	9	9	8/24/18	102	106	0
Ward Seed	EXP 10227 BMR	13288	0.67	9	9	9/14/18	115	125	0
Ward Seed	EXP 10228 BMR	12644	0.74	9	8	8/24/18	102	107	0
Ward Seed	GW 2120	13992	0.74	10	9	8/24/18	102	113	0
Ward Seed	GW 400 BMR	13901	0.76	10	9	8/24/18	102	109	0
Ward Seed	GW 475 BMR	14165	0.71	10	9	8/24/18	102	117	0
Ward Seed	Silo Pro BMR	12332	0.74	9	9	9/14/18	115	86	0
Average		14080	0.74	10	9	-	110	105	0.55
LSD (0.05)		1942							

**Table 8b. Silage performance test near Garden City  
2018 Garden City, Kansas Silage Performance Test, Finney County**

Brand	Variety	Forage quality													Total starch
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ	TDN	
----- % -----															
Agrilead	374x66	34.19	55.71	71.83	4.40	51.20	51.81	0.29	0.58	0.62	28.82	7.74	106.59	56.71	11.87
Agrilead	AL374x66	34.69	57.24	70.50	4.55	51.33	53.23	0.28	0.57	0.61	27.14	7.82	104.43	56.02	9.23
Alta Seeds	ADV XF033	37.64	61.80	65.50	4.64	49.90	57.47	0.25	0.54	0.58	24.91	5.56	85.23	53.72	6.30
Alta Seeds	ADV XF372	36.13	58.09	72.93	3.50	57.13	54.02	0.28	0.57	0.61	23.92	8.30	106.70	56.22	4.70
Alta Seeds	AF7401	36.08	58.14	71.03	3.61	55.53	54.07	0.28	0.57	0.61	25.69	6.75	100.24	56.25	6.03
Alta Seeds	AF8301	39.46	62.27	64.97	5.15	47.93	57.91	0.22	0.52	0.55	23.72	5.28	76.92	51.42	9.93
Chromatin Inc.	NK300	40.94	65.80	62.07	4.59	48.20	61.19	0.20	0.50	0.53	19.89	5.45	73.96	50.22	6.47
Chromatin Inc.	SP2876 BMR	38.97	62.41	68.60	5.25	54.43	58.04	0.26	0.55	0.58	22.40	6.88	93.35	54.24	3.33
Chromatin Inc.	SP3808SB BMR	37.88	62.57	69.40	3.21	56.53	58.19	0.26	0.55	0.59	19.93	8.24	100.50	54.53	2.47
Chromatin Inc.	SP4555 BMR	38.81	60.46	68.37	4.75	51.83	56.23	0.26	0.55	0.59	24.58	6.95	94.22	54.41	7.13
Dyna-Gro Seed	705F	38.41	62.05	65.40	4.71	48.57	57.71	0.23	0.52	0.55	23.48	5.91	81.36	52.08	7.50
Dyna-Gro Seed	F74FS23 BMR	33.89	57.05	73.50	3.32	55.93	53.05	0.31	0.59	0.64	28.04	7.89	113.34	58.29	7.57
Dyna-Gro Seed	F76FS77 BMR	37.44	60.64	70.90	3.69	56.90	56.40	0.27	0.56	0.60	22.11	8.38	103.92	55.63	3.70
Dyna-Gro Seed	FX18340	38.57	61.10	69.17	4.71	53.90	56.82	0.27	0.56	0.59	24.65	6.05	92.10	54.97	6.43
Dyna-Gro Seed	Super Sile 20	37.58	62.80	64.37	4.72	49.33	58.41	0.24	0.53	0.57	24.45	5.46	82.43	52.97	4.63
Dyna-Gro Seed	Super Sile 30	40.24	64.98	63.43	5.12	49.47	60.43	0.22	0.52	0.55	22.97	4.77	74.82	51.69	4.80
KSU (check)	KS Orange	38.26	62.94	66.77	5.14	50.67	58.53	0.26	0.56	0.59	24.67	6.01	91.27	54.82	7.60

*continued*

**Table 8b. Silage performance test near Garden City  
2018 Garden City, Kansas Silage Performance Test, Finney County**

Brand	Variety	Forage quality											Crude protein	RFQ	TDN	Total starch
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	%				
Sharp Bros Seed	Canex BMR 210	37.68	61.13	70.00	4.65	55.10	56.85	0.29	0.58	0.62	25.18	6.89	102.17	56.78	5.07	
Sharp Bros Seed	Canex BMR 600	36.82	62.22	69.00	3.74	56.33	57.87	0.30	0.58	0.62	25.40	6.34	101.24	57.21	3.50	
Sharp Bros Seed	Silex BMR 540	35.50	58.67	71.60	4.18	55.77	54.57	0.29	0.58	0.62	26.00	7.06	104.41	56.98	6.17	
Star Seed	Brutus BMR	37.02	60.95	68.73	4.29	55.03	56.69	0.28	0.57	0.60	24.18	6.84	99.18	55.85	3.07	
Star Seed	Packer	39.02	62.93	64.43	4.57	49.23	58.53	0.23	0.52	0.55	22.94	5.76	81.05	52.01	4.97	
Ward Seed	EXP 10002 BMR	37.19	58.47	70.30	4.05	51.70	54.38	0.26	0.55	0.59	26.24	5.82	89.41	54.62	10.07	
Ward Seed	EXP 10218	40.44	66.52	64.87	4.82	52.03	61.86	0.24	0.53	0.57	21.50	5.71	83.03	52.92	2.94	
Ward Seed	EXP 10222 BMR	37.05	59.90	70.97	3.71	55.47	55.71	0.26	0.55	0.59	23.26	6.79	94.27	54.48	3.97	
Ward Seed	EXP 10225 BMR	38.26	62.30	68.70	3.93	53.97	57.94	0.27	0.56	0.60	24.60	5.45	89.74	55.29	6.03	
Ward Seed	EXP 10226 BMR	36.44	59.14	72.10	3.65	55.23	55.00	0.29	0.57	0.61	25.23	7.33	103.85	56.55	8.13	
Ward Seed	EXP 10227 BMR	42.71	68.92	59.87	5.58	48.90	64.09	0.21	0.51	0.54	20.30	4.51	70.40	50.93	1.93	
Ward Seed	EXP 10228 BMR	38.13	60.33	70.50	4.49	54.00	56.11	0.25	0.55	0.58	22.50	7.88	97.21	54.05	3.07	
Ward Seed	GW 2120	36.42	59.02	69.50	4.78	51.03	54.89	0.27	0.56	0.60	26.38	6.67	96.30	55.23	9.17	
Ward Seed	GW 400 BMR	36.84	55.52	75.23	3.73	55.90	51.64	0.30	0.59	0.63	27.71	8.14	111.71	57.80	9.13	
Ward Seed	GW 475 BMR	36.77	59.73	72.20	3.91	55.10	55.55	0.28	0.57	0.60	24.44	7.16	100.47	55.77	6.07	
Ward Seed	Silo Pro BMR	33.28	56.58	73.77	3.10	57.77	52.62	0.31	0.60	0.64	26.21	8.88	118.00	58.44	5.90	
Average		37.54	60.86	68.80	4.31	53.07	56.60	0.26	0.55	0.59	24.35	6.69	94.66	54.82	6.03	

Values in bold are in the top LSD group.

Acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro true dry matter digestibility after 48 hours (IVTDMD@48hr), % of NDF digestible after 48 hours (NDFD@48hr), nitrogen free NDF (NDFn), net energy for gain (NEG), net energy for lactation (NEL), net energy for maintenance (NEM), non-fibrous carbohydrates (NFC), relative forage quality (RFQ), total digestible nutrients (TDN).

**Table 9a. Silage performance test near Hays  
2018 Hays, Kansas Silage Performance Test, Ellis County**

Brand	Variety	Performance							
		Yield lb DM/a	Harvest moisture %	Stand	Vigor	Flowering date	Days to harvest	Height in.	Lodging %
Alta Seeds	ADV XF033	<b>15605</b>	0.68	10	9	---	123	82	0
Alta Seeds	ADV XF372	11325	0.66	9	8	---	109	69	0
Alta Seeds	AF7401	11588	0.69	9	8	---	123	76	0
Alta Seeds	AF8301	13212	0.67	10	10	---	109	76	0
Arrow Seed	Silo Mor II BMR	<b>13683</b>	0.68	9	8	---	123	82	0
Dyna-Gro Seed	705F	12862	0.65	10	10	---	109	80	0
Dyna-Gro Seed	F74FS23 BMR	<b>13809</b>	0.69	10	10	---	109	101	0
Dyna-Gro Seed	F76FS77 BMR	<b>14345</b>	0.69	10	10	---	123	74	0
Dyna-Gro Seed	FX18340	11724	0.74	10	40	---	95	101	0
Dyna-Gro Seed	Super Sile 20	<b>15662</b>	0.68	10	10	---	123	100	0
Dyna-Gro Seed	Super Sile 30	<b>14275</b>	0.65	10	10	---	109	95	0
KSU (check)	KS Orange	<b>15847</b>	0.69	10	40	---	95	114	12
Sharp Bros Seed	Canex BMR 210	11484	0.74	10	10	---	95	111	15
Sharp Bros Seed	Canex BMR 600	<b>16870</b>	0.68	10	10	---	123	102	0
Sharp Bros Seed	Silex BMR 540	<b>14244</b>	0.70	9	10	---	123	83	12
Star Seed	Brutus BMR	13112	0.68	9	8	---	123	88	0
Star Seed	Packer	<b>16827</b>	0.65	10	10	---	123	76	0

*continued*

**Table 9a. Silage performance test near Hays  
2018 Hays, Kansas Silage Performance Test, Ellis County**

Brand	Variety	Performance							
		Yield	Harvest moisture	Stand	Vigor	Flowering date	Days to harvest	Height	Lodging
		lb DM/a	%					in.	%
Walter Moss Seed	4 Ever Green	<b>14019</b>	0.76	9	8	---	123	94	0
Ward Seed	EXP 10002 BMR	<b>14099</b>	0.69	10	9	---	95	104	0
Ward Seed	EXP 10218	<b>13482</b>	0.71	10	9	---	123	98	0
Ward Seed	EXP 10222 BMR	<b>15200</b>	0.72	10	10	---	109	89	0
Ward Seed	EXP 10225 BMR	<b>15289</b>	0.65	10	10	---	109	94	0
Ward Seed	EXP 10226 BMR	<b>13550</b>	0.67	9	9	---	109	94	0
Ward Seed	EXP 10227 BMR	<b>16719</b>	0.66	10	10	---	109	104	0
Ward Seed	EXP 10228 BMR	12780	0.74	10	9	---	95	95	0
Ward Seed	GW 2120	<b>13923</b>	0.74	10	10	---	95	98	0
Ward Seed	GW 400 BMR	<b>15693</b>	0.71	10	10	---	95	101	0
Ward Seed	GW 475 BMR	12128	0.71	10	10	---	95	95	0
Ward Seed	Silo Pro BMR	11207	0.68	9	8	---	123	83	0
Average		13950.48	0.69	10	11	---	111	92	1.32
LSD (0.05)		3458							

**Table 9b. Silage performance test near Hays  
2018 Hays, Kansas Silage Performance Test, Ellis County**

Brand	Variety	Forage quality												Total starch	
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ		TDN
----- % -----															
Alta Seeds	ADV XF033	39.46	63.76	66.77	4.83	51.50	59.29	0.26	0.55	0.59	25.35	5.69	89.68	54.69	4.93
Alta Seeds	ADV XF372	37.86	59.46	70.90	4.17	52.00	55.30	0.28	0.56	0.60	27.92	5.30	89.90	55.69	11.10
Alta Seeds	AF7401	36.26	57.55	73.30	3.93	53.80	53.52	0.29	0.58	0.62	27.84	7.33	105.75	57.01	11.00
Alta Seeds	AF8301	38.37	60.29	67.83	4.43	47.53	56.07	0.24	0.54	0.57	28.11	4.24	75.93	53.29	14.67
Arrow Seed	Silo Mor II BMR	38.80	62.67	68.47	4.78	53.20	58.28	0.28	0.57	0.61	26.84	5.48	93.94	56.37	6.57
Dyna-Gro Seed	705F	39.77	62.87	66.43	4.69	48.07	58.47	0.23	0.53	0.56	25.67	4.56	74.61	52.64	10.13
Dyna-Gro Seed	F74FS23 BMR	34.99	56.02	72.60	3.53	52.33	52.10	0.30	0.58	0.63	30.01	6.32	101.02	57.45	13.47
Dyna-Gro Seed	F76FS77 BMR	38.67	62.13	70.93	3.80	55.50	57.78	0.27	0.56	0.60	24.44	6.39	94.98	55.51	6.13
Dyna-Gro Seed	FX18340	40.44	61.86	69.30	5.33	51.73	57.53	0.25	0.55	0.58	25.67	5.23	84.58	54.13	8.97
Dyna-Gro Seed	Super Sile 20	40.72	66.32	64.57	5.17	50.00	61.68	0.24	0.53	0.57	23.42	4.97	78.61	52.89	4.93
Dyna-Gro Seed	Super Sile 30	39.20	63.17	66.90	4.90	50.70	58.75	0.25	0.55	0.58	25.00	6.03	88.97	54.09	6.40
KSU (check)	KS Orange	40.24	62.83	64.97	6.23	46.50	58.43	0.23	0.53	0.56	25.54	5.68	81.75	52.39	8.70
Sharp Bros Seed	Canex BMR 210	39.76	63.32	69.17	4.95	54.30	58.89	0.29	0.57	0.61	25.05	6.77	100.96	56.59	5.47
Sharp Bros Seed	Canex BMR 600	38.32	61.73	69.33	4.59	53.13	57.41	0.28	0.57	0.61	25.62	6.88	100.12	56.20	6.73
Sharp Bros Seed	Silex BMR 540	38.07	62.03	70.43	3.93	55.70	57.69	0.29	0.58	0.62	26.11	6.01	99.23	57.13	6.00
Star Seed	Brutus BMR	40.77	65.81	66.47	4.78	52.57	61.20	0.26	0.55	0.59	23.94	5.04	85.59	54.49	6.80
Star Seed	Packer	37.67	59.74	68.57	4.76	49.60	55.56	0.27	0.56	0.60	28.34	5.48	89.76	55.14	11.23

*continued*

**Table 9b. Silage performance test near Hays  
2018 Hays, Kansas Silage Performance Test, Ellis County**

Brand	Variety	Forage quality												Total starch	
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	Crude protein	RFQ		TDN
----- % -----															
Walter Moss Seed	4 Ever Green	43.18	68.70	65.00	5.44	51.33	63.89	0.22	0.51	0.54	21.30	4.05	68.24	51.19	4.00
Ward Seed	EXP 10002 BMR	38.07	57.78	71.87	4.39	49.70	53.73	0.26	0.55	0.59	28.26	5.46	86.70	54.42	14.60
Ward Seed	EXP 10218	41.90	67.57	64.73	5.43	50.87	62.84	0.23	0.52	0.55	21.32	5.54	78.78	51.98	3.70
Ward Seed	EXP 10222 BMR	38.32	61.66	70.50	4.22	53.07	57.34	0.27	0.56	0.60	26.44	5.21	88.58	55.35	8.20
Ward Seed	EXP 10225 BMR	36.47	56.06	72.17	3.75	50.57	52.14	0.27	0.56	0.60	29.80	5.31	89.42	55.68	18.33
Ward Seed	EXP 10226 BMR	37.86	60.24	69.57	3.83	51.43	56.02	0.27	0.56	0.60	27.45	5.03	86.78	55.34	11.90
Ward Seed	EXP 10227 BMR	41.15	64.45	65.07	5.03	47.47	59.94	0.22	0.52	0.55	24.58	4.15	71.19	51.67	12.40
Ward Seed	EXP 10228 BMR	39.51	62.61	70.33	4.67	52.73	58.23	0.25	0.54	0.58	22.75	7.17	92.24	53.73	6.17
Ward Seed	GW 2120	38.22	59.74	68.40	5.17	47.83	55.56	0.25	0.54	0.58	27.09	5.99	87.37	53.84	11.07
Ward Seed	GW 400 BMR	36.96	55.55	73.00	4.37	49.70	51.66	0.27	0.56	0.60	29.49	6.48	96.51	55.60	16.20
Ward Seed	GW 475 BMR	39.87	60.94	69.83	4.73	50.07	56.67	0.26	0.55	0.58	24.44	5.88	88.74	54.26	10.63
Ward Seed	Silo Pro BMR	38.52	62.86	70.83	3.87	56.77	58.46	0.28	0.57	0.61	24.13	6.76	99.94	56.24	3.10
Average		38.94	61.71	68.90	4.61	51.37	57.39	0.26	0.55	0.59	25.93	5.67	88.62	54.66	9.09

Values in bold are in the top LSD group.

Acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro true dry matter digestibility after 48 hours (IVTDMD@48hr), % of NDF digestible after 48 hours (NDFD@48hr), nitrogen free NDF (NDFn), net energy for gain (NEG), net energy for lactation (NEL), net energy for maintenance (NEM), non-fibrous carbohydrates (NFC), relative forage quality (RFQ), total digestible nutrients (TDN).

**Table 10a. Silage performance test near Scandia**  
**2018 Scandia, Kansas Silage Performance Test, Republic County**

Brand	Variety	Performance							
		Yield lb DM/a	Harvest moisture %	Stand	Vigor	Flowering date	Days to harvest	Height in.	Lodging %
Alta Seeds	ADV XF033	<b>12623</b>	0.76	10	10	9/14/18	102	83	1
Alta Seeds	ADV XF372	9888	0.80	10	10	9/14/18	102	73	0
Alta Seeds	AF7401	10554	0.78	9	10	9/14/18	102	71	0
Alta Seeds	AF8301	9877	0.74	10	10	9/11/18	102	81	8
Arrow Seed	Silo Mor II BMR	8698	0.75	10	10	9/14/18	105	85	3
Dyna-Gro Seed	705F	11055	0.78	10	10	9/11/18	102	83	6
Dyna-Gro Seed	F74FS23 BMR	7257	0.80	8	10	9/11/18	102	113	1
Dyna-Gro Seed	F76FS77 BMR	10014	0.78	9	9	9/14/18	105	74	0
Dyna-Gro Seed	FX18340	5485	0.80	10	9	8/23/18	95	111	2
Dyna-Gro Seed	Super Sile 20	8831	0.79	9	10	9/14/18	105	126	1
Dyna-Gro Seed	Super Sile 30	<b>14568</b>	0.76	10	10	9/11/18	102	100	8
KSU (check)	KS Orange	9590	0.75	7	8	8/30/18	95	119	0
Star Seed	Brutus BMR	9282	0.77	10	10	9/14/18	102	88	4
Star Seed	Packer	10627	0.78	10	10	9/9/18	102	92	2
Ward Seed	EXP 10002 BMR	6812	0.75	8	10	8/25/18	95	105	4
Ward Seed	EXP 10218	11569	0.80	10	10	9/14/18	105	101	5
Ward Seed	EXP 10222 BMR	7190	0.76	10	10	9/9/18	95	96	5
Ward Seed	EXP 10225 BMR	8651	0.74	10	10	9/9/18	102	103	5
Ward Seed	EXP 10226 BMR	7173	0.73	9	10	8/25/18	95	99	1
Ward Seed	EXP 10227 BMR	9202	0.70	10	10	9/11/18	102	117	5
Ward Seed	EXP 10228 BMR	5395	0.76	10	10	8/30/18	95	105	7
Ward Seed	GW 2120	8867	0.78	9	10	8/25/18	95	106	0
Ward Seed	GW 400 BMR	8989	0.78	10	10	8/25/18	95	105	1
Ward Seed	GW 475 BMR	8197	0.75	10	10	8/25/18	95	107	0
Ward Seed	Silo Pro BMR	8910	0.79	10	10	9/9/18	102	86	0
Average		9172	0.77	10	10		100	97	3
LSD (0.05)		2525							

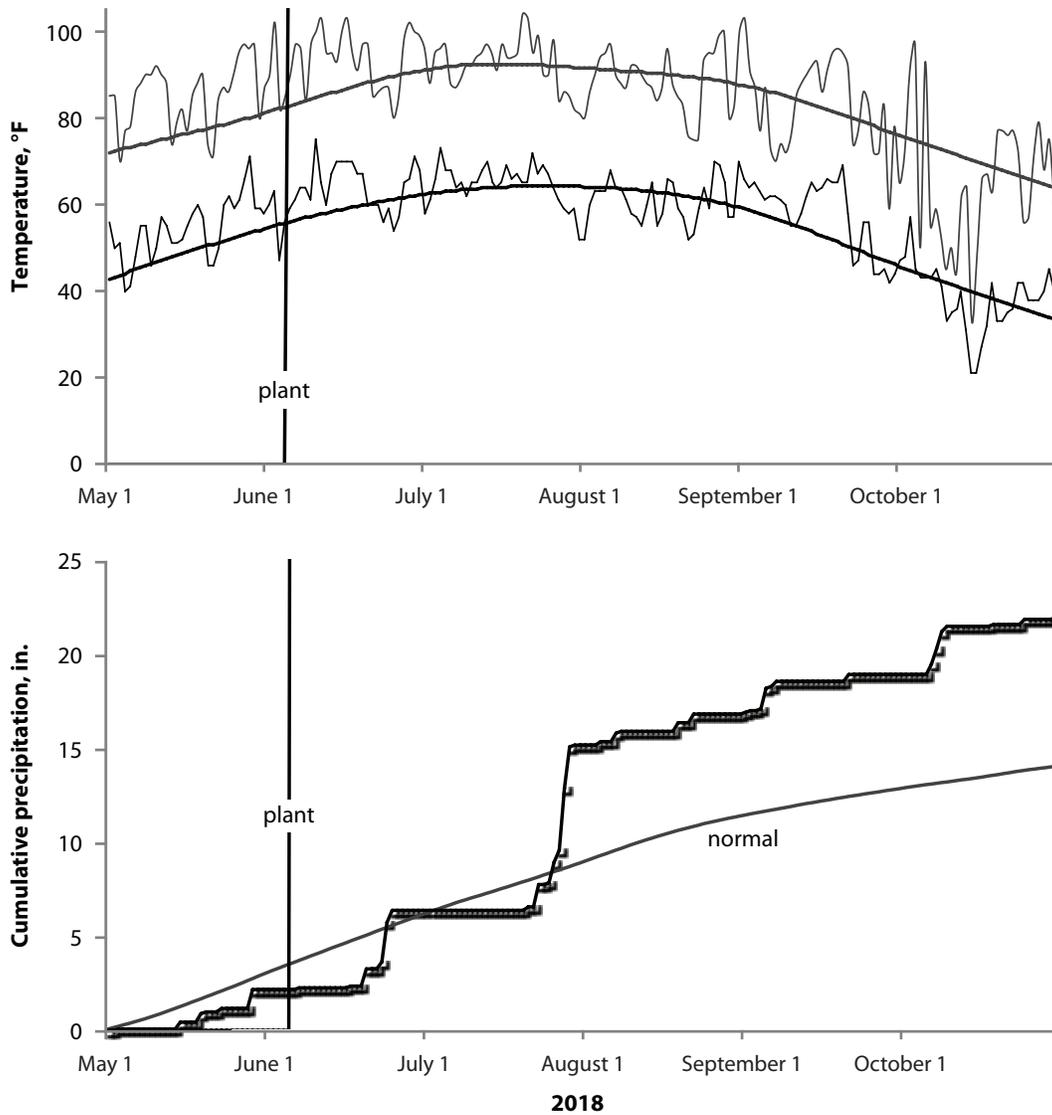
**Table 10b. Silage performance test near Scandia  
2018 Scandia, Kansas Silage Performance Test, Republic County**

Brand	Variety	Forage quality											Crude protein	RFQ	TDN	Total starch
		ADF	NDF	IVTDMD @48hr	Lignin	NDFD @48hr	NDFn	NEG	NEL	NEM	NFC	%				
Alta Seeds	ADV XF033	41.37	68.09	65.57	5.63	51.17	63.32	0.23	0.52	0.55	18.41	7.21	86.08	51.96	1.90	
Alta Seeds	ADV XF372	38.98	63.20	74.40	3.83	59.40	58.78	0.27	0.56	0.60	18.80	9.12	105.83	55.60	0.00	
Alta Seeds	AF7401	38.15	61.49	74.10	4.17	57.80	57.19	0.27	0.56	0.60	19.95	9.47	106.70	55.46	1.57	
Alta Seeds	AF8301	40.68	65.81	66.40	5.39	49.60	61.21	0.22	0.52	0.55	20.48	6.80	84.15	51.87	4.70	
Arrow Seed	Silo Mor II BMR	37.01	61.43	71.80	4.58	55.33	57.13	0.28	0.57	0.61	22.15	9.18	108.74	56.16	3.37	
Dyna-Gro Seed	705F	42.96	69.60	65.20	5.65	51.07	64.73	0.20	0.50	0.53	16.43	6.92	78.26	50.10	1.20	
Dyna-Gro Seed	F74FS23 BMR	40.10	65.75	69.73	4.87	53.87	61.15	0.25	0.54	0.57	19.46	7.68	93.21	53.52	2.90	
Dyna-Gro Seed	F76FS77 BMR	38.08	62.36	73.30	4.07	57.33	58.00	0.28	0.56	0.60	21.48	7.90	103.14	55.73	1.23	
Dyna-Gro Seed	FX18340	42.46	67.86	68.70	5.41	55.67	63.11	0.24	0.54	0.57	17.44	7.18	88.34	53.08	1.80	
Dyna-Gro Seed	Super Sile 20	42.50	70.17	63.47	5.59	49.50	65.26	0.20	0.50	0.53	18.76	5.29	72.69	50.22	3.10	
Dyna-Gro Seed	Super Sile 30	41.70	68.81	63.67	5.45	49.53	63.99	0.21	0.51	0.54	19.71	5.63	76.84	50.97	2.80	
KSU (check)	KS Orange	40.39	66.72	67.10	5.08	53.30	62.05	0.26	0.55	0.58	20.26	7.21	93.77	54.25	2.43	
Star Seed	Brutus BMR	38.69	64.01	70.53	4.84	56.23	59.53	0.28	0.57	0.60	21.01	8.22	104.62	55.91	1.17	
Star Seed	Packer	43.28	69.30	65.10	5.66	51.20	64.45	0.21	0.51	0.54	18.03	6.09	77.63	51.08	1.30	
Ward Seed	EXP 10002 BMR	43.37	68.93	66.80	4.92	53.80	64.11	0.22	0.52	0.55	16.73	6.45	80.58	51.61	0.00	
Ward Seed	EXP 10218	42.20	68.82	67.00	4.97	53.10	64.00	0.23	0.53	0.56	17.97	7.11	85.79	52.29	0.53	
Ward Seed	EXP 10222 BMR	40.80	67.43	67.83	4.72	54.23	62.71	0.25	0.55	0.58	19.23	7.47	93.84	54.11	2.13	
Ward Seed	EXP 10225 BMR	44.10	70.52	66.27	4.55	55.03	65.58	0.23	0.53	0.56	16.34	6.14	80.86	52.49	0.00	
Ward Seed	EXP 10226 BMR	38.17	63.89	70.50	4.18	54.93	59.41	0.27	0.56	0.59	20.87	7.95	100.75	55.05	3.50	
Ward Seed	EXP 10227 BMR	45.21	73.14	60.57	6.04	48.33	68.02	0.19	0.49	0.52	16.79	4.97	66.55	49.21	0.00	
Ward Seed	EXP 10228 BMR	42.06	67.88	67.27	4.77	53.80	63.13	0.24	0.53	0.56	17.58	7.29	87.86	52.67	0.00	
Ward Seed	GW 2120	39.31	65.05	67.50	5.03	50.97	60.49	0.24	0.53	0.57	20.96	7.68	92.26	52.97	5.00	
Ward Seed	GW 400 BMR	35.67	59.69	73.60	3.85	56.03	55.51	0.30	0.58	0.62	23.59	9.60	115.74	57.26	5.53	
Ward Seed	GW 475 BMR	39.29	64.41	71.20	3.95	56.57	59.90	0.28	0.57	0.61	21.61	7.49	101.61	55.96	2.07	
Ward Seed	Silo Pro BMR	37.80	62.33	73.43	4.24	57.63	57.97	0.28	0.57	0.61	20.78	8.93	108.49	56.26	2.37	
Average		40.57	66.27	68.44	4.86	53.82	61.63	0.25	0.54	0.57	19.39	7.40	91.77	53.43	2.02	

Values in bold are in the top LSD group.

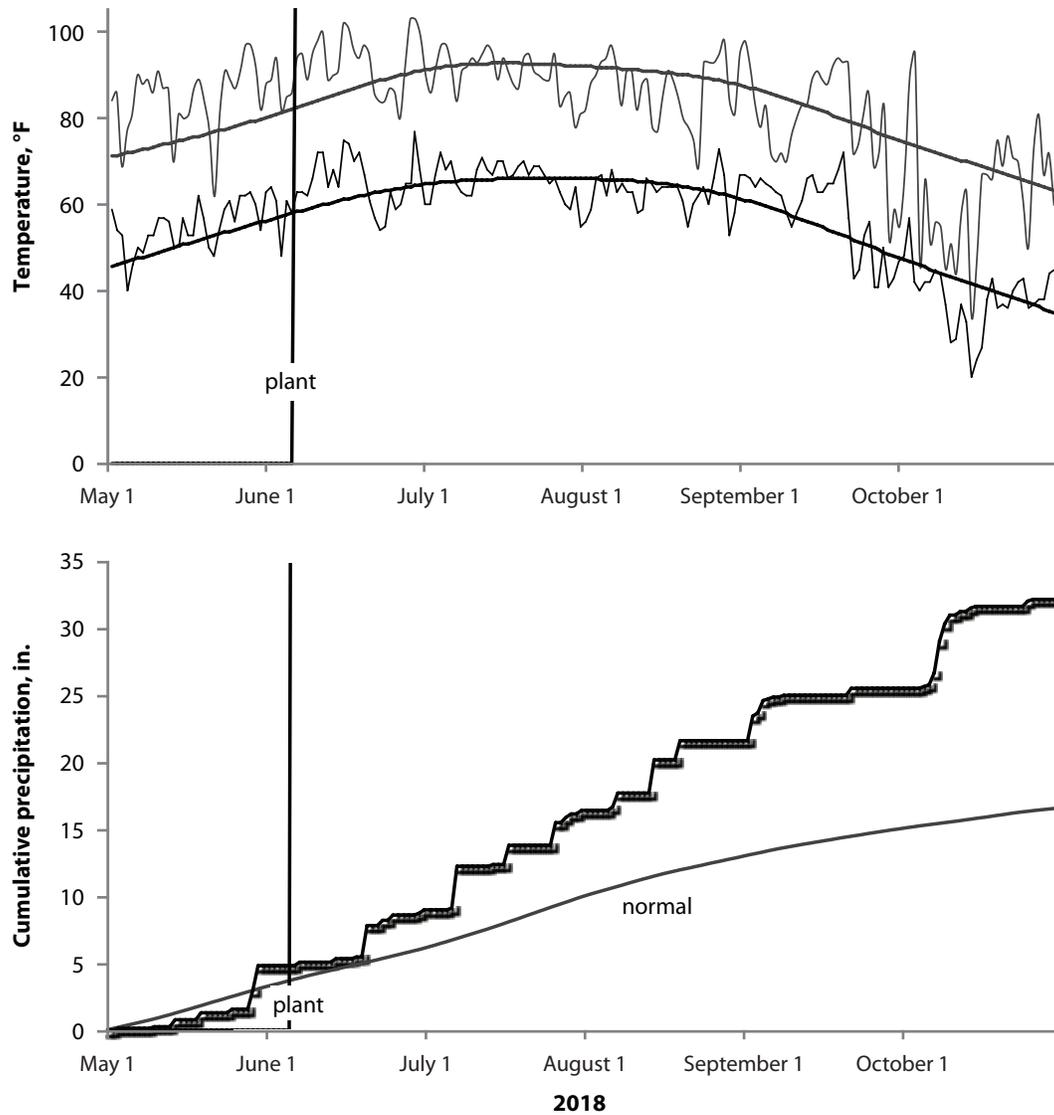
Acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro true dry matter digestibility after 48 hours (IVTDMD@48hr), % of NDF digestible after 48 hours (NDFD@48hr), nitrogen free NDF (NDFn), net energy for gain (NEG), net energy for lactation (NEL), net energy for maintenance (NEM), non-fibrous carbohydrates (NFC), relative forage quality (RFQ), total digestible nutrients (TDN).

# CROPPING AND TILLAGE SYSTEMS



**Figure 1. Precipitation and temperature during the 2018 growing season near Garden City, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.**

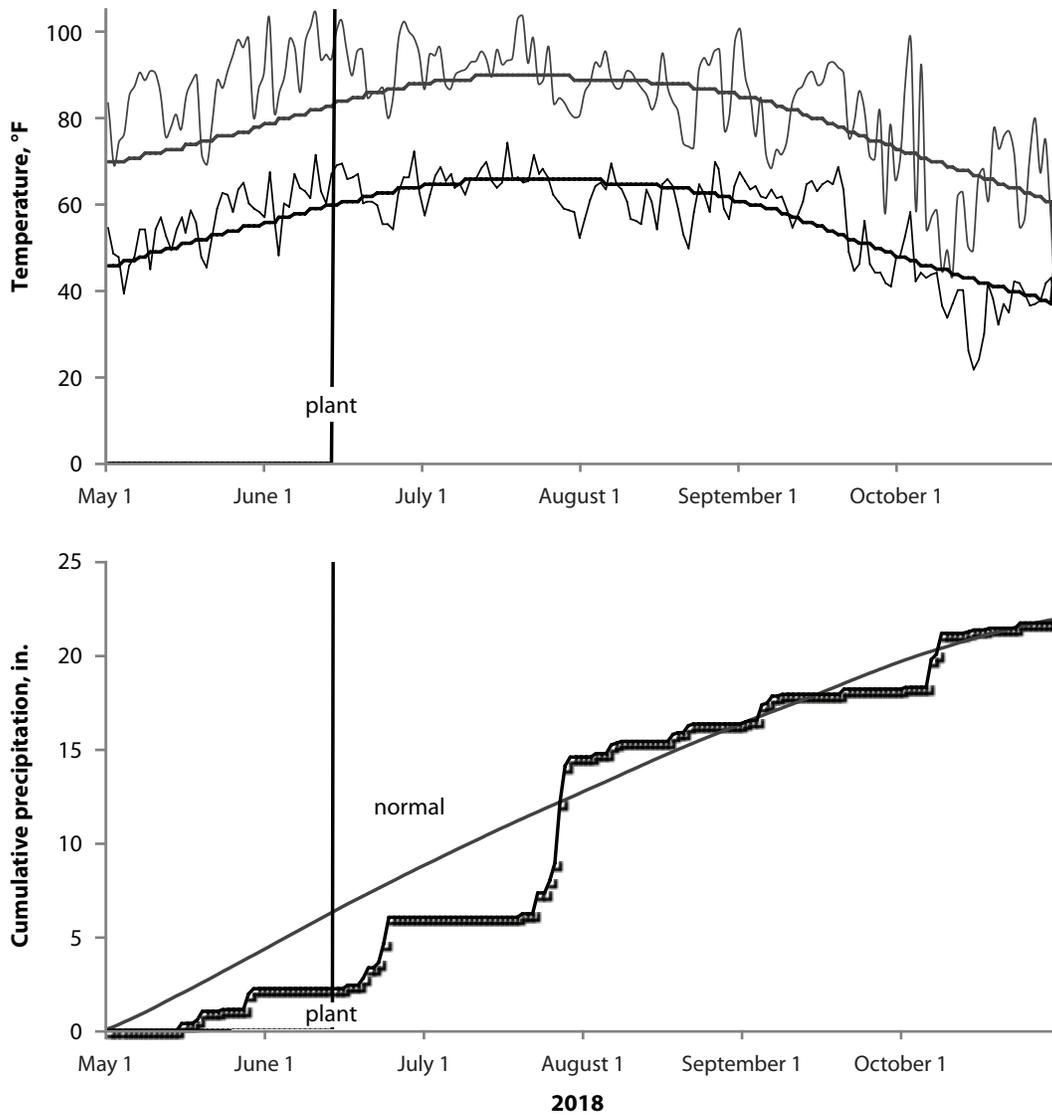
## CROPPING AND TILLAGE SYSTEMS



**2018**

Figure 2. Precipitation and temperature during the 2018 growing season near Hays, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.

# CROPPING AND TILLAGE SYSTEMS



**Figure 3. Precipitation and temperature during the 2018 growing season near Scandia, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.**

# Long-Term Nitrogen and Phosphorus Fertilization of Irrigated Corn

*A. Schlegel and D. Bond*

## Summary

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated corn in western Kansas. In 2018, N applied alone increased yields by 76 bu/a, whereas P applied alone increased yields by more than 17 bu/a. Nitrogen and P applied together increased yields up to 169 bu/a. This is 26 bu/a more than the 10-year average, where N and P fertilization increased corn yields up to 143 bu/a. Application of 120 lb/a N (with highest P rate) produced 97% of the maximum yield in 2018, which is slightly greater than the 10-year average. Application of 80 instead of 40 lb  $P_2O_5$ /a increased average yields 9 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<sub>g</sub>) was 43% and apparent fertilizer phosphorus recovery in the grain (AFPR<sub>g</sub>) was 62%.

## Introduction

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

## Procedures

This field study is conducted at the Tribune Unit of the Kansas State University Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 were N rates of 0, 40, 80, 120, 160, and 200 lb/a without P and K; with 40 lb/a  $P_2O_5$  and 0 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 [DeKalb 61-69 (2009), Pioneer 1173H (2010), Pioneer 1151XR (2011), Pioneer 0832 (2012-2013), Pioneer 1186AM (2014), Pioneer 35F48 AM1 (2015), Pioneer 1197 (2016), and Pioneer 0801 (2017-2018)] were planted at approximately 32,000 seeds/a in late April or early May. Hail damaged the 2010, 2015, and 2017 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<sub>g</sub>) 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<sub>g</sub>). Grasshoppers were treated via aerial application of insecticide.

### Results

Corn yields in 2018 were 15% greater than the 10-year average (Table 1). Nitrogen alone increased yields 76 bu/a, whereas P alone increased yields 17 bu/a. However, N and P applied together increased corn yields up to 169 bu/a. Maximum yield was obtained with 160 lb/a N with 80 lb/a P<sub>2</sub>O<sub>5</sub>. Corn yields in 2018 (averaged across all N rates) were 9 bu/a greater with 80 than with 40 lb/a P<sub>2</sub>O<sub>5</sub>.

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 (lb/a) was attained with 200 lb N and 80 lb P<sub>2</sub>O<sub>5</sub>/a. At the highest N and P rate, AFNR<sub>g</sub> was 43% and AFPR<sub>g</sub> was 62%. Similar to N, average P concentration increased with increased P rates but decreased with higher N rates. Grain P content (lb/bu) of approximately 0.15 lb P/bu (0.34 lb P<sub>2</sub>O<sub>5</sub>/bu) was greater at the highest P rate with low N rates. Grain P removal averaged 27 lb P/a at the highest yields.

### Acknowledgment

The International Plant Nutrition Institute partially supported this research project.

## SOIL FERTILITY

**Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2009-2018**

Fertilizer		Yield										
N	P <sub>2</sub> O <sub>5</sub>	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
----- lb/a -----		----- bu/a -----										
0	0	85	20	92	86	70	86	92	74	44	82	73
0	40	110	21	111	85	80	95	103	78	47	93	82
0	80	106	28	105	94	91	98	104	86	52	99	86
40	0	108	23	114	109	97	106	113	105	60	110	94
40	40	148	67	195	138	125	153	164	145	92	160	139
40	80	159	61	194	135	126	149	162	135	90	159	137
80	0	123	34	136	128	112	117	131	118	70	117	109
80	40	179	85	212	197	170	187	195	196	132	212	176
80	80	181	90	220	194	149	179	193	193	129	207	173
120	0	117	28	119	134	114	115	124	109	62	102	102
120	40	202	90	222	213	204	213	212	212	142	218	193
120	80	215	105	225	211	194	216	216	223	162	243	201
160	0	139	49	157	158	122	128	144	142	84	139	126
160	40	210	95	229	227	199	211	215	226	154	230	200
160	80	223	95	226	239	217	233	216	238	165	251	210
200	0	155	65	179	170	139	144	162	159	114	158	146
200	40	207	97	218	225	198	204	214	216	148	231	196
200	80	236	104	231	260	220	238	221	235	174	243	216

*continued*

## SOIL FERTILITY

**Table 1. Nitrogen (N) and phosphorus (P) fertilization on irrigated corn yields, Tribune, KS, 2009-2018**

Fertilizer		Yield										
N	P <sub>2</sub> O <sub>5</sub>	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
----- lb/a -----		----- bu/a -----										
<b>ANOVA (P&gt;F)</b>												
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
<b>MEANS</b>												
Nitrogen, lb/a												
0		100 e	23 e	103 d	88 f	80 e	93 e	100 e	79 e	48 e	91 d	81 e
40		138 d	50 d	167 c	127 e	116 d	136 d	146 d	129 d	81 d	143 c	123 d
80		161 c	70 c	189 b	173 d	143 c	161 c	173 c	169 c	110 c	179 b	153 c
120		178 b	74 bc	189 b	186 c	171 b	181 b	184 b	182 b	122 b	188 b	165 b
160		191 a	80 ab	204 a	208 b	179 ab	190 ab	192 ab	202 a	134 a	207 a	179 a
200		199 a	89 a	209 a	218 a	186 a	196 a	199 a	203 a	145 a	211 a	186 a
LSD <sub>(0.05)</sub>		12	9	13	10	10	10	9	10	11	13	8
P <sub>2</sub> O <sub>5</sub> , lb/a												
0		121 c	36 b	133 b	131 c	109 b	116 c	128 b	118 b	72 c	118 c	108 c
40		176 b	76 a	198 a	181 b	163 a	177 b	184 a	179 a	119 b	191 b	164 b
80		187 a	81 a	200 a	189 a	166 a	186 a	185 a	185 a	129 a	200 a	171 a
LSD <sub>(0.05)</sub>		9	7	9	7	7	7	6	7	8	9	6

\*Note: Hail events on 7/23/10, 5/28/15, and 8/18/17.

## SOIL FERTILITY

**Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2009-2018**

Fertilizer		Grain				Grain removal			
N	P <sub>2</sub> O <sub>5</sub>	N	P	N	P	N	P	*AFNR <sub>g</sub>	*AFPR <sub>g</sub>
----- lb/a -----		----- % -----		----- lb/bu -----		----- lb/a -----		----- % -----	
0	0	0.98	0.226	0.46	0.107	33	8	---	---
0	40	0.94	0.304	0.44	0.144	36	12	---	23
0	80	0.94	0.317	0.45	0.150	37	13	---	15
40	0	1.16	0.181	0.55	0.086	51	8	45	---
40	40	0.96	0.299	0.45	0.141	62	20	73	67
40	80	0.97	0.318	0.46	0.151	62	21	72	37
80	0	1.26	0.177	0.59	0.084	63	9	38	---
80	40	1.04	0.251	0.49	0.119	86	21	67	73
80	80	1.01	0.305	0.48	0.145	82	25	61	49
120	0	1.27	0.171	0.60	0.081	61	8	23	---
120	40	1.13	0.225	0.53	0.107	102	20	58	71
120	80	1.09	0.295	0.52	0.139	103	28	58	57
160	0	1.25	0.175	0.59	0.083	74	10	25	---
160	40	1.17	0.240	0.55	0.114	110	22	48	83
160	80	1.15	0.276	0.55	0.131	114	27	51	55
200	0	1.22	0.188	0.58	0.089	83	13	25	---
200	40	1.18	0.235	0.56	0.111	108	22	38	79
200	80	1.17	0.291	0.55	0.138	119	30	43	62

*continued*

## SOIL FERTILITY

**Table 2. Nitrogen (N) and phosphorus (P) fertilization on grain N and P content of irrigated corn, Tribune, KS, 2009-2018**

Fertilizer		Grain				Grain removal			
N	P <sub>2</sub> O <sub>5</sub>	N	P	N	P	N	P	*AFNR <sub>g</sub>	*AFPR <sub>g</sub>
----- lb/a -----		----- % -----		----- lb/bu -----		----- lb/a -----		----- % -----	
<b>ANOVA (P&gt;F)</b>									
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	0.043	0.094
<b>MEANS</b>									
Nitrogen, lb/a									
0		0.95 e	0.282 a	0.45 e	0.134 a	35 e	11 e	---	19 d
40		1.03 d	0.266 b	0.49 d	0.126 b	58 d	16 d	63 a	52 c
80		1.10 c	0.244 c	0.52 c	0.116 c	77 c	18 c	55 b	61 b
120		1.16 b	0.230 d	0.55 b	0.109 d	88 b	19 bc	46 c	64 ab
160		1.19 a	0.231 d	0.56 a	0.109 d	99 a	20 ab	41 c	69 ab
200		1.19 a	0.238 cd	0.56 a	0.113 cd	103 a	21 a	35 d	70 a
LSD <sub>(0.05)</sub>		0.02	0.011	0.01	0.005	4	1	5	9
P <sub>2</sub> O <sub>5</sub> , lb/a									
0		1.19 a	0.186 c	0.56 a	0.088 c	61 b	9 c	31 b	---
40		1.07 b	0.259 b	0.51 b	0.123 b	84 a	19 b	57 a	66 a
80		1.05 b	0.300 a	0.50 b	0.142 a	86 a	24 a	57 a	46 b
LSD <sub>(0.05)</sub>		0.01	0.008	0.01	0.004	3	1	4	5

\*AFNR<sub>g</sub> = Apparent fertilizer N recovery (grain). AFPR<sub>g</sub> = Apparent fertilizer P recovery (grain).

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

*A. Schlegel and D. Bond*

## Summary

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated grain sorghum in western Kansas. In 2018, N applied alone increased yields 44 bu/a, whereas N and P applied together increased yields up to 67 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 75 bu/a. Application of 80 lb/a N (with P) produced the maximum yield in 2018, which is slightly less than the 10-yr average. Application of potassium (K) has had no effect on sorghum yield throughout the study period. Average grain N content reached a maximum of ~0.7 lb/bu while grain P content reached a maximum of 0.15 lb/bu (0.34 lb P<sub>2</sub>O<sub>5</sub>/bu) and grain K content reached a maximum of 0.19 lb/bu (0.23 lb K<sub>2</sub>O/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<sub>2</sub>O<sub>5</sub> and zero K; and with 40 lb/a P<sub>2</sub>O<sub>5</sub> and 40 lb/a K<sub>2</sub>O. 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 2009–2011, Pioneer 84G62 in 2012–2014, Pioneer 86G32 in 2015, Pioneer 84G62 in 2016–2017, and Pioneer 85P44 in 2018) 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<sub>g</sub>) 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<sub>g</sub>) and apparent fertilizer K recovery (AFKR<sub>g</sub>).

## Results

Grain sorghum yields in 2018 were 5% lower than the 10-year average (Table 1). Nitrogen alone increased yields 44 bu/a while P alone increased yields less than 10 bu/a. However, N and P applied together increased yields up to 67 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 75 bu/a. In 2018, 40 lb/a N (with P) produced about 88% of maximum yield, which is greater than the 10-year average of 85%. The 10-year average for 80 lb/a N (with P) and 120 lb/a N (with P) was 94 and 95% 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 of N/a or greater with P. Similar to N, the 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<sub>2</sub>O<sub>5</sub>/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.

## SOIL FERTILITY

**Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2009–2018**

Fertilizer			Grain sorghum yield										
N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
----- lb/a -----			----- bu/a -----										
0	0	0	64	51	75	78	62	90	89	80	70	77	<b>74</b>
0	40	0	70	51	83	90	77	94	102	91	79	87	<b>83</b>
0	40	40	76	55	88	93	72	96	97	91	80	83	<b>83</b>
40	0	0	84	66	106	115	94	115	122	106	87	93	<b>99</b>
40	40	0	118	77	121	140	114	144	160	142	120	126	<b>126</b>
40	40	40	109	73	125	132	110	142	155	137	118	131	<b>123</b>
80	0	0	115	73	117	132	102	120	133	120	104	103	<b>112</b>
80	40	0	136	86	140	163	136	151	173	154	123	144	<b>141</b>
80	40	40	108	84	138	161	133	164	178	160	129	140	<b>140</b>
120	0	0	113	70	116	130	100	116	127	108	93	91	<b>106</b>
120	40	0	130	88	145	172	137	162	177	164	121	128	<b>142</b>
120	40	40	136	90	147	175	142	170	178	170	131	143	<b>148</b>
160	0	0	108	74	124	149	117	139	150	135	120	107	<b>122</b>
160	40	0	128	92	152	178	146	171	181	173	137	134	<b>149</b>
160	40	40	140	88	151	174	143	176	179	161	131	139	<b>148</b>
200	0	0	110	78	128	147	119	139	155	151	123	121	<b>127</b>
200	40	0	139	84	141	171	136	165	177	167	131	134	<b>145</b>
200	40	40	129	87	152	175	138	170	179	170	131	130	<b>146</b>

*continued*

## SOIL FERTILITY

**Table 1. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on irrigated grain sorghum yields, Tribune, KS, 2009–2018**

Fertilizer			Grain sorghum yield										
N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Mean
----- lb/a -----			----- bu/a -----										
<b>ANOVA (P&gt;F)</b>													
Nitrogen			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	<b>0.001</b>
Linear			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	<b>0.001</b>
Quadratic			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	<b>0.001</b>
P-K			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	<b>0.001</b>
Zero P vs. P			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	<b>0.001</b>
P vs. P-K			0.324	0.892	0.278	0.826	0.644	0.117	0.806	0.943	0.727	0.549	<b>0.833</b>
N × P-K			0.053	0.229	0.542	0.186	0.079	0.012	0.002	0.001	0.084	0.003	<b>0.007</b>
<b>MEANS</b>													
Nitrogen, lb/a													
0			70c	52c	82d	87d	70d	94e	96d	87d	76d	82c	<b>80d</b>
40			104b	72b	117c	129c	106c	134d	146c	129c	108c	117b	<b>116c</b>
80			120a	81a	132b	152b	124b	145c	161b	145b	119b	129a	<b>131b</b>
120			126a	82a	136ab	159ab	126b	149bc	161b	147b	115bc	121ab	<b>132b</b>
160			125a	84a	142a	167a	135a	162a	170a	156a	129a	127a	<b>140a</b>
200			126a	83a	141a	165a	131ab	158ab	170a	163a	129a	128a	<b>139a</b>
LSD <sub>(0.05)</sub>			11	5	8	9	8	9	8	8	9	9	<b>6</b>
P <sub>2</sub> O <sub>5</sub> -K <sub>2</sub> O, lb/a													
0 - 0			99b	68b	111b	125b	99b	120b	129b	117b	99b	99b	<b>107b</b>
40 - 0			120a	80a	130a	152a	124a	148a	162a	149a	119a	126a	<b>131a</b>
40 - 40			116a	79a	133a	152a	123a	153a	161a	148a	120a	128a	<b>131a</b>
LSD <sub>(0.05)</sub>			7	4	6	6	5	6	5	6	6	6	<b>4</b>

**Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2009–2018**

Fertilizer			Grain						Grain removal			*AFNR <sub>g</sub>	*AFPR <sub>g</sub>	*AFKR <sub>g</sub>
N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	N	P	K	N	P	K	N	P	K			
lb/a			%			lb/bu			lb/a			%		
0	0	0	1.05	0.256	0.358	0.51	0.125	0.176	38	9	13	---	---	---
0	40	0	1.04	0.311	0.382	0.51	0.152	0.187	42	13	15	---	20	---
0	40	40	1.04	0.310	0.382	0.51	0.152	0.187	42	13	16	---	20	8
40	0	0	1.15	0.233	0.346	0.57	0.114	0.170	55	11	17	44	---	---
40	40	0	1.12	0.314	0.371	0.55	0.154	0.182	69	19	23	78	59	---
40	40	40	1.12	0.309	0.370	0.55	0.152	0.181	67	19	22	73	55	29
80	0	0	1.35	0.218	0.340	0.66	0.107	0.167	73	12	19	45	---	---
80	40	0	1.23	0.295	0.358	0.60	0.145	0.175	84	20	25	58	64	---
80	40	40	1.20	0.304	0.359	0.59	0.149	0.176	81	21	25	55	67	35
120	0	0	1.41	0.204	0.337	0.69	0.100	0.165	73	11	17	29	---	---
120	40	0	1.32	0.283	0.355	0.65	0.139	0.174	92	20	25	45	60	---
120	40	40	1.32	0.302	0.357	0.65	0.148	0.175	96	22	26	48	73	39
160	0	0	1.41	0.228	0.345	0.69	0.112	0.169	84	14	21	29	---	---
160	40	0	1.39	0.304	0.360	0.68	0.149	0.177	101	22	26	40	75	---
160	40	40	1.36	0.280	0.353	0.67	0.137	0.173	98	20	26	38	63	38
200	0	0	1.43	0.234	0.349	0.70	0.115	0.171	88	15	22	25	---	---
200	40	0	1.39	0.281	0.358	0.68	0.138	0.175	98	20	25	30	61	---
200	40	40	1.40	0.288	0.359	0.68	0.141	0.176	99	20	26	31	65	38

*continued*

Table 2. Nitrogen (N), phosphorus (P), and potassium (K) fertilizers on grain N, P, and K content of irrigated grain sorghum, Tribune, KS, 2009–2018

Fertilizer			Grain						Grain removal			*AFNR <sub>g</sub>	*AFPR <sub>g</sub>	*AFKR <sub>g</sub>
N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	N	P	K	N	P	K	N	P	K			
----- lb/a -----			----- % -----			----- lb/bu -----			----- lb/a -----			----- % -----		
<b>ANOVA (P&gt;F)</b>														
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	0.011	0.001	0.001	0.011	0.001	0.001	0.001	0.001	0.042	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	0.819	---
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			0.477	0.846	0.726	0.477	0.846	0.726	0.813	0.843	0.962	---	---	---
N × P-K			0.236	0.013	0.347	0.236	0.013	0.347	0.147	0.001	0.005	0.019	0.110	---
<b>MEANS</b>														
Nitrogen, lb/a														
0			1.04e	0.292a	0.374a	0.51e	0.143a	0.183a	40e	11c	15d	---	20c	8c
40			1.13d	0.286a	0.362b	0.55d	0.140a	0.178b	63d	16b	21c	65a	57b	29b
80			1.26c	0.272b	0.353c	0.62c	0.133b	0.173c	80c	18ab	23b	53b	65ab	35a
120			1.35b	0.263b	0.350c	0.66b	0.129b	0.172c	87b	17ab	23b	41c	66a	39a
160			1.39ab	0.271b	0.353c	0.68ab	0.133b	0.173c	95a	19a	24a	36c	69a	38a
200			1.41a	0.268b	0.355c	0.69a	0.131b	0.174c	95a	18a	24a	29d	63ab	38a
LSD <sub>(0.05)</sub>			0.04	0.012	0.006	0.02	0.006	0.003	5	1	1	6	8	5
P <sub>2</sub> O <sub>5</sub> -K <sub>2</sub> O, lb/a														
0 - 0			1.30a	0.229b	0.346b	0.64a	0.112b	0.170b	69b	12b	18b	35b	---	---
40 - 0			1.25b	0.298a	0.364a	0.61b	0.146a	0.178a	81a	19a	23a	50a	56	---
40 - 40			1.24b	0.299a	0.363a	0.61b	0.146a	0.178a	81a	19a	23a	49a	57	---
LSD <sub>(0.05)</sub>			0.03	0.009	0.004	0.01	0.004	0.002	3	1	1	5	5	---

\*AFNR<sub>g</sub> = Apparent fertilizer N recovery (grain). AFPR<sub>g</sub> = Apparent fertilizer P recovery (grain). AFKR<sub>g</sub> = Apparent fertilizer K recovery (grain).

# Application Timing Efficacy of Enlist Duo in Irrigated Corn

*R.S. Currie and P.W. Geier*

## Summary

In this study, herbicides were tested to compare application timing for weed control in irrigated corn. All herbicides tested provided season-long control (90% or more) of Palmer amaranth, Russian thistle, quinoa, and common sunflower. The inclusion of Enlist Duo to SureStart II as an early postemergence (V2) treatment increased kochia and johnsongrass control compared to a preemergence treatment of SureStart II alone early in the season. However, by later in the year, control of kochia and johnsongrass was best when Enlist Duo application was delayed until the V4 stage. Enlist Duo provided equal control of all weeds when applied at 3.5 or 4.67 pt/a, and corn yields did not differ between Enlist Duo rates within application timings. Corn treated at the V2 stage yielded 210–216% more grain than untreated corn, whereas corn receiving Enlist Duo at the V4 stage yielded 257–263% more grain than the weedy controls.

## Introduction

Enlist Duo was first approved for use in the United States in 2014 on herbicide-resistant corn and soybean, and has since been approved for use on herbicide-resistant cotton. Enlist Duo combines two common herbicides, glyphosate and 2,4-D, to help manage herbicide-resistant weed species. The 2,4-D component is a choline salt formulation, which minimizes the drift and volatilization potential compared to the ester and amine formulations. The objective of this study was to compare Enlist Duo at two rates and two application timings for weed control in irrigated corn.

## Experimental Procedures

An experiment at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated the premix of Enlist Duo (2,4-D/glyphosate) at two rates and two application timings in corn. The premix was applied at 3.5 or 4.67 pt/a when corn was at the 4 leaf stage (V4) following preemergence application of SureStart II (acetochlor/flumetsulam/clopyralid) at 2.0 pt/a. Enlist Duo was also applied at the same rates early postemergence when corn was in the 2 leaf stage (V2) and included the treatment of SureStart II at 2.0 pt/a. All treatments were applied using a tractor-mounted, compressed-CO<sub>2</sub> sprayer delivering 19.4 GPA at 30 psi and 4.1 mph. Application, environmental, crop, and weed information are shown in Table 1. Natural weed populations were supplemented by overseeding the experimental area with quinoa (to simulate common lambsquarters) and domesticated sunflower (to simulate common sunflower). Plots were 10 × 32 feet and arranged in a randomized complete block with four replications. Soil was a Beeler silt loam with 2.4% organic matter and pH 7.6. Visual weed control was determined on June 11 and August 2, 2018, which was 12 days after the V2 applications (12 DA-B) and 51 days after the V4 applications (51 DA-C), respectively. Grain yields were determined October 5, 2018, by mechanically harvesting the center two rows of each plot and adjusting weights to 15.5% moisture.

## Results and Discussion

Control of Palmer amaranth, Russian thistle, common sunflower, and quinoa was 90% or more with all herbicides at 12 DA-B and 51 DA-C, and did not differ between treatments (data not shown). Kochia control at 12 DA-B was 14% greater when Enlist Duo was included with SureStart II at the V2 stage compared to SureStart II alone preemergence (Table 2). However, by 51 DA-C, kochia control was best when Enlist Duo was applied at the V4 stage, and no differences occurred between rates for kochia control. Similarly, Enlist Duo applied at the V2 stage increased johnsongrass control compared to SureStart II alone preemergence at 12 DA-B, but johnsongrass control was best at 51 DA-C when Enlist Duo was applied at the V4 stage. Increasing the Enlist Duo rate from 3.5–4.67 pt/a did not improve johnsongrass control with either application timing at 51 DA-C. Corn receiving herbicide treatment at the V2 stage yielded 81–84 bu/a more grain than untreated corn, whereas corn treated at the V4 stage yielded 114–118 bu/a more grain than the control plots. Grain yields did not differ between Enlist Duo rates within applications timings.

*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	V2	V4
Application date	May 9, 2018	May 30, 2018	June 12, 2018
Air temperature (°F)	92	89	82
Relative humidity (%)	20	32	57
Soil temperature (°F)	71	80	74
Wind speed (mph)	5 to 9	3 to 5	2 to 4
Wind direction	South-southwest	Southeast	East-southeast
Soil moisture	Good	Good	Good
Corn			
Height (inch)	---	5 to 8	8 to 12
Leaves (number)	0	1 to 2	4 to 5
Kochia			
Height (inch)	---	1 to 2	3 to 5
Density (plants/10 feet <sup>2</sup> )	0	0.5	2.0
Palmer amaranth			
Height (inch)	---	0.5 to 1	2 to 4
Density (plants/10 feet <sup>2</sup> )	0	0.5	2
Russian thistle			
Height (inch)	---	1 to 2	2 to 5
Density (plants/10 feet <sup>2</sup> )	0	0.5	0.5
Common sunflower			
Height (inch)	---	1 to 2	2 to 4
Density (plants/10 feet <sup>2</sup> )	0	0.2	0.2
Quinoa			
Height (inch)	---	1 to 2	2 to 3
Density (plants/10 feet <sup>2</sup> )	0	0.2	0.3
Green foxtail			
Height (inch)	---	1 to 2	2 to 4
Density (plants/10 feet <sup>2</sup> )	0	0.2	0.2

**Table 2. Enlist Duo application timings in irrigated corn**

Treatment	Rate	Timing <sup>a</sup>	Kochia		Johnsongrass		Corn yield
			12 DA-B <sup>b</sup>	51 DA-C <sup>c</sup>	12 DA-B	51 DA-C	
	per acre		----- % visual -----				bu/a
SureStart II	2.0 pt	PRE	65	89	68	89	187.1
Enlist Duo	3.5 pt	V4					
Ammonium sulfate	2.5%	V4					
SureStart II	2.0 pt	PRE	70	93	80	94	191.5
Enlist Duo	4.67 pt	V4					
Ammonium sulfate	2.5%	V4					
SureStart II	2.0 pt	V2	79	70	98	65	153.6
Enlist Duo	3.5 pt	V2					
Ammonium sulfate	2.5%	V2					
SureStart II	2.0 pt	V2	84	75	93	73	157.1
Enlist Duo	4.67 pt	V2					
Ammonium sulfate	2.5%	V2					
Untreated			---	---	---	---	72.8
LSD (0.05)			11	6	11	8	17.5

<sup>a</sup>PRE = preemergence, V2 = corn with two visible leaf collars, V4 = corn with four visible leaf collars.

<sup>b</sup>DA-B = days after the V2 application timing.

<sup>c</sup>DA-C = days after the V4 application timing.

# Efficacy of Zest Application Timings in Irrigated Acetolactase Synthase-Resistant Grain Sorghum

*R.S. Currie and P.W. Geier*

## Summary

Acetolactase synthase inhibiting (ALS) herbicides were evaluated for efficacy in ALS-resistant grain sorghum. Kochia and quinoa control were similar among all herbicides tested regardless of evaluation date. Cinch ATZ alone preemergence, and Cinch plus Resolve and Harmony GT PRE followed by Zest POST controlled puncturevine 73-78%. Late-season green foxtail control was best when Zest was included as an early postemergence or postemergence application. Cinch ATZ applied alone preemergence, Cinch ATZ preemergence followed by Zest POST, and Cinch plus Resolve and Harmony GT PRE followed by Zest POST controlled Palmer amaranth 81–84%, and resulted in the highest grain yields.

## Introduction

Nicosulfuron is an acetolactase synthase inhibiting (ALS) herbicide that has long been used to control grass weeds in corn under the brand name Accent. Many of the ALS herbicides severely injure or kill sorghum species, including shattercane, johnsongrass, and grain sorghum. The evolution of shattercane with resistance to ALS herbicides allowed for development of commercial sorghum hybrids with this same resistance and the potential to use ALS herbicides to control nonresistant weed species in sorghum. Therefore, the objective of this study was to evaluate the ALS herbicides Zest (nicosulfuron), Resolve (rimsulfuron), and Harmony GT (thifensulfuron) for efficacy in ALS-resistant grain sorghum.

## Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated nicosulfuron-containing herbicide treatments for efficacy and crop tolerance in ALS-resistant grain sorghum. Herbicides were applied preemergence (PRE), PRE followed by postemergence (POST), or early postemergence (EPOST). A tractor-mounted, compressed-CO<sub>2</sub> sprayer delivering 19.4 GPA at 3.0 mph and 30 psi was used to apply all herbicides. Application, environmental, crop, and weed information are given in Table 1. Natural weed populations were supplemented by overseeding the experimental area with quinoa (to simulate common lambsquarters). Soil was a Ulysses silt loam containing 3.4% organic matter and pH 7.9. Plots were 10 × 32 feet and arranged in a randomized complete block with four replications. Weed control was visually determined on July 16 and August 16, 2018, which were 6 and 37 days after the POST treatments (DA-C), respectively. Grain sorghum necrosis was determined on July 6 and July 16, 2018, which was 3 days after the EPOST treatments (DA-B) and 6 DA-C, respectively. Grain yields were determined on October 29, 2018, by mechanically harvesting the center two rows of each plot and adjusting weights to 14.0% moisture.

## Results and Discussion

All herbicides controlled kochia 88–100% and quinoa 98–100% regardless of evaluation date, and did not differ between herbicides (data not shown). Palmer amaranth control was best when Cinch ATZ (*S*-metolachlor/atrazine) was applied PRE alone, Cinch ATZ PRE was followed by Zest POST, and when Cinch (*S*-metolachlor) plus Resolve and Harmony GT PRE was followed by Zest POST (Table 2). At 37 DA-C, puncturevine control exceeded 90% with all herbicides except Cinch ATZ alone PRE or Resolve plus Harmony GT and atrazine PRE followed by Zest and atrazine POST. All herbicide combinations that included Zest either EPOST or POST controlled green foxtail 93% or more at 37 DA-C. Grain sorghum necrosis at 3 DA-B was 18% with the EPOST treatment of Cinch ATZ, Zest, and atrazine, but decreased to 6% by 6 DA-C (Table 3). Necrosis was also less than 10% with the other Zest treatments at 6 DA-C. Grain yields increased by 22–43 bu/a with most herbicide treatments compared to the nontreated controls (Table 3). However, sorghum receiving Resolve plus Harmony GT and atrazine PRE followed by Zest and atrazine POST, 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	Early postemergence	Postemergence
Application date	June 6, 2018	July 3, 2018	July 10, 2018
Air temperature (°F)	67	80	80
Relative humidity (%)	68	47	52
Soil temperature (°F)	69	75	77
Wind speed (mph)	5 to 8	4 to 6	2 to 5
Wind direction	South	South	South
Soil moisture	Good	Good	Good
Grain sorghum			
Height (inch)	---	3 to 6	5 to 9
Leaves (number)	0	2 to 4	4 to 6
Palmer amaranth			
Height (inch)	---	1 to 4	1 to 5
Density (plants/10 feet <sup>2</sup> )	0	2.5	1.0
Puncturevine			
Height (inch)	---	1 to 5	1 to 3
Density (plants/10 feet <sup>2</sup> )	0	1.0	0.3
Quinoa			
Height (inch)	---	1 to 3	---
Density (plants/10 feet <sup>2</sup> )	0	0.2	0
Kochia			
Height (inch)	---	1 to 3	---
Density (plants/10 feet <sup>2</sup> )	0	0.2	0
Green foxtail			
Height (inch)	---	1 to 3	1 to 3
Density (plants/10 feet <sup>2</sup> )	0	1.0	0.2

**Table 2. Efficacy of Zest application timings in grain sorghum**

Treatment <sup>a</sup>	Rate	Timing <sup>b</sup>	Palmer amaranth		Puncturevine		Green foxtail	
			6 DA-C <sup>c</sup>	37 DA-C	6 DA-C	37 DA-C	6 DA-C	37 DA-C
	per acre		----- % Visual -----					
Cinch ATZ	3.2 pt	PRE	79	84	78	73	91	78
Resolve	1.0 oz	PRE	50	50	100	78	91	93
Harmony GT	0.25 oz	PRE						
Atrazine	0.75 qt	PRE						
Zest	0.67 oz	POST						
Atrazine	0.75 qt	POST						
COC	2.0%	POST						
AMS	2.0 lb	POST						
Cinch	1.33 pt	PRE	78	81	83	97	93	100
Resolve	1.0 oz	PRE						
Harmony GT	0.25 oz	PRE						
Zest	0.67 oz	POST						
COC	2.0%	POST						
AMS	2.0 lb	POST						
Cinch ATZ	2.0 pt	PRE	78	83	100	94	91	100
Zest	0.67 oz	POST						
Atrazine	0.75 qt	POST						
COC	2.0%	POST						
AMS	2.0 lb	POST						
Cinch ATZ	3.2 pt	EPOST	60	53	83	94	91	98
Zest	0.67 oz	EPOST						
Atrazine	0.75 qt	EPOST						
COC	2.0%	EPOST						
AMS	2.0 lb	EPOST						
LSD (0.05)			9	7	7	12	NS	7

<sup>a</sup>COC = crop oil concentrate. AMS = ammonium sulfate.

<sup>b</sup>PRE = preemergence. EPOST = early postemergence. POST = postemergence.

<sup>c</sup>DA-C = days after the postemergence treatments.

**Table 3. Grain sorghum response to Zest application timings**

Treatment <sup>a</sup>	Rate	Timing <sup>b</sup>	Necrosis		Grain yield
			3 DA-B <sup>c</sup>	6 DA-C <sup>d</sup>	
			----- % Visual -----		bu/a
Cinch ATZ	3.2 pt	PRE	0	0	55.1
Resolve	1.0 oz	PRE	0	5	23.7
Harmony GT	0.25 oz	PRE			
Atrazine	0.75 qt	PRE			
Zest	0.67 oz	POST			
Atrazine	0.75 qt	POST			
COC	2.0%	POST			
AMS	2.0 lb	POST			
Cinch	1.33 pt	PRE	0	1	57.4
Resolve	1.0 oz	PRE			
Harmony GT	0.25 oz	PRE			
Zest	0.67 oz	POST			
COC	2.0%	POST			
AMS	2.0 lb	POST			
Cinch ATZ	2.0 pt	PRE	0	9	55.1
Zest	0.67 oz	POST			
Atrazine	0.75 qt	POST			
COC	2.0%	POST			
AMS	2.0 lb	POST			
Cinch ATZ	3.2 pt	EPOST	18	6	36.2
Zest	0.67 oz	EPOST			
Atrazine	0.75 qt	EPOST			
COC	2.0%	EPOST			
AMS	2.0 lb	EPOST			
Untreated			0	0	14.0
LSD (0.05)			2	4	10.9

<sup>a</sup>COC = crop oil concentrate. AMS = ammonium sulfate.

<sup>b</sup>PRE = preemergence. EPOST = early postemergence. POST = postemergence.

<sup>c</sup>DA-B = days after the early postemergence treatments.

<sup>d</sup>DA-C = days after the postemergence treatments.

# Zest Efficacy and Crop Response in Two Acetolactase Synthase-Tolerant Grain Sorghum Hybrids

*R.S. Currie and P.W. Geier*

## Summary

Two ALS-tolerant grain sorghum hybrids were evaluated for efficacy and crop tolerance to Zest (nicosulfuron). Weed control and crop response in two herbicide-tolerant sorghum hybrids were similar. All herbicides controlled kochia, common sunflower, velvetleaf, and quinoa well. Palmer amaranth control was inadequate when no preemergence (PRE) herbicide was applied. Puncturevine and green foxtail control was 90% or more with all Zest (nicosulfuron) treatments applied early postemergence (EPOST) or postemergence (POST). Sorghum injury from the Zest treatments was minor and transient. Relative to the untreated controls, grain yields were greater when a PRE or PRE followed by POST program was used. However, sorghum receiving an EPOST treatment alone yielded no better than the weedy checks.

## Introduction

Following the discovery of a wild sorghum biotype with resistance to acetolactase synthase (ALS)-inhibiting herbicides, the development of commercial grain sorghum hybrids with ALS resistance began. Accent (nicosulfuron) is an ALS-inhibiting herbicide commonly used in corn to control grasses and small broadleaf weeds. Prior to the development of ALS-tolerant sorghum, nicosulfuron would have severely injured the crop. However, the use of ALS-inhibiting herbicides may potentially help sorghum producers manage grass weeds that could otherwise go uncontrolled. The objective of this study was to compare two ALS-tolerant grain sorghum hybrids for efficacy and crop tolerance to Zest (nicosulfuron).

## Experimental Procedures

Two experiments were conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, in 2018 to determine the efficacy of and tolerance to nicosulfuron application timings in two ALS-tolerant sorghum hybrids. One study was planted to sorghum hybrid XSA5527 (Hybrid 1) while the second study was planted to hybrid XSA4820 (Hybrid 2). All herbicide treatments were applied using a tractor-mounted, compressed CO<sub>2</sub> sprayer delivering 19.4 GPA at 4.1 mph and 30 psi. Application, environmental, crop, and weed information is given in Table 1. Natural weed populations were supplemented by overseeding the experimental area with quinoa (to simulate common lambsquarters) and domesticated sunflower (to simulate common sunflower). Soil was a Ulysses silt loam with 3.4% organic matter and pH of 7.9 for both experiments. Grain sorghum necrosis was evaluated visually on July 16, 2018, and stunting was visually estimated on August 16, 2018. These dates were 6 and 37 days after the final herbicide applications (DA-C), respectively. Visual weed control was determined on August 16, 2018 (37 DA-C) as well. Grain yields were

measured on October 29, 2018, by mechanically harvesting the center two rows of each plot and adjusting weights to 14.0% moisture.

## Results and Discussion

Trends for weed control and crop response were similar between experiments. Kochia, quinoa, and common sunflower control was 90–100% and did not differ between herbicides (data not shown), nor did velvetleaf control (88–99%). Palmer amaranth control was best when Cinch ATZ (*S*-metolachlor/atrazine) was applied PRE or when followed by Zest plus atrazine POST (Table 2). Zest plus atrazine applied EPOST controlled Palmer amaranth only 50%. Cinch ATZ applied alone PRE provided no more than 78% puncturevine and green foxtail control, whereas any Zest treatment applied EPOST or POST controlled these weeds 90–100%. Minor sorghum necrosis (6 DA-C) and stunting (37 DA-C) occurred on each hybrid with POST treatments of Zest plus atrazine (Table 3). Yields were best when Cinch ATZ was applied alone PRE or followed by Zest plus atrazine POST (Table 3). Sorghum receiving Zest plus atrazine EPOST yielded no more than nontreated sorghum, and this was likely due to the poor Palmer amaranth control with this treatment.

*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	
	XSA5527	XSA4820	XSA5527	XSA4820	XSA5527	XSA4820
Sorghum hybrid						
Application date	June 5	June 5	July 3	July 3	July 10	July 10
Air temperature (°F)	67	67	80	80	80	80
Humidity (%)	68	68	47	47	52	52
Soil temperature (°F)	69	69	75	75	77	77
Wind speed (mph)	5 to 8	5 to 8	3 to 6	3 to 6	2 to 5	2 to 5
Wind direction	South	South	South	South	South	South
Soil moisture	Good	Good	Good	Good	Good	Good
Grain sorghum						
Height (inch)	---	---	3 to 6	1 to 4	5 to 9	5 to 9
Leaves (number)	0	0	2 to 4	2 to 4	4 to 6	4 to 6
Palmer amaranth						
Height (inch)	---	---	1 to 3	1 to 4	1 to 5	1 to 5
Density (plants/10 feet <sup>2</sup> )	0	0	3	5	1	1
Puncturevine						
Height (inch)	---	---	1 to 5	2 to 6	1 to 3	1 to 3
Density (plants/10 feet <sup>2</sup> )	0	0	1	1	0.3	0.3
Kochia						
Height (inch)	---	---	1 to 2	1 to 3	1 to 3	1 to 3
Density (plants/10 feet <sup>2</sup> )	0	0	0.2	0.1	0.1	0.1
Green foxtail						
Height (inch)	---	---	1 to 3	1 to 4	1 to 3	1 to 2
Density (plants/10 feet <sup>2</sup> )	0	0	3	0.1	0.3	0.1
Velvetleaf						
Height (inch)	---	N/A <sup>a</sup>	1 to 3	N/A	1 to 3	N/A
Density (plants/10 feet <sup>2</sup> )	0	N/A	0.2	N/A	0.1	N/A
Common sunflower						
Height (inch)	N/A	---	N/A	1 to 3	N/A	1 to 3
Density (plants/10 feet <sup>2</sup> )	N/A	0	N/A	0.1	N/A	0.1

<sup>a</sup>N/A = weed species not present in that experiment.

**Table 2. Efficacy of Zest in two acetolactase synthase-tolerant hybrids<sup>a</sup>**

Treatment	Rate	Timing <sup>b</sup>	Palmer amaranth		Puncturevine		Green foxtail	
			Hybrid 1 <sup>c</sup>	Hybrid 2 <sup>d</sup>	Hybrid 1	Hybrid 2	Hybrid 1	Hybrid 2
	per acre		----- % Visual -----					
Cinch ATZ	3.2 pt	PRE	80	83	78	65	78	73
Cinch ATZ	2.0 pt	PRE	79	79	98	100	100	93
Zest	0.67 oz	POST						
Atrazine	0.75 qt	POST						
Crop oil concentrate	2.0%	POST						
Ammonium sulfate	2.0 lb	POST						
Cinch ATZ	2.0 pt	PRE	79	78	99	98	100	94
Zest	1.33 oz	POST						
Atrazine	0.75 qt	POST						
Crop oil concentrate	2.0%	POST						
Ammonium sulfate	2.0 lb	POST						
Zest	0.67 oz	EPOST	50	50	100	100	100	90
Atrazine	0.75 qt	EPOST						
Crop oil concentrate	2.0%	EPOST						
Ammonium sulfate	2.0 lb	EPOST						
LSD (0.05)			11	12	6	6	8	11

<sup>a</sup>Weed control ratings were taken on August 16, 2018, which was 37 days after postemergence applications.

<sup>b</sup>PRE = preemergence. EPOST = early postemergence. POST = postemergence.

<sup>c</sup>Hybrid 1 was Pioneer XSA5527.

<sup>d</sup>Hybrid 2 was Pioneer XSA4820.

**Table 3. Crop response of two acetolactase synthase-tolerant hybrids receiving Zest treatments**

Treatment	Rate	Timing <sup>c</sup>	Necrosis <sup>a</sup>		Stunting <sup>b</sup>		Grain yield	
			Hybrid 1 <sup>d</sup>	Hybrid 2 <sup>e</sup>	Hybrid 1	Hybrid 2	Hybrid 1	Hybrid 2
	per acre		----- % Visual -----				----- bu/a -----	
Cinch ATZ	3.2 pt	PRE	0	0	0	0	55.8	32.0
Cinch ATZ	2.0 pt	PRE	6	10	4	4	42.6	34.9
Zest	0.67 oz	POST						
Atrazine	0.75 qt	POST						
Crop oil concentrate	2.0%	POST						
Ammonium sulfate	2.0 lb	POST						
Cinch ATZ	2.0 pt	PRE	9	9	6	6	47.7	31.9
Zest	1.33 oz	POST						
Atrazine	0.75 qt	POST						
Crop oil concentrate	2.0%	POST						
Ammonium sulfate	2.0 lb	POST						
Zest	0.67 oz	EPOST	1	0	0	0	26.4	14.4
Atrazine	0.75 qt	EPOST						
Crop oil concentrate	2.0%	EPOST						
Ammonium sulfate	2.0 lb	EPOST						
Untreated	---	---	0	0	0	0	22.6	12.3
LSD (0.05)			5	2	NS	5	14.6	7.0

<sup>a</sup>Necrosis was evaluated on July 16, 2018, which was 6 days after the postemergence treatments.

<sup>b</sup>Stunting was evaluated on August 16, 2018, which was 37 days after the postemergence treatments.

<sup>c</sup>PRE = preemergence. EPOST = early postemergence. POST = postemergence.

<sup>d</sup>Hybrid 1 was Pioneer XSA5527.

<sup>e</sup>Hybrid 2 was Pioneer XSA4820.

# Comparisons of Terbuthylazine and Atrazine Rates and Tank Mixtures in Irrigated Corn

*R.S. Currie and P.W. Geier*

## Summary

A comparison of terbuthylazine and atrazine rates alone and in combination with other herbicides in corn was conducted. All herbicides controlled Russian thistle and common sunflower by 90% or more. Preemergence control of green foxtail required a tank mixture of mesotrione (Stalwart C, Stalwart 3W, SA-0070128, and SA-0070129) with terbuthylazine or atrazine to be effective. Both terbuthylazine and atrazine alone provided similar kochia control, but control tended to increase with the addition of mesotrione. Palmer amaranth control was similar among terbuthylazine rates early in the season, but increased as atrazine rate increased. Crabgrass control increased as terbuthylazine rate increased early in the season and with both terbuthylazine and atrazine rates later in the year. Despite differences in weed control, no differences occurred among herbicides for corn yield.

## Introduction

Terbuthylazine is a triazine herbicide, similar to atrazine, which controls susceptible weeds by inhibiting photosynthesis. It has become a widely used herbicide in countries that restrict atrazine use, such as those in the European Union. Terbuthylazine is currently not marketed in the United States as an agricultural herbicide, but may have utility in corn and sorghum growing regions. The objective of this study was to compare terbuthylazine and atrazine rates alone and in combination with other herbicides in corn.

## Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, compared terbuthylazine and atrazine rates applied preemergence for weed control in corn. Herbicides were applied using a tractor-mounted, compressed CO<sub>2</sub> sprayer delivering 19.4 GPA at 4.1 mph and 30 psi. All preemergence (PRE) herbicides were followed by glyphosate at 22 oz/a plus ammonium sulfate at 1.0% late postemergence (POST). Application, environmental, weeds, and crop information is given in Table 1. Natural weed populations were supplemented by overseeding the experimental area with domesticated sunflower (to simulate common sunflower) and domesticated crabgrass (to simulate large crabgrass). Plots were 10 × 35 feet and arranged in a randomized complete block design replicated four times. Soil was a Beeler silt loam with 2.4% organic matter and pH of 7.6. Residual weed control of the preemergence treatments was visually estimated on June 13, 2018, which was 40 days after the preemergence applications (40 DA-A). Late season weed control following the postemergence treatments was determined on August 13, 2018, 56 days after the glyphosate application (56 DA-B). Yields were determined on October 4, 2018, by me-

chanically harvesting the center two rows of each plot and adjusting weights to 15.5% moisture.

## Results and Discussion

No differences between herbicides occurred for Russian thistle control (90% or more) and common sunflower (93% or more) regardless of rating date (data not shown). Only the treatments containing mesotrione controlled green foxtail more than 88% at 40 DA-A, but foxtail control exceeded 97% regardless of treatment by 56 DA-B (data not shown). Kochia control at 40 DA-A exceeded 90% with all herbicides except terbuthylazine at 22 oz/a and atrazine at 16 oz/a (Table 2). By 56 DA-B, terbuthylazine alone at 15.5, 23, 31 oz/a and atrazine at any rate alone provided less kochia control than treatments with the best kochia control (100%). Terbuthylazine at 15.5 oz/a alone and atrazine at 24 oz/a alone controlled Palmer amaranth 83–85% at 40 DA-A. However, only plots receiving atrazine alone at 16 or 32 oz/a PRE provided less than 90% Palmer amaranth control at 56 DA-B. Crabgrass control at 40 DA-A was 85% or less with terbuthylazine at 15.5, 23, and 31 oz/a and atrazine at any rate alone PRE, and crabgrass control remained less than 85% for these treatments at 56 DA-B. Differences among herbicides in weed control did not translate into grain yield differences in this study. Herbicide-treated plots yielded 160–171 bu/a, and did not differ from the nontreated plots (148 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**

	Preemergence	Postemergence
Application timing	Preemergence	Postemergence
Application date	May 4, 2018	June 18, 2018
Air temperature (°F)	54	77
Relative humidity (%)	59	58
Soil temperature (°F)	53	72
Wind speed (mph)	4 to 6	6 to 9
Wind direction	West	West-southwest
Soil moisture	Good	Good
Corn		
Height (inch)	---	18 to 24
Leaves (number)	0	5 to 7
Palmer amaranth		
Height (inch)	---	6 to 9
Density (plants/10 feet <sup>2</sup> )	0	0.5
Kochia		
Height (inch)	---	3 to 9
Density (plants/10 feet <sup>2</sup> )	0	0.3
Russian thistle		
Height (inch)	---	4 to 10
Density (plants/10 feet <sup>2</sup> )	0	0.3
Common sunflower		
Height (inch)	---	3 to 6
Density (plants/10 feet <sup>2</sup> )	0	0.1
Green foxtail		
Height (inch)	---	2 to 6
Density (plants/10 feet <sup>2</sup> )	0	0.3
Crabgrass		
Height (inch)	---	2 to 4
Density (plants/10 feet <sup>2</sup> )	0	0.2

**Table 2. Terbutylazine comparisons in corn**

Treatment <sup>a</sup>	Rate	Timing <sup>b</sup>	Kochia		Palmer amaranth		Crabgrass	
			40 DA-A <sup>c</sup>	56 DA-B <sup>d</sup>	40 DA-A	56 DA-B	40 DA-A	56 DA-B
	per acre		----- % Visual -----					
Terbutylazine	15.5 oz	PRE	91	83	83	90	80	73
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
Terbutylazine	23 oz	PRE	90	86	95	90	85	78
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
Terbutylazine	31 oz	PRE	94	88	95	95	83	80
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
Terbutylazine	46 oz	PRE	93	93	90	95	93	83
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
Terbutylazine	23 oz	PRE	99	95	99	100	99	89
Stalwart C	27 oz	PRE						
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
Atrazine	16 oz	PRE	85	83	88	83	86	70
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
Atrazine	24 oz	PRE	93	83	85	94	85	80
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
Atrazine	32 oz	PRE	98	88	93	85	80	78
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
Atrazine	48 oz	PRE	97	90	100	97	79	80
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
Atrazine	24 oz	PRE	96	92	100	100	97	88
Stalwart C	27 oz	PRE						
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
Stalwart 3W	3.0 qt	PRE	100	99	100	98	100	94
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
SA-0070128	3.0 qt	PRE	100	100	100	94	99	91
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
SA-0070129	3.0 qt	PRE	100	100	100	96	99	94
Glyphosate	22 oz	POST						
AMS	1.0%	POST						
LSD (0.05)			9	9	12	10	11	7

<sup>a</sup>AMS = ammonium sulfate.<sup>b</sup>PRE = preemergence. POST = postemergence.<sup>c</sup>DA-A = days after the preemergence applications<sup>d</sup>DA-B = days after the postemergence applications.

# Liberty Compared to Glyphosate Products in Irrigated Corn

*R.S. Currie and P.W. Geier*

## Summary

Postemergence treatments of Liberty (glufosinate) were compared to Durango DMA and Roundup PowerMax (glyphosate) after various preemergence treatments for efficacy in corn. Control of common sunflower, green foxtail, Russian thistle, and quinoa exceeded 92% regardless of herbicide treatment or evaluation date. Similarly, all preemergence (PRE) treatments controlled Palmer amaranth, kochia, and crabgrass by 93% or more. Later in the season, control of kochia was slightly less when Verdict (saflufenacil/dimethenamid) and atrazine PRE was followed by Roundup PowerMax and atrazine postemergence (POST). Palmer amaranth and crabgrass control was less when Verdict and atrazine PRE was followed by Roundup PowerMax or Liberty and atrazine POST. Herbicide treatments increased grain yields by 49–70% relative to the untreated controls.

## Introduction

The use of glyphosate has increased steadily since its introduction in 1974, and became a major component of many herbicide programs with the introduction of glyphosate-resistant crops in the 1990s. Although it remains a valuable tool for weed control, the rise in glyphosate usage has led to increases in glyphosate-resistant weed species. Kochia and Palmer amaranth are examples of two troublesome weeds which have confirmed glyphosate-resistant populations in Kansas. One key management tool for combating resistance is the use of herbicides with multiple modes of action. The objective of this study was to compare postemergence treatments of Liberty (glufosinate) to Durango DMA and Roundup PowerMax (glyphosate) after various preemergence treatments 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 Liberty to Durango or Roundup PowerMax as postemergence (POST) treatments following various preemergence (PRE) treatments in corn. All treatments were applied using a tractor-mounted, compressed CO<sub>2</sub> sprayer delivering 19.4 GPA at 3.0 mph and 30 psi. Application, environmental, crop, and weed information is given in Table 1. Natural weed populations were supplemented by overseeding the experimental area with quinoa (to simulate common lambsquarters), domesticated sunflower (to simulate common sunflower), and domesticated crabgrass (to simulate large crabgrass). Plots were 10 × 35 feet and arranged in a randomized complete block with four replications. Soil was a Ulysses silt loam with pH 7.6 and 2.4% organic matter. Visual weed control was determined on June 6, 2018, which was 31 days after the PRE treatments (31 DA-A), and on July 25, 2018, which was 43 days after the POST treatments (43 DA-B). Yields were determined on October 5, 2018, 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 93–100%, green foxtail 95–100%, common sunflower 96–100%, and quinoa 100% regardless of evaluation date, and did not differ between treatments (data not shown). Likewise, all PRE herbicides controlled kochia and Palmer amaranth similarly at 31 DA-A (Table 2). Kochia control was slightly less with Verdict (saflufenacil/dimethenamid) and atrazine PRE followed by Roundup PowerMax and atrazine POST compared to other treatments at 43 DA-B. Palmer amaranth control at 43 DA-B was 96% or more with all herbicides, except when Verdict plus atrazine PRE was followed by Roundup PowerMax with atrazine or Liberty with atrazine POST. Preemergence herbicides controlled crabgrass by 95% or more at 31 DA-A, and only the treatments of Verdict plus atrazine PRE followed by Roundup PowerMax with atrazine or Liberty with atrazine POST provided less than 94% crabgrass control at 43 DA-B. All herbicide-treated corn yielded 56–79 bu/a more grain than nontreated corn (Table 2), and yield was greatest from corn receiving Acuron PRE followed by Liberty plus atrazine POST (194 bu/a).

*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**

	Preemergence	Postemergence
Application timing	Preemergence	Postemergence
Application date	May 11, 2018	June 12, 2018
Air temperature (°F)	89	74
Relative humidity (%)	32	63
Soil temperature (°F)	77	73
Wind speed (mph)	0 to 4	4 to 6
Wind direction	South	East-southeast
Soil moisture	Good	Good
Corn		
Height (inch)	---	8 to 12
Leaves (number)	0	5 to 6
Palmer amaranth		
Height (inch)	---	2 to 3
Density (plants/10 feet <sup>2</sup> )	0	0.1
Kochia		
Height (inch)	---	1 to 3
Density (plants/10 feet <sup>2</sup> )	0	0.8
Russian thistle		
Height (inch)	---	1 to 4
Density (plants/10 feet <sup>2</sup> )	0	0.1
Common sunflower		
Height (inch)	---	2 to 4
Density (plants/10 feet <sup>2</sup> )	0	0.1
Quinoa		
Height (inch)	---	2 to 3
Density (plants/10 feet <sup>2</sup> )	0	0.1
Green foxtail		
Height (inch)	---	1 to 2
Density (plants/10 feet <sup>2</sup> )	0	0.1
Crabgrass		
Height (inch)	---	---
Density (plants/10 feet <sup>2</sup> )	0	0

**Table 2. Liberty and glyphosate comparisons in corn**

Treatment <sup>a</sup>	Rate	Timing <sup>a</sup>	Kochia		Palmer amaranth		Crabgrass		Corn yield bu/a
			31 DA-A <sup>b</sup>	43 DA-B <sup>c</sup>	31 DA-A	43 DA-B	31 DA-A	43 DA-B	
	per acre		----- % Visual -----						
Balance Flexx	4.0 oz	PRE	99	100	94	96	95	96	181.1
Atrazine	32 oz	PRE							
Liberty	32 oz	POST							
Capreno	3.0 oz	POST							
Atrazine	16 oz	POST							
AMS	1.0%	POST							
Corvus	4.0 oz	PRE	100	100	95	96	96	94	179.7
Atrazine	32 oz	PRE							
Liberty	32 oz	POST							
Diflexx Duo	24 oz	POST							
Atrazine	16 oz	POST							
AMS	1.0%	POST							
Harness Max	2.5 qt	PRE	98	100	98	99	100	98	179.0
Atrazine	32 oz	PRE							
Durango	32 oz	POST							
Atrazine	16 oz	POST							
AMS	1.0%	POST							
Harness Max	2.5 qt	PRE	100	100	98	98	100	95	178.3
Atrazine	32 oz	PRE							
Liberty	32 oz	POST							
Atrazine	16 oz	POST							
AMS	1.0%	POST							
Resicore	2.5 qt	PRE	100	100	100	98	99	94	185.9
Atrazine	32 oz	PRE							
Durango	32 oz	POST							
Atrazine	16 oz	POST							
AMS	1.0%	POST							
Resicore	2.5 qt	PRE	100	100	100	99	100	94	171.7
Atrazine	32 oz	PRE							
Liberty	32 oz	POST							
Atrazine	16 oz	POST							
AMS	1.0%	POST							
Verdict	14 oz	PRE	96	94	99	93	98	90	171.1
Atrazine	32 oz	PRE							
RU PowerMax	32 oz	POST							
Atrazine	16 oz	POST							
AMS	1.0%	POST							
Verdict	14 oz	PRE	99	100	98	88	99	93	186.5
Atrazine	32 oz	PRE							
Liberty	32 oz	POST							
Atrazine	16 oz	POST							
AMS	1.0%	POST							

*continued*

**Table 2. Liberty and glyphosate comparisons in corn**

Treatment <sup>a</sup>	Rate	Timing <sup>a</sup>	Kochia		Palmer amaranth		Crabgrass		Corn yield bu/a
			31 DA-A <sup>b</sup>	43 DA-B <sup>c</sup>	31 DA-A	43 DA-B	31 DA-A	43 DA-B	
	per acre		----- % Visual -----						
Acuron	2.5 qt	PRE	100	98	100	99	100	99	187.0
RU PowerMax	32 oz	POST							
Atrazine	16 oz	POST							
AMS	1.0%	POST							
Acuron	2.5 qt	PRE	100	100	99	100	100	96	194.4
Liberty	32 oz	POST							
Atrazine	16 oz	POST							
AMS	1.0%	POST							
Balance Flexx	4.0 oz	PRE	98	100	99	99	95	100	184.2
Atrazine	32 oz	PRE							
Halex GT	3.6 pt	POST							
Status	5.0 oz	POST							
AMS	1.0%	POST							
Balance Flexx	4.0 oz	PRE	98	100	93	100	100	100	190.4
Atrazine	32 oz	PRE							
Halex GT	3.6 pt	POST							
Liberty	32 oz	POST							
AMS	1.0%	POST							
Untreated	---	---	---	---	---	---	---	---	114.6
LSD (0.05)			NS	3	NS	5	4	5	18.1

<sup>a</sup>AMS = ammonium sulfate. Durango = Durango DMA. RU PowerMax = Roundup PowerMax.

<sup>b</sup>PRE = preemergence. POST = postemergence.

<sup>c</sup>DA-A = days after the preemergence applications.

<sup>d</sup>DA-B = days after the postemergence applications.

# Anthem Maxx Tank Mixture Comparisons in Irrigated Corn

*R.S. Currie and P.W. Geier*

## Summary

The use of multiple herbicide modes of action in single versus sequential applications was examined for efficacy in corn. Common sunflower control was complete with all early postemergence and postemergence herbicides late in the season. Control of Russian thistle, Palmer amaranth, and green foxtail were 95% or more with all early postemergence and postemergence herbicides except Halex GT. All herbicide treatments increased grain yield 15–33% compared to the nontreated controls except Halex GT applied early postemergence.

## Introduction

Several strategies are important components to combat herbicide resistance development in weeds. Use of herbicides with multiple modes of action in combinations; applying herbicides to small, actively-growing weeds; and sequential applications to eliminate escapes can all reduce selection pressure for weed resistance. Cultural practices such as crop rotation and tillage are also key management components. In this study, the use of multiple herbicide modes of action in single versus sequential applications was examined for efficacy in corn.

## Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, compared the premix of Anthem Maxx (pyroxasulfone/fluthiacet) with various herbicides for preemergence (PRE), early postemergence (EPOST), or sequential (PRE followed by postemergence (POST)) efficacy in corn. All herbicide treatments were applied using a tractor-mounted, compressed CO<sub>2</sub> sprayer delivering 19.4 GPA at 3.0 mph and 4.1 mph. Application, environmental, crop, and weed information is given in Table 1. Natural weed populations were supplemented by overseeding the experimental area with domesticated sunflower (to simulate common sunflower). Plots were 10 × 35 feet and arranged in a randomized complete block with four replications. Soil was a Beeler silt loam containing 2.4% organic matter and pH 7.6. Weed control was visually determined on May 18 and July 25, 2018. These dates were 21 days after the PRE treatments (21 DA-A) and 55 days after the POST treatments (55 DA-C), respectively. Since Palmer amaranth emerged later than the other weeds in the trial, it was evaluated on June 7 (7 DA-C) and July 25, 2018 (55 DA-C). Corn yields were determined on October 4, 2018, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 15.5% moisture.

## Results and Discussion

Only the treatments of Anthem Maxx plus Balance Flexx (isoxaflutole) and atrazine PRE and Anthem Maxx plus Callisto (mesotrione), Hornet WDG (clopyralid/flumetsulam), and atrazine PRE provided less than 100% common sunflower control at 21 DA-A (data not shown). However, sunflower control was complete regardless

of treatment by 55 DA-C. All PRE herbicides controlled kochia 100%, Russian thistle 95–100%, and green foxtail 85–100% at 21 DA-A (Table 2). When Halex GT (*S*-metolachlor/glyphosate/mesotrione) was applied alone EPOST, kochia, Russian thistle, and green foxtail control was 91, 86, and 89%, respectively, at 55 DA-C. This treatment also provided the least Palmer amaranth control at 7 and 55 DA-C (94 and 83%, respectively). Herbicide-treated corn yielded 21–47 bu/a more grain than the nontreated controls (Table 2), except when Halex GT alone was applied EPOST.

*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	April 27, 2018	May 22, 2018	May 31, 2018
Air temperature (°F)	62	63	87
Relative humidity (%)	34	79	35
Soil temperature (°F)	51	64	78
Wind speed (mph)	5 to 8	7 to 10	2 to 5
Wind direction	West-southwest	South	South
Soil moisture	Good	Good	Good
<b>Corn</b>			
Height (inch)	---	3 to 5	6 to 9
Leaves (number)	0	2 to 3	3 to 4
<b>Palmer amaranth</b>			
Height (inch)	---	1 to 2	2 to 3
Density (plants/10 feet <sup>2</sup> )	0	0.1	0.1
<b>Kochia</b>			
Height (inch)	---	1 to 4	2 to 4
Density (plants/10 feet <sup>2</sup> )	0	0.2	0.2
<b>Russian thistle</b>			
Height (inch)	---	3 to 5	3 to 5
Density (plants/10 feet <sup>2</sup> )	0	0.3	0.2
<b>Common sunflower</b>			
Height (inch)	---	2 to 4	1 to 3
Density (plants/10 feet <sup>2</sup> )	0	0.1	0.1
<b>Quinoa</b>			
Height (inch)	---	2 to 5	---
Density (plants/10 feet <sup>2</sup> )	0	0.3	0
<b>Green foxtail</b>			
Height (inch)	---	1 to 3	1 to 2
Density (plants/10 feet <sup>2</sup> )	0	0.2	0.2

**Table 2. Anthem Maxx comparisons in corn**

Treatment	Rate	Timing <sup>a</sup>	Kochia	Palmer	Russian	Green	Corn yield
			55 DA-C <sup>b</sup>	amaranth 55 DA-C	thistle 55 DA-C	foxtail 55 DA-C	
	per acre		----- % Visual -----				bu/a
Anthem Maxx	4.0 oz	PRE	100	100	100	100	166.8
Atrazine	32 oz	PRE					
Callisto	4.0 oz	POST					
Atrazine	16 oz	POST					
Glyphosate	22 oz	POST					
Crop oil concentrate	1.0%	POST					
Ammonium sulfate	1.0%	POST					
Anthem Maxx	4.0 oz	PRE	100	100	100	100	180.6
Callisto	5.0 oz	PRE					
Atrazine	32 oz	PRE					
Status	3.0 oz	POST					
Atrazine	16 oz	POST					
Glyphosate	22 oz	POST					
Crop oil concentrate	1.0%	POST					
Ammonium sulfate	1.0%	POST					
Anthem Maxx	4.0 oz	PRE	100	100	100	100	179.6
Balance Flexx	3.0 oz	PRE					
Atrazine	32 oz	PRE					
Status	3.0 oz	POST					
Atrazine	16 oz	POST					
Glyphosate	22 oz	POST					
Crop oil concentrate	1.0%	POST					
Ammonium sulfate	1.0%	POST					
Anthem Maxx	4.0 oz	PRE	100	100	100	100	169.8
Hornet WDG	4.0 oz	PRE					
Atrazine	32 oz	PRE					
Callisto	3.0 oz	POST					
Atrazine	16 oz	POST					
Glyphosate	22 oz	POST					
Crop oil concentrate	1.0%	POST					
Ammonium sulfate	1.0%	POST					
Anthem Maxx	4.0 oz	PRE	100	100	98	93	181.6
Callisto	5.0 oz	PRE					
Atrazine	48 oz	PRE					
Anthem Maxx	4.0 oz	PRE	100	100	98	99	179.1
Balance Flexx	3.0 oz	PRE					
Atrazine	48 oz	PRE					
Anthem Maxx	4.0 oz	PRE	100	100	98	100	160.8
Hornet WDG	4.0 oz	PRE					
Atrazine	48 oz	PRE					
Acuron	2.5 qt	PRE	100	98	100	93	168.4
Resicore	2.5 qt	PRE	94	100	100	100	186.9

*continued*

**Table 2. Anthem Maxx comparisons in corn**

Treatment	Rate	Timing <sup>a</sup>	Kochia	Palmer amaranth	Russian thistle	Green foxtail	Corn yield
			55 DA-C <sup>b</sup>	55 DA-C	55 DA-C	55 DA-C	
	per acre		----- % Visual -----				bu/a
Anthem Maxx	4.0 oz	PRE	95	96	93	98	171.4
Callisto	6.0 oz	PRE					
Hornet WDG	4.0 oz	PRE					
Atrazine	48 oz	PRE					
Anthem Maxx	4.0 oz	EPOST	100	100	100	95	176.5
Callisto	3.0 oz	EPOST					
Atrazine	32 oz	EPOST					
Glyphosate	22 oz	EPOST					
Crop oil concentrate	1.0%	EPOST					
Ammonium sulfate	1.0%	EPOST					
Halex GT	3.6 pt	EPOST	91	83	86	89	160.1
Nonionic surfactant	0.25%	EPOST					
Ammonium sulfate	1.0%	EPOST					
Acuron	2.0 qt	EPOST	100	100	98	95	175.4
Glyphosate	22 oz	EPOST					
Crop oil concentrate	1.0%	EPOST					
Untreated	---	---	---	---	---	---	139.5
LSD (0.05)			5	4	5	7	20.9

<sup>a</sup>PRE = preemergence. EPOST = early postemergence. POST = postemergence.

<sup>b</sup>DA-C = days after the postemergence applications.

# Vida Alone and in Tank Mixtures for Kochia Control in Fallow

*R.S. Currie and P.W. Geier*

## Summary

To learn more about kochia control in fallow, a comparison of Vida alone and in tank mixtures was conducted. Glyphosate alone provided no more than 40% kochia control, and was similar to Vida or 2,4-D alone late in the season. The tank mixture of Vida plus Gramoxone and Spartan controlled kochia the best regardless of rating date, and was the only treatment to provide more than 95% control at 28 days.

## Introduction

Glyphosate has long been an important herbicide in fallow and row crops. However, in 2007, glyphosate resistance in kochia was first confirmed in Kansas, and has subsequently spread to at least ten states in the United States and three Canadian provinces. Consequently, new or different herbicide modes of action are needed to combat herbicide resistance. The objective of this study was to compare Vida alone and in tank mixtures to control kochia in fallow.

## Experimental Procedures

An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to compare Vida (pyraflufen) alone and in tank mixtures to standard treatments for postemergence kochia control in fallow. Herbicides were applied using a tractor-mounted, compressed CO<sub>2</sub> sprayer delivering 19.4 GPA at 30 psi and 4.1 mph. Application, environmental, and weed information are shown in Table 1. Plots were 10 × 32 feet and arranged in a randomized complete block design with four replications. Soil was a Ulysses silt loam with 3.4% organic matter and pH of 7.9. Kochia control was visually estimated on June 22, July 3, and July 16, 2018. These dates were 4, 15, and 28 days after treatment (DAT), respectively.

## Results and Discussion

Vida alone provided no more than 33% kochia control regardless of rating date (Table 2), and was no better than glyphosate, 2,4-D amine, or dicamba alone. The tank mixture of Vida plus Gramoxone (paraquat) and Spartan (sulfentrazone) provided the best kochia control at 4, 15, and 28 DAT (58, 97, and 97%, respectively). Tank mixing of these three herbicides increased kochia control 11 to 74% compared to the individual herbicides applied alone. Vida plus Gramoxone and Spartan was the only treatment to control kochia more than 95% 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 date	June 18, 2018
Air temperature (°F)	97
Relative humidity (%)	28
Soil temperature (°F)	87
Wind speed (mph)	7 to 10
Wind direction	South
Soil moisture	Dry
Kochia	
Height (inch)	6 to 15
Density (plants/10 feet <sup>2</sup> )	>10

**Table 2. Kochia control with Vida in fallow**

Treatment	Rate	Kochia		
		4 DAT <sup>a</sup>	15 DAT	28 DAT
	oz/a	----- % Visual -----		
Vida	2.0	10	23	33
Crop oil concentrate	0.5%			
Ammonium sulfate	2.0%			
Vida	2.0	17	33	40
Glyphosate	22			
2,4-D amine	8.0			
Ammonium sulfate	2.0%			
Vida	2.0	45	79	79
Gramoxone	32			
Nonionic surfactant	0.25%			
Ammonium sulfate	2.0%			
Vida	2.0	28	50	60
Glyphosate	22			
Dicamba	16			
Ammonium sulfate	2.0%			
Glyphosate	22	18	35	40
Ammonium sulfate	1.0%			
2,4-D amine	8.0	13	20	33
Nonionic surfactant	0.25%			
Gramoxone	32	43	85	86
Nonionic surfactant	0.25%			
Dicamba	16	28	50	50
Nonionic surfactant	0.25%			
Ammonium sulfate	2.0%			
Vida	2.0	30	65	65
Spartan	6.0			
Crop oil concentrate	0.5%			
Ammonium sulfate	2.0%			
Vida	2.0	35	69	69
Spartan	6.0			
Glyphosate	22			
Ammonium sulfate	2.0%			
Vida	2.0	30	70	68
Spartan	6.0			
2,4-D amine	8.0			
Nonionic surfactant	0.25%			
Ammonium sulfate	2.0%			
Vida	2.0	58	97	97
Spartan	6.0			
Gramoxone	32			
Nonionic surfactant	0.25%			
Ammonium sulfate	2.0%			

*continued*

**Table 2. Kochia control with Vida in fallow**

Treatment	Rate	Kochia		
		4 DAT <sup>a</sup>	15 DAT	28 DAT
	oz/a	----- % Visual -----		
Vida	2.0	23	38	35
Glyphosate	22			
Ammonium sulfate	2.0%			
Spartan	6.0	30	70	70
Crop oil concentrate	0.5%			
LSD (0.05)		6	8	9

<sup>a</sup>DAT = days after treatment.

# Comparisons of Acuron, Surestart II, and Valor for Residual Weed Control in Grain Sorghum

*R.S. Currie and P.W. Geier*

## Summary

Herbicides were compared to standard treatments for preplant efficacy and crop response in grain sorghum. All herbicides controlled buffalobur and velvetleaf similarly late in the season. SureStart II and Acuron provided the best Palmer amaranth, puncturevine, and green foxtail control. Valor at 1 or 2 oz/a provided less than 70% puncturevine and green foxtail control late in the season. Only minimal visual injury was observed, and all herbicides increased sorghum yield 47–122% relative to the untreated controls.

## Introduction

The herbicide premixes Acuron (*S*-metolachlor/atrazine/mesotrione/bicyclopyrone) and SureStart II (acetochlor/flumetsulam/clopyralid) are commonly used in corn, but not registered for use in grain sorghum. Valor (flumioxazin) is also used in corn, but can only be applied 30 days preplant to sorghum and only if sufficient moisture is received prior to planting. Injury concerns with these herbicides have kept them from being labeled in sorghum less than 30 days prior to planting; however, data are limited on their use. The objective of this study was to compare these herbicides to standard treatments for preplant efficacy and crop response 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 herbicides for residual weed control in sorghum. All herbicides were applied 14 days prior to sorghum planting using a tractor-mounted, compressed CO<sub>2</sub> sprayer delivering 19.4 GPA at 30 psi and 4.1 mph. Application and environmental information is shown in Table 1. Plots were 10 × 35 feet and arranged in a randomized complete block with four replications. Soil was a Ulysses silt loam with pH 7.9, containing 3.4% organic matter. Visual weed control was evaluated on June 27 and August 14, 2018. These dates were 26 and 74 days after sorghum planting (DAP), respectively. Sorghum yields were determined on October 29, 2018, by mechanically harvesting the middle two rows of each plot and adjusting grain weights to 14% moisture.

## Results and Discussion

Valor at 1 and 2 oz/a were the only treatments to control buffalobur less than 90% at 26 DAP (data not shown). However, no differences between herbicides occurred for buffalobur control at 74 DAP (83–100%). All herbicides controlled velvetleaf by 95% or more at 26 and 74 DAP (data not shown). SureStart II and Acuron generally provided the best control of Palmer amaranth, puncturevine, and green foxtail throughout the season (Table 2). Bicep Lite II Magnum (*S*-metolachlor/atrazine), Lumax EZ (*S*-meto-

lachlor/atrazine/mesotrione), and Degree Xtra (acetochlor/atrazine) also controlled Palmer amaranth and green foxtail well, regardless of rating date. Valor at 1 or 2 oz/a provided 70% or less puncturevine and green foxtail control at 74 DAP. Visual sorghum injury was minimal and transient in this study (data not shown). Although all herbicide-treated sorghum yielded more grain than the nontreated controls, yields were best when Acuron at 2.0 or 2.5 qt/a or Lumax EZ at 2.7 qt/a were used. These treatments yielded more grain than sorghum receiving Valor at 1 or 2 oz/a.

*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 date	May 13, 2018
Air temperature (°F)	66
Relative humidity (%)	74
Soil temperature (°F)	67
Wind speed (mph)	4 to 7
Wind direction	South-southeast
Soil moisture	Fair

**Table 2. Efficacy of herbicides applied 14 days preplant in sorghum**

Treatment	Rate	Palmer amaranth		Puncturevine		Green foxtail		Sorghum yield
		26 DAP <sup>a</sup>	74 DAP	26 DAP	74 DAP	26 DAP	74 DAP	
	per acre	----- % Visual -----						bu/a
Acuron	2.0 qt	98	93	95	85	93	80	89.3
Acuron	2.5 qt	100	95	99	90	94	90	90.6
Lumax EZ	2.7 qt	99	95	87	78	90	88	90.2
SureStart II	1.5 qt	99	95	100	91	98	90	86.1
Valor	1.0 oz	90	78	73	65	68	38	60.0
Valor	2.0 oz	89	88	75	70	70	53	74.8
Bicep Lite II Magnum	1.5 qt	100	90	80	68	89	85	80.7
Degree Xtra	2.25 qt	100	95	80	75	89	83	82.9
Untreated	---	---	---	---	---	---	---	40.7
LSD (0.05)		8	11	6	8	9	9	13.8

<sup>a</sup>DAP = days after sorghum planting.

# Comparison of Preemergence Herbicides for Residual Weed Control in Grain Sorghum

*R.S. Currie and P.W. Geier*

## Summary

Herbicides were studied to determine preemergence efficacy in grain sorghum. Velvetleaf and quinoa control did not differ between herbicides late in the season, and no treatment controlled puncturevine more than 81%. The three-way mixture of Callisto, atrazine, and Dual Magnum controlled Palmer amaranth and green foxtail as well as or better than any herbicide tested, whereas most herbicides controlled kochia 88% or more. Compared to the nontreated controls, all herbicides increased sorghum yield 46–146% except Callisto alone at 6 oz/a.

## Introduction

Early season weed control in grain sorghum is essential to preserve crop yield. With limited choices for postemergence weed control, especially grass control, an effective preemergence herbicide is vital to allow the sorghum time to emerge and become competitive. The objective of this study was to compare various herbicides for preemergence efficacy in grain sorghum.

## Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated various preemergence herbicide treatments for residual efficacy in grain sorghum. All herbicides were applied the day after sorghum planting using a tractor-mounted, compressed CO<sub>2</sub> sprayer delivering 19.4 GPA at 30 psi and 4.2 mph. Application and environmental information is shown in Table 1. To supplement natural weed populations, the experimental area was overseeded with quinoa to simulate common lambsquarters. Plots were 10 × 35 feet and arranged in a randomized complete block replicated four times. Soil was Ulysses silt loam with pH 7.9 and 3.4% organic matter. Visual weed control was determined on June 27 and August 15, 2018, which corresponded to 33 and 82 days after treatment (DAT). Sorghum yields were determined October 29, 2018, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 14.0% moisture.

## Results and Discussion

Velvetleaf control was 95–100% and 88–100% at 33 and 82 DAT, respectively, and did not differ among herbicides (data not shown). Bicep Lite II Magnum (*S*-metolachlor/atrazine) at 1.5 qt/a and Warrant (acetochlor) at 2.0 qt/a controlled quinoa 93 and 88% at 33 DAT, which was slightly less than herbicides that provided 100% control (data not shown). However, by 82 DAT, quinoa control did not differ between treatments. Palmer amaranth at 33 DAT was more than 88% controlled with Degree Xtra (acetochlor/atrazine), Halex GT (*S*-metolachlor/mesotrione/glyphosate) plus atrazine, and Callisto (mesotrione) plus atrazine plus Dual Magnum (*S*-metolachlor) (Table 2). By 82 DAT, only Halex GT plus atrazine and Callisto plus atrazine and Dual Magnum controlled Palmer amaranth 85% or more. These three-way mixes, along with Verdict

(saflufenacil/dimethenamid) plus Outlook (dimethenamid) generally provided the best puncturevine control at 33 and 82 DAT. However, puncturevine control did not exceed 81% with any treatment by 82 DAT. Warrant alone was the only treatment to provide less than 93% kochia control at 33 DAT. At 82 DAT, kochia control was 88% or more with all herbicides except Warrant, Dual Magnum, Stalwart C (metolachlor), and Callisto, each applied alone. Green foxtail control was less than 80% with atrazine alone, Callisto alone, and the tank mixture of Callisto and atrazine early in the season. Foxtail control declined by 82 DAT such that only Verdict plus Outlook and Callisto plus atrazine plus Dual Magnum were the only herbicides to provide 80% or more control. All herbicides except Callisto alone increased sorghum yield compared to the nontreated controls (Table 3). Yields were improved the most when Degree Xtra, Callisto plus atrazine plus Dual Magnum, and Halex GT plus atrazine were applied.

*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 date	May 25, 2018
Air temperature (°F)	72
Relative humidity (%)	67
Soil temperature (°F)	67
Wind speed (mph)	2 to 5
Wind direction	Southeast
Soil moisture	Good

**Table 2. Preemergence herbicides efficacy in sorghum**

Treatment	Rate	Palmer amaranth		Puncturevine		Kochia		Green foxtail	
		33 DAT <sup>a</sup>	82 DAT	33 DAT	82 DAT	33 DAT	82 DAT	33 DAT	82 DAT
	per acre	----- % Visual -----							
Atrazine	1.0 qt	68	45	60	45	100	88	65	58
Bicep II Magnum	1.6 qt	83	75	70	63	98	95	80	75
Bicep Lite II Magnum	1.5 qt	80	70	75	55	95	95	80	73
Degree Xtra	2.25 qt	88	80	73	68	99	88	83	75
Dual Magnum	1.5 pt	75	78	70	53	93	78	80	70
Stalwart C	1.47 pt	70	60	63	50	93	80	85	68
Warrant	2.0 qt	70	60	65	58	85	80	80	65
Verdict	10 oz	80	78	83	73	100	91	90	88
Outlook	10 oz								
Callisto	6.0 oz	70	60	63	58	100	75	65	55
Callisto	6.0 oz	83	73	85	60	100	98	74	68
Atrazine	1.0 qt								
Callisto	6.0 oz	96	96	88	80	100	99	80	80
Atrazine	1.0 qt								
Dual Magnum	1.5 pt								
Halex GT	6.0 pt	93	85	84	81	100	98	84	79
Nonionic surfactant	0.25%								
Atrazine	1.0 qt								
LSD (0.05)		12	12	7	10	9	12	10	8

<sup>a</sup>DAT is days after herbicide treatment.

**Table 3. Sorghum yield following preemergence herbicide application**

Treatment	Rate	Sorghum yield
	per acre	bu/a
Atrazine	1.0 qt	56.5
Bicep II Magnum	1.6 qt	72.7
Bicep Lite II Magnum	1.5 qt	69.1
Degree Xtra	2.25 qt	86.6
Dual Magnum	1.5 pt	70.3
Stalwart C	1.47 pt	55.5
Warrant	2.0 qt	56.4
Verdict	10 oz	76.3
Outlook	10 oz	
Callisto	6.0 oz	51.8
Callisto	6.0 oz	73.0
Atrazine	1.0 qt	
Callisto	6.0 oz	93.2
Atrazine	1.0 qt	
Dual Magnum	1.5 pt	
Halex GT	6.0 pt	78.8
Nonionic surfactant	0.25 %	
Atrazine	1.0 qt	
Untreated	---	37.9
LSD (0.05)		14.8

# Split Applications of Coyote and Lumax for Efficacy in Grain Sorghum

*R.S. Currie and P.W. Geier*

## Summary

In an effort to determine the efficacy of herbicide application timing in sorghum, full herbicide rates were applied 14 days preplant, and compared with split applications of half rates applied at two timings. Generally, weed control was best when half of the labeled rates were applied 14 days preplant followed by the other half preemergence, compared to full rates applied 14 days preplant. However, control of velvetleaf and common sunflower was excellent (95% or more) regardless of when the treatments were applied. Grain sorghum yields were similar among all herbicide treatments, and each treatment increased yield from 2 to 2.5-fold relative to the nontreated controls.

## Introduction

Applying preemergence herbicides prior to planting a crop may have several benefits. These applications may be done at a time when fieldwork is not as busy. Preemergence herbicides could also be mixed with burndown herbicides to control emerged weeds thus saving time and equipment costs. However, all preemergence herbicides have a limited persistence in the soil, and this length of weed control begins as soon as they are applied. The objective of this study was to compare full herbicide rates applied 14 days preplant to split applications of half rates applied at two timings, for efficacy in sorghum.

## Experimental Procedures

An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to compare single and sequential applications of mesotrione-based herbicides in grain sorghum. Treatments were applied at full rates 14 days preplant (DPP), or as split applications with half the rate applied 14 DPP and the other half applied preemergence (PRE). All treatments were applied using a tractor-mounted, compressed CO<sub>2</sub> sprayer delivering 19.4 GPA at 4.2 mph and 30 psi. Application and environmental information are shown in Table 1. Natural weed populations were supplemented by overseeding the experimental area with domesticated sunflower to simulate common sunflower. Plots were 10 × 35 feet and arranged in a randomized complete block with four replications. Soil was a Ulysses silt loam with pH 7.9 and 3.4% organic matter. Visual weed control was estimated on July 12 and August 13, 2018. These dates were 41 and 73 days after sorghum planting (DAP). Sorghum yields were determined on October 29, 2018, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 14.0% moisture.

## Results and Discussion

All herbicides controlled velvetleaf and common sunflower similarly (95% or more) at 41 and 73 DAT, and did not differ between treatments (data not shown). Palmer amaranth control at 41 DAP was greater than 95% when the split application of Coyote (*S*-metolachlor/mesotrione) plus atrazine was applied 14 DPP and PRE, and when the

full rate of Lumax (*S*-metolachlor/mesotrione/atrazine) was applied PRE (Table 2). The split application of Coyote plus atrazine was more efficacious at this date than the full rate applied PRE. By 73 DAP, the split application of the three-way premix Lumax controlled Palmer amaranth better than any of the 14 DPP treatments alone. The split application of Lumax controlled kochia better than the single preplant application of the same herbicide at 41 and 73 DAP, while no differences occurred between the single and split applications of Coyote plus atrazine. Both herbicide combinations evaluated in this study controlled puncturevine more effectively when applied as split applications compared to single applications. Although differences between herbicides and application timings were not significant for green foxtail control at 41 DAP, the split application of Lumax provided better foxtail control than either single application at 73 DAP. Grain sorghum yields were similar among the herbicides evaluated, but all herbicides increased yields 40 to 51 bu/a compared to the nontreated controls (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	14 days preplant	Preemergence
Application date	May 18, 2018	June 5, 2018
Air temperature (°F)	66	67
Relative humidity (%)	74	68
Soil temperature (°F)	67	69
Wind speed (mph)	4 to 6	5 to 8
Wind direction	South-southeast	South
Soil moisture	Fair	Good

**Table 2. Efficacy of Coyote and Lumax application timings in sorghum**

Treatment	Rate	Timing <sup>a</sup>	Palmer amaranth		Kochia		Puncturevine		Green foxtail	
			37 DAP <sup>b</sup>	69 DAP	37 DAP	69 DAP	37 DAP	69 DAP	37 DAP	69 DAP
	qt/a									
Coyote	2.0	14 DPP	86	81	88	78	63	48	81	73
Atrazine	0.65	14 DPP								
Coyote	1.0	14 DPP	98	89	95	85	78	68	88	78
Atrazine	0.325	14 DPP								
Coyote	1.0	PRE								
Atrazine	0.325	PRE								
Lumax	2.5	14 DPP	96	86	85	78	65	55	88	75
Lumax	1.25	14 DPP	94	95	96	90	73	75	78	85
Lumax	1.25	PRE								
LSD (0.05)			8	8	9	8	7	13	NS	8

<sup>a</sup>14 DPP = 14 days preplant. PRE = preemergence.

<sup>b</sup>DAP = days after sorghum planting.

# Efficacy of Sequential Herbicide Applications in Glufosinate- and Glyphosate-Resistant Corn

*R.S. Currie and P.W. Geier*

## Summary

To determine their efficacy in corn, this study compared two preemergence programs and sequential glufosinate (Interline) or glyphosate (Roundup PowerMax). Control of common sunflower and Russian thistle was excellent regardless of herbicide treatment. Preemergence herbicides alone provided no more than 78% johnsongrass control early in the season. By late season, only those plots receiving Roundup PowerMax had more than 85% johnsongrass control. However, corn yields did not differ among treatments, and all herbicides increased yield 70–97% relative to nontreated corn.

## Introduction

With the recent increase in glyphosate-resistant weeds, management practices that minimize resistance development have become even more important. Use of premixtures (multiple modes of action), tank mixtures, and non-glyphosate herbicides are increasingly needed to manage changing weed spectrums. The use of a strong residual herbicide program as well as control of escaped weeds is important. The objective of this study was to compare two preemergence programs and sequential glufosinate (Interline) or glyphosate (Roundup PowerMax) 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 Coyote (*S*-metolachlor/mesotrione) as a preemergence (PRE) or postemergence (POST) treatment with Interline (glufosinate) or Roundup PowerMax (glyphosate) for efficacy in corn. All plots also received a late postemergence (LPOST) application of Interline or Roundup PowerMax. Herbicides were applied using a tractor-mounted, compressed CO<sub>2</sub> sprayer delivering 19.4 GPA at 4.2 mph and 30 psi. Application, environmental, crop, and weed information is shown in Table 1. Natural weed populations were supplemented by overseeding the experimental area with domesticated sunflower to simulate common sunflower. Plots were 10 × 32 feet and arranged in a randomized complete block with four replications. Soil was a Beeler silt loam with 2.4% organic matter and pH 7.6. Visual weed control was determined on May 30, June 26, and August 2, 2018. These dates were 14 days after the PRE treatments (14 DA-A), and 13 and 50 days after the LPOST treatments (13 and 50 DA-C). Corn yields were determined on October 5, 2018, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 15.5% moisture.

## Results and Discussion

All herbicides controlled common sunflower and Russian thistle by 95% or more regardless of rating date, and did not differ between treatments (data not shown). At 14 DA-A, Coyote plus Tricor (metribuzin) and Tricor plus Satellite HydroCap (pen-

dimethalin) controlled johnsongrass similarly, 73–78%, when applied PRE (Table 2). Johnsongrass control was 95% or more with all herbicides except Tricor plus Satellite HydroCap PRE followed by Coyote plus Interline POST and Interline LPOST at 13 DA-C. By 50 DA-C, only those plots receiving Roundup PowerMax POST and LPOST had greater than 80% johnsongrass control. Grain yields were 50–69 bu/a greater with herbicide-treated corn compared to the nontreated controls, but yields did not differ between treatments (Table 2).

*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	Postemergence	Late postemergence
Application date	May 16, 2018	May 31, 2018	June 13, 2018
Air temperature (°F)	88	71	86
Relative humidity (%)	31	57	39
Soil temperature (°F)	71	65	76
Wind speed (mph)	2 to 5	2 to 4	3 to 5
Wind direction	South-southeast	Southwest	East-southeast
Soil moisture	Good	Good	Good
Corn			
Height (inch)	---	2 to 4	9 to 12
Leaves (number)	0	1 to 2	4 to 5
Johnsongrass			
Height (inch)	---	1 to 4	1 to 4
Density (plants/10 feet <sup>2</sup> )	0	5.0	2.5
Common sunflower			
Height (inch)	---	1 to 2	---
Density (plants/10 feet <sup>2</sup> )	0	1	0
Russian thistle			
Height (inch)	---	---	---
Density (plants/10 feet <sup>2</sup> )	0	0	0

**Table 2. Coyote, Interline, and Roundup PowerMax applications in corn**

Treatment	Rate	Timing <sup>a</sup>	Johnsongrass			Corn yield bu/a
			14 DA-A <sup>b</sup>	13 DA-C <sup>c</sup>	50 DA-C	
	per acre		----- % Visual -----			
Coyote	2.0 qt	PRE	78	95	79	131.1
Tricor	5.3 oz	PRE				
Interline	29 oz	POST				
Ammonium sulfate	2.0%	POST				
Interline	29 oz	LPOST				
Ammonium sulfate	2.0%	LPOST				
Coyote	2.0 qt	PRE	78	100	89	136.4
Tricor	5.3 oz	PRE				
Roundup PowerMax	24 oz	POST				
Ammonium sulfate	2.0%	POST				
Roundup PowerMax	24 oz	LPOST				
Ammonium sulfate	2.0%	LPOST				
Tricor	5.3 oz	PRE	78	89	76	122.2
Satellite HydroCap	3.0 pt	PRE				
Coyote	2.0 qt	POST				
Interline	29 oz	POST				
Nonionic surfactant	0.25%	POST				
Ammonium sulfate	2.0%	POST				
Interline	29 oz	LPOST				
Ammonium sulfate	2.0%	LPOST				
Tricor	5.3 oz	PRE	73	99	89	141.0
Satellite HydroCap	3.0 pt	PRE				
Coyote	2.0 qt	POST				
Roundup PowerMax	24 oz	POST				
Ammonium sulfate	2.0%	POST				
Roundup PowerMax	24 oz	LPOST				
Ammonium sulfate	2.0%	LPOST				
Untreated	---	---	---	---	---	71.8
LSD (0.05)			NS	5	10	29.2

<sup>a</sup>PRE = preemergence. POST = early postemergence. LPOST = late postemergence.

<sup>b</sup>DA-A = days after the preemergence treatments.

<sup>c</sup>DA-C = days after the late postemergence treatments.

# 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  
Crop Quest  
Dow AgroSciences  
Dragonline  
DuPont  
DuPont Pioneer  
FMC Corporation  
Garden City Farm Equipment  
Gowen  
Great Plains Canola Association

Hydro Resources  
Kansas Corn Commission  
Kansas Forage and Grassland Council  
Monsanto Company  
Nutrien  
Pioneer Hi-Bred  
Poole Chemical Co, Inc  
Premier Tillage  
Servi-Tech  
Sharp Brothers Seed  
Shield Ag Equipment  
Teeter Irrigation  
United Phosphorus, Inc  
United Sorghum Checkoff Program

## Grant Support

BASF Corp.  
Bayer CropScience  
Corteva AgriScience  
Deere and Company  
Dow AgroSciences  
DuPont Ag Products  
FMC Corporation  
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

Monsanto Company  
USDA Ogallala Water Coordinated  
Agriculture Project  
Sipcam Agro.  
Syngenta  
United Phosphorus, Inc.  
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 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 Vandever**  
*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 2019

This publication is intended for distribution at Southwest Research-Extension Center Field Day 2019. Full reports are also available at <http://newprairiepress.org/kaesrr>

Copyright 2019 Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Contents of this publication may be freely reproduced for educational purposes. All other rights reserved. In each case, give credit to the author(s), Field Day 2019, Southwest Research-Extension Center, Kansas State University, August 2019. Contribution no. 20-031-S from the Kansas Agricultural Experiment Station.

## **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 *2019 Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland*, Report of Progress 1148, available from the KSRE Bookstore, Umberger Hall, Kansas State University, or at: [www.bookstore.ksre.ksu.edu](http://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](http://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 2019**