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# Southwest Research-Extension Center Reports: Field Day 2017

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SOUTHWEST RESEARCH-EXTENSION CENTER

# Field Day 2017

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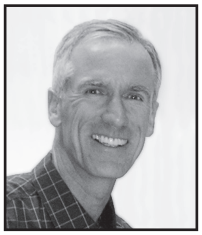

### *Robert (Bob) Gillen*
*Southwest Research-Extension Center Head*

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.

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

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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.

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Debra works with local agents on projects, program development, and training. Her research focuses on families, rural social systems, and community developmental processes.

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*Weed Scientist*

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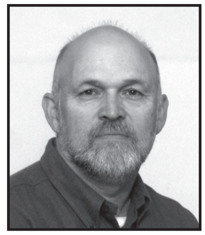
Randall joined the staff in 1991. His research focus is on weed control in corn.



### *Jeff Elliott*
*Research Farm Manager*

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

### *Anserd (AJ) Foster*
*Extension Specialist, Crops and Soils*

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

SOUTHWEST RESEARCH-EXTENSION CENTER

# Field Day 2017

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# Weather Information for Tribune

*D. Bond and J. Slattery*

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

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

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

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

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

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

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

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

Max = maximum.
Min = minimum.
Normal latest freeze (32°F) in spring: May 6. In 2016: May 2.
Normal earliest freeze (32°F) in fall: October 7. In 2016: October 7.
Normal frost-free (>32°F) period: 154 days. In 2016: 158 days.
Normal for precipitation and temperature is 30-year average (1981–2010) from National Weather Service.
Normal for latest freeze, earliest freeze, wind, and evaporation is 30-year average (1981–2010) from Tribune weather data.
* Normal for October wind and evaporation is 10-year average (2001–2010) from Tribune weather data; October was not included in annual totals.

# Weather Information for Garden City, 2016

*J. Elliott*

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

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

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

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

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

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

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

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

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

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

# Value of Fungicide Application in Wheat Production in Southwest Kansas

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

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

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

Previous research has reported variable results regarding the value of fungicide application in the Great Plains. In Kansas, several years of research have indicated that a single fungicide application to a susceptible variety, on average, could provide a 10% yield increase relative to the untreated control. To maximize the benefit of a fungicide application, producers should know the vulnerability of the variety to be treated. Susceptible varieties are more likely to provide a yield benefit compared to a variety with a moderate to high level of resistance. It is also important to pay attention to weather conditions and scouting reports within a field, a region, and even surrounding states to the south.

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

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

## Experimental Procedures

An experiment was established at the Southwest Research-Extension Center in Garden City, KS, in fall 2015. The design of the experiment was a randomized complete block design with three replications consisting of eleven fungicide application treatments and two wheat varieties: Oakley CL (highly resistant to stripe rust) and TAM 111 (highly susceptible to stripe rust). The experimental treatments are summarized in Table 1. The plots were seeded on September 29, 2015, at a seeding rate of 240 lb/a. The seeding rate was twice the recommended rate for irrigated wheat. This was a result of a problem with the drill, the plots were planted twice at the recommended 120 lb/a. The plots were 7.5-ft × 30-ft. The plots were fertilized with 100 lb of N at green up in March of 2016 and were sprayed with a mixture of 0.4 pint of Starane, 0.375 quart of MCPA, and 0.1 oz of Ally the first week of April for weed control. Fungicides were applied at 15 GPA with a $CO_2$ backpack sprayer when the flag leaf was fully emerged and the ligule was visible (Feekes, GS 9). A plot combine 5 ft wide was used to harvest 25 ft from each plot for yield. Subsample was collected from each plot to determine the test weight and moisture content. Yield was adjusted to 13% moisture.

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

## Results and Discussion

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

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

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

## Conclusion

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

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

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

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

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

NA- Not applicable.

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

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

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

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

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

NDVI_ B: measurement taken before fungicide application, NDVI_A: measurement taken 30 days after fungicide application.
LSD = least significant difference.
CV = coefficient of variation.
TAM = TAM 111.
OAK = Oakley CL.

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

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

(#), Negative return to treatment.
TAM = TAM 111.
OAK = Oakley CL.

# Determining Profitable Annual Forage Rotations

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

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

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

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

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

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

### *Study Objectives*

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

## Experimental Procedures

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

### *Treatments Included*

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

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

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

## Results and Discussion

### *Rotation Yield*

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

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

### *Crop Yield*

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

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

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

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

### *Soil Water*

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

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

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

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

| | Total treatment yield (dry matter lb/a) | | | | |
|---|---|---|---|---|---|
| Crop rotation | 2013 | 2014 | 2015 | 2016 | Average† |
| S-S | 4,262 | 7,426 | 10,244 | 8,025 | 7,489 |
| T/S-S-O (no-tillage) | 3,451 | 13,322 | 25,732 | 16,067 | 14,643 |
| T/S-S-O (min-tillage) | 4,020 | 20,130 | 28,742 | 18,404 | 17,824 |
| T/S-S-S-O (no-tillage) | 7,702 | 27,260 | 38,091 | 27,320 | 25,093 |
| T/S-S-S-O (min-tillage) | 8,896 | 30,266 | 36,394 | 23,831 | 24,847 |
| T-S-O‡ | * | * | 18,404 | 10,060 | 14,232 |
| | Annualized treatment yield (dry matter lb/a) | | | | |
| | 2013 | 2014 | 2015 | 2016 | Average† |
| S-S | 4,262 | 7,426 | 10,244 | 8,025 | 7,489 |
| T/S-S-O (no-tillage) | 1,150 | 4,441 | 8,577 | 5,356 | 4,881 |
| T/S-S-O (min-tillage) | 1,340 | 6,710 | 9,581 | 6,135 | 5941 |
| T/S-S-S-O (no-tillage) | 1,926 | 6,815 | 9,523 | 6,830 | 6,273 |
| T/S-S-S-O (min-tillage) | 2,224 | 7,566 | 9,099 | 5,958 | 6,212 |
| T-S-O | * | * | 6,135 | 3,353 | 4,744 |
| $LSD_{0.05}$§ | 1,508 | 3,038 | 1,488 | 801 | 938 |
| | Yield per harvest (dry matter lb/a) | | | | |
| | 2013 | 2014 | 2015 | 2016 | Average† |
| S-S | 4,262 | 7,426 | 10,244 | 8,025 | 7,489 |
| T/S-S-O (no-tillage) | 863 | 3,331 | 6,433 | 4,017 | 3,661 |
| T/S-S-O (min-tillage) | 1,005 | 5,032 | 7,185 | 4,601 | 4,456 |
| T/S-S-S-O (no-tillage) | 1,540 | 5,452 | 7,618 | 5,464 | 5,019 |
| T/S-S-S-O (min-tillage) | 1,779 | 6,053 | 12,131 | 4,766 | 6,183 |
| T-S-O | * | * | 3,681 | 3,353 | 3,517 |
| $LSD_{0.05}$§ | 1,323 | 2,566 | 1,331 | 693 | 791 |

† Average of years 2013-2016.
‡ T-S-O treatment started in 2015.
§ Forage sorghum (S), Continuous forage sorghum (S-S), Winter triticale/double crop forage sorghum (T/S), and spring oat (O).

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

| | | | 2013 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Dry matter yield | | Plant available water | | WUE | | PSE | |
| Rotation | Treatment | Crop | lb/a | $P < 0.05$ | Inches in 6 ft depth | $P < 0.05$ | lb/a inch$^{-1}$ | $P < 0.05$ | % | $P < 0.05$ |
| s-S[†‡] | 1 | Sorghum | 4,262.00 | a[¶] | 3.55 | ab | 591.60 | a | 0.38 | ac |
| t/S-s-o (no-tillage) | 2 | Sorghum | 1,385.40 | cd | 1.14 | dg | 319.00 | bd | -0.19 | bc |
| t/s-S-o (no-tillage) | 2 | Sorghum | 2,612.70 | bc | 1.70 | cg | 356.30 | bd | 0.09 | ac |
| t/S-s-o (min-tillage) | 3 | Sorghum | 972.00 | de | 0.93 | fg | 188.80 | ef | 0.71 | a |
| t/s-S-o (min-tillage) | 3 | Sorghum | 3,875.90 | ab | 3.08 | ac | 523.50 | ab | 0.17 | ac |
| t/S-s-s-o (no-tillage) | 4 | Sorghum | 1,199.30 | de | 0.39 | g | 273.20 | cd | 0.48 | ac |
| t/s-S-s-o (no-tillage) | 4 | Sorghum | 3,086.50 | ab | 2.86 | ad | 401.40 | ac | 0.26 | ac |
| t/s-s-S-o (no-tillage) | 4 | Sorghum | 3,955.00 | a | 2.55 | bf | 484.50 | ab | 0.14 | ac |
| t/S-s-s-o (min-tillage) | 5 | Sorghum | 9,61.30 | de | 1.11 | eg | 209.10 | ce | -0.35 | c |
| t/s-S-s-o (min-tillage) | 5 | Sorghum | 4,220.60 | a | 3.25 | ac | 602.20 | a | 0.16 | ac |
| t/s-s-S-o (min-tillage) | 5 | Sorghum | 3,989.50 | a | 2.89 | ac | 410.50 | ac | 0.25 | ac |
| t-S-o | 6 | Sorghum | *§ | * | * | * | * | * | | |
| T/s-s-o (no-tillage) | 2 | Triticale | 142.10 | de | 1.56 | cg | 31.50 | ef | -0.21 | bc |
| T/s-s-o (min-tillage) | 3 | Triticale | 188.40 | de | 1.10 | eg | 40.70 | ef | 0.02 | ac |
| T/s-s-s-o (no-tillage) | 4 | Triticale | 310.70 | de | 0.81 | g | 61.80 | ef | -0.03 | ac |
| T/s-s-s-o (min-tillage) | 5 | Triticale | 722.20 | de | 1.55 | cg | 163.20 | ef | 0.00 | ac |
| T-s-o | 6 | Triticale | * | * | * | * | * | * | | |
| t/s-s-O (no-tillage) | 2 | Oat | 0.00 | e | 2.68 | be | 0.00 | f | -0.06 | ac |
| t/s-s-O (min-tillage) | 3 | Oat | 0.00 | e | 3.16 | ac | 0.00 | f | 0.11 | ac |
| t/s-s-s-O (no-tillage) | 4 | Oat | 0.00 | e | 3.46 | ab | 0.00 | f | 0.48 | ac |
| t/s-s-s-O (min-tillage) | 5 | Oat | 0.00 | e | 4.49 | a | 0.00 | f | 0.61 | ab |
| t-s-O | 6 | Oat | * | * | * | * | * | * | * | * |
| LSD $_{0.05}$[§] | | | 1,321.70 | | 1.73 | | 206.83 | | 0.83 | |

*continued*

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

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

*continued*

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

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

*continued*

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

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

*continued*

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

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

† Crop within rotation is identified by capitalization.
‡ S is forage sorghum, T is triticale, and O is oat.
§ T-S-O treatment started in 2015.
¶ Means in columns followed by different letters are statistically different at $P \leq 0.05$.

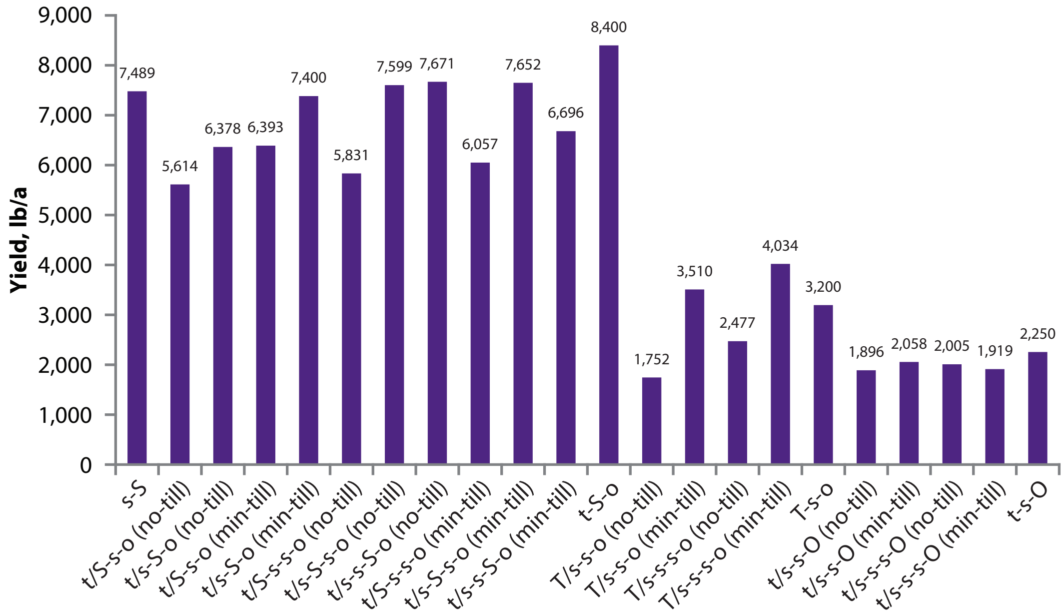


**Figure 1. Forage dry-matter yield for all crop rotations and phases averaged across years from 2013 to 2016. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop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

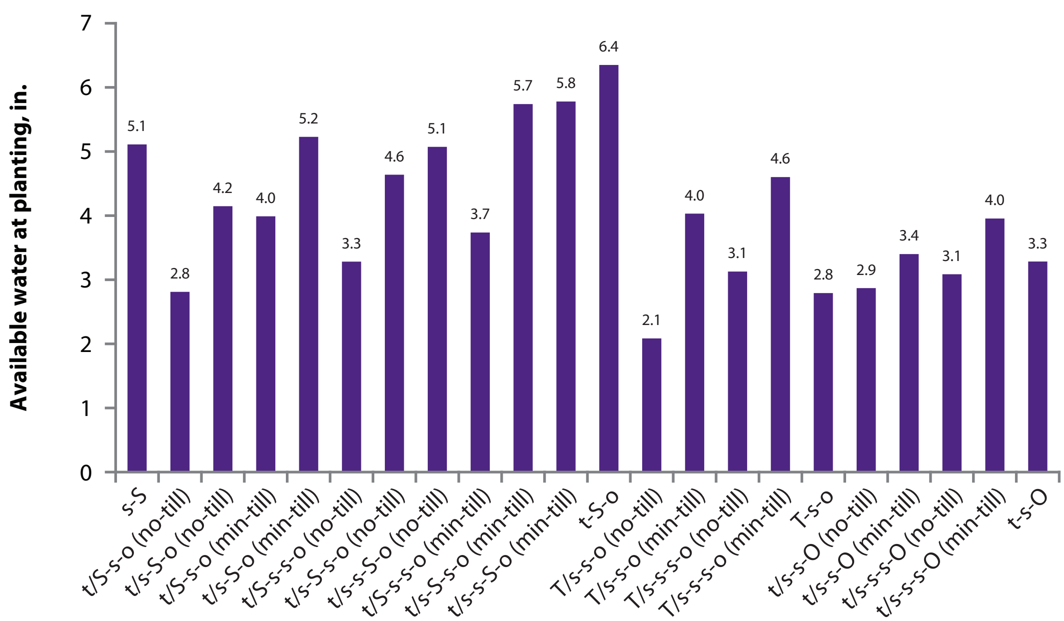


**Figure 2. Plant available water in a six-foot soil profile at planting for all crop rotations and phases averaged across years from 2013 to 2016. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum.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

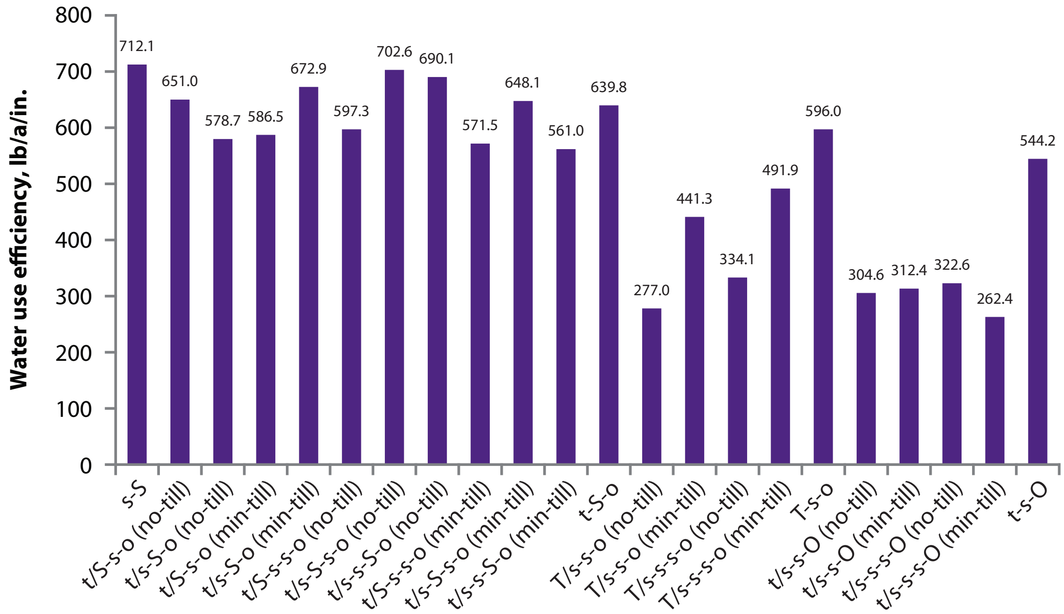


**Figure 3. Water use efficiency (WUE) [forage dry matter yield/((ending-beginning soil water content) + growing season precipitation)] for all crop rotations and phases averaged across years from 2013 to 2016. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization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

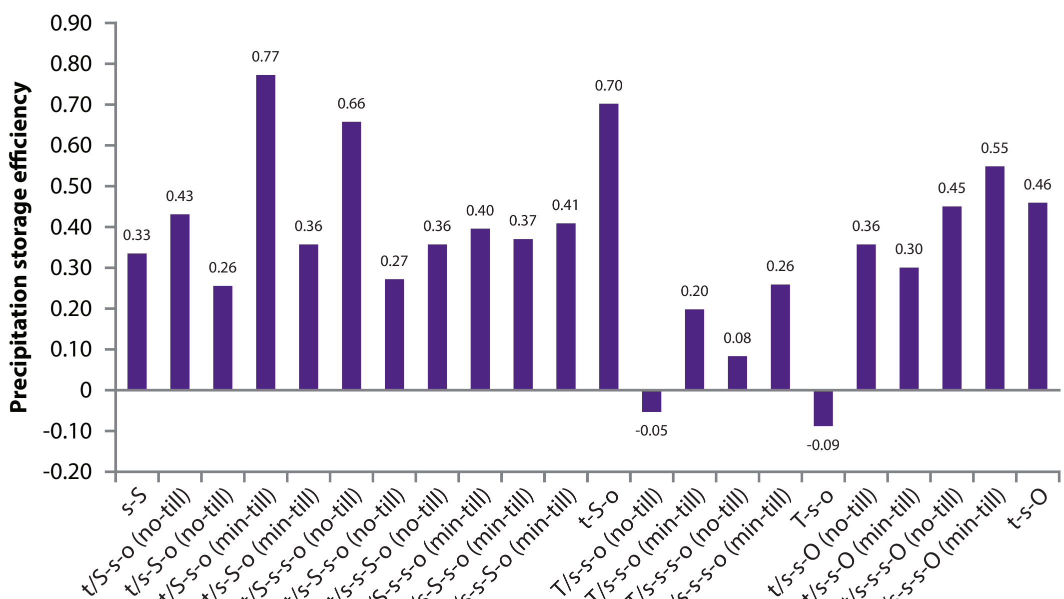


**Figure 4. Precipitation storage efficiency (PSE) [precipitation/(ending-beginning soil water content)] for the fallow period preceding the crop for all crop rotations and phases averaged across years from 2013 to 2016. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization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

# Integrated Grain and Forage Rotations

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


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

This study was started in 2013, with crops grown in-phase beginning in 2014. Grain crops were more sensitive to moisture stress than forage crops. Growing a double-crop forage sorghum after wheat reduced grain sorghum yield the second year, but never reduced second-year forage sorghum yield in the years of this study. If double-crop forage sorghum is profitable, it appears the cropping system can be intensified by growing second-year forage sorghum. Caution should be used when planting double-crop forage sorghum by evaluating soil moisture condition and precipitation outlook, since other research has found cropping intensity should be reduced in dry years. The "flex-fallow" concept could be used to make a decision on whether to plant double-crop forage sorghum to increase the chance of success. Importantly, this research showed forages are more tolerant to moisture stress than grain crops and the potential exists to increase cropping intensity by integrating forages into the rotation.


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

## Experimental Procedures
A study beginning in 2013 evaluated various integrated grain and forage rotations compared to a no-tillage wheat-grain sorghum-fallow rotation. All phases of the rotation were present every year and in-phase by 2014. A total of 11 crop rotations were evaluated. Beginning in 2013, the wheat/forage sorghum-grain sorghum-oat rotation was replaced with a wheat/forage sorghum-grain sorghum-fallow rotation since the no-fallow rotation tended to be too intensively cropped during dry years. The study design was a split-plot randomized complete block design with four replications; crop phase

(wheat-sorghum-fallow) was the main plot and alternative crop choices were the split-plot. Each split-plot was 30-ft wide and 120-ft long.

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

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

Volumetric soil moisture content was measured at planting and harvest of winter wheat, grain sorghum, forage sorghum, spring oat, or fallow using a Giddings Soil Probe by 1-ft increments to a 6-ft soil depth. In addition, volumetric soil content was measured in the 0-3-in. soil depth at wheat planting to quantify moisture in the seed planting depth. Grain yield was corrected for moisture content, and test weight was measured using a grain analysis computer (GAC 2100, Dickey-John). Seed weight was determined from a 1,000-seed count using a seed counter computer (801, 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 were grown in place of one another in the rotation (Table 2). Wheat yields were reduced when oat was grown in place of fallow. Previous research found growing oats in place of fallow reduced wheat yields when wheat yield potential was less than 50 bu/a. A flex-crop was grown in 2013, but not 2014 or 2015. Dry conditions developed soon after planting a flex-crop in 2013, and growing a flex-crop in place of fallow reduced 2014 wheat yield 67%. Dry fall conditions and rabbit feeding killed the wheat crop in 2016 and there was no yield that year.

### *Grain Sorghum*

Grain sorghum yield was highly correlated with plant available moisture at planting, which explained 44% of the variability in grain yield (Figure 1). Approximately 7.8 bushels were grown for every acre-inch of plant available water at planting. Plant available moisture was highest when forage sorghum was not double-cropped between wheat and grain sorghum (Table 3), and tended to be higher when nothing was grown in the fallow phase ahead of winter wheat. Growing double-crop forage sorghum ahead of grain sorghum reduced grain sorghum yield 61% in 2014, 38% in 2015, and 20% in 2016. Growing a forage sorghum crop after wheat reduced the water use efficiency of the subsequent grain sorghum crop each year but did not affect precipitation storage efficiency. Growing a forage sorghum crop reduced the test weight and seed weight of grain sorghum in 2015 only.

### *Forage Sorghum*

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

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

Surprisingly, second-year forage sorghum yields following double-crop forage sorghum were similar to full-season forage sorghum following wheat with fallow between wheat harvest and sorghum planting (Table 4). Yet forage sorghum planted after double-crop forage sorghum had an average of 3 inches less soil moisture compared to forage sorghum planted after wheat with a fallow period between crops. In dry years this difference in plant available soil water may result in yield differences, but it did not affect yield in this study. The yield plateau of a forage crop is lower than a grain crop, which might explain why there was no yield penalty for second-year forage sorghum grown after either fallow or double-crop forage sorghum. These results suggest that as long as the benefits of growing a double-crop forage sorghum crop exceeded costs, an extra forage sorghum crop could be grown in the rotation. A partial enterprise analysis of this phase of the rotation only indicated double-crop forage sorghum yield needs to be at least 30% of full-season forage sorghum, or at least 2,000 lb/a, for a double-crop forage sorghum crop that is grazed to be profitable. The additional variable expenses of growing double-crop forage sorghum would be around $25.00/a.

### *Spring Oat*

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

## Conclusions

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

Grain sorghum yield was more sensitive to moisture stress than forage sorghum. Growing a double-crop forage sorghum after wheat reduced grain yield 20 to 60% the second year but never reduced forage sorghum yield in the years of this study. However, in low precipitation years, full-season forage sorghum yields might be more negatively impacted than they were in this study. Moisture conditions affected double-crop forage sorghum yields more than full-season forage sorghum, and yields were reduced up to 70% compared to full-season yields. As long as double-crop forage sorghum is profitable, which we identified to be around 2,000 lb/a yield when grazed, it appears the cropping system can be intensified without negatively affecting second-year forage sorghum yield. Caution should be used when planting double-crop forage sorghum, by evaluating soil moisture condition and precipitation outlook, since other research has found cropping intensity should be reduced in dry years. The “flex-fallow” concept could be used to make a decision on whether or not to plant double-crop forage sorghum to increase the chance of success. Of important note, this research showed forages are more tolerant to moisture stress than grain crops, and the potential exists to increase cropping intensity by integrating forages into the rotation.

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

| No. | Crop rotation | Abbreviation |
|---|---|---|
| 1 | Wheat-grain sorghum-flex-fallow | ww-gs-fx |
| 2 | Wheat-grain sorghum-fallow | ww-gs-fl |
| 3 | Wheat/forage sorghum-forage sorghum-oat | ww/fs-fs-o |
| 4 | Wheat-forage sorghum-oat | ww-fs-o |
| 5[†] | Wheat/forage sorghum-grain sorghum-oat | ww/fs-gs-o |
| 6 | Wheat-grain sorghum-oat | ww-gs-o |
| 7 | Wheat-forage sorghum-oat (tilled) | ww-fs-o(t) |
| 8 | Wheat-forage sorghum-fallow | ww-fs-fl |
| 9 | Wheat-forage sorghum-flex-fallow | ww-fs-fx |
| 10 | Wheat/forage sorghum-forage sorghum-flex-fallow | ww/fs-fs-fx |
| 11 | Wheat/forage sorghum-grain sorghum-flex-fallow | ww/fs-gs-fx |
| 12[†] | Wheat/forage sorghum-grain sorghum-fallow | ww/fs-gs-fl |

† Beginning in 2013, treatment 12 replaced treatment 5.

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

| | | 2014 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Yield | | Plant available water | | WUE | | PSE | |
| Rotation[†] | Crop | bu/a | $P < 0.05$ | Inches in 6 ft depth | $P < 0.05$ | bu/a inch$^{-1}$ | $P < 0.05$ | % | $P < 0.05$ |
| WW-gs-fx[¶] | WW | 2.0 | bc | 2.4 | ab | 0.13 | bc | 0.27 | ab |
| WW-gs-fl | WW | 6.0 | a | 3.8 | ab | 0.38 | a | 0.19 | b |
| WW/fs-fs-o | WW | 1.0 | c | 3.0 | ab | 0.05 | c | 0.30 | ab |
| WW-fs-o | WW | 0.1 | c | 2.9 | ab | 0.01 | c | 0.27 | ab |
| WW/fs-gs-o | WW | 0.4 | c | 1.4 | B | 0.03 | c | 0.21 | b |
| WW-gs-o | WW | 0.2 | c | 2.5 | ab | 0.01 | c | 0.24 | b |
| WW-fs-o(t) | WW | 2.3 | bc | 4.1 | a | 0.13 | bc | 0.43 | a |
| WW-fs-fl | WW | 5.1 | ab | 3.7 | ab | 0.27 | ab | 0.22 | b |
| WW-fs-fx | WW | * | * | * | * | * | * | * | * |
| WW/fs-fs-fx | WW | * | * | * | * | * | * | * | * |
| WW/fs-gs-fx | WW | * | * | * | * | * | * | * | * |
| LSD | | 3.1 | | 2.6 | | 0.20 | | 0.18 | |

*continued*

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

| | | 2015 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Yield | | Plant available water | | WUE | | PSE | |
| Rotation[†‡] | Crop | bu/a | $P < 0.05$ | Inches in 6 ft depth | $P < 0.05$ | bu/a | $P < 0.05$ | % | $P < 0.05$ |
| WW-gs-fx[¶] | WW | 16.1 | a[§] | 4.7 | ab | 1.11 | a | * | * |
| WW-gs-fl | WW | 14.6 | ab | 5.4 | a | 0.98 | ab | 0.20 | a |
| WW/fs-fs-o | WW | 6.4 | de | 1.9 | d | 0.45 | c | 0.12 | a |
| WW-fs-sg | WW | 6.8 | cde | 2.8 | bcd | 0.58 | bc | 0.17 | a |
| WW/fs-gs-o | WW | 8.1 | cde | 1.6 | d | 0.64 | bc | 0.16 | a |
| WW-gs-o | WW | 8.0 | cde | 2.3 | cd | 0.59 | bc | 0.10 | a |
| WW-fs-o(t) | WW | 7.7 | cde | 2.4 | cd | 0.57 | bc | 0.12 | a |
| WW-fs-fl | WW | 10.3 | bcd | 4.6 | ab | 0.67 | bc | * | * |
| WW-fs-fx | WW | 11.8 | abc | 4.1 | abc | 0.93 | ab | 0.88 | a |
| WW/fs-fs-fx | WW | 4.8 | e | 2.7 | bcd | 0.34 | c | 0.12 | a |
| WW/fs-gs-fx | WW | 8.1 | cde | 1.6 | d | 0.64 | bc | 0.16 | a |
| LSD | | 5.4 | | 2.1 | | 0.44 | | 0.15 | |

| | | Average | | | |
|---|---|---|---|---|---|
| | | Yield | Plant available water | WUE | PSE |
| | | bu/a | Inches in 6 ft depth | bu/a | % |
| WW-gs-fx | WW | 9.1 | 3.6 | 0.62 | 0.27 |
| WW-gs-fl | WW | 10.3 | 4.6 | 0.68 | 0.20 |
| WW/fs-fs-o | WW | 3.7 | 2.5 | 0.25 | 0.21 |
| WW-fs-sg | WW | 3.5 | 2.8 | 0.29 | 0.22 |
| WW/fs-gs-o | WW | 4.2 | 1.5 | 0.33 | 0.18 |
| WW-gs-o | WW | 4.1 | 2.4 | 0.30 | 0.17 |
| WW-fs-o(t) | WW | 5.0 | 3.2 | 0.35 | 0.28 |
| WW-fs-fl | WW | 7.7 | 4.2 | 0.47 | 0.22 |
| WW-fs-fx | WW | 11.8 | 4.1 | 0.93 | 0.88 |
| WW/fs-fs-fx | WW | 4.8 | 2.7 | 0.34 | 0.12 |
| WW/fs-gs-fx | WW | 8.1 | 1.6 | 0.64 | 0.16 |
| LSD | | | | | |

† WW is winter wheat, fs is forage sorghum, gs is grain sorghum, fl is fallow, fx is flex-fallow, fx(t) is flex-fallow with summer tillage, and o is spring oat.

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

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

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

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

| | | 2014 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Yield | | Test weight | | Seed weight | | PAW | | WUE | | PSE | |
| Rotation[†] | Crop | bu/a | $P < 0.05$ | lb/bu | $P < 0.05$ | g/1,000 seed | $P < 0.05$ | Inches in 6 ft depth | $P < 0.05$ | bu/a inch$^{-1}$ | $P < 0.05$ | % | $P < 0.05$ |
| ww-GS-fx[¶] | GS | 47.5 | a[§] | 58.0 | a | 21.3 | a | 4.5 | a | 2.96 | a | 0.22 | a |
| ww-GS-fl | GS | 49.5 | a | 59.1 | a | 22.6 | a | 4.4 | a | 2.99 | a | 0.18 | a |
| ww/fs-GS-o[‡] | GS | 17.8 | b | 57.7 | a | 21.1 | a | 4.2 | a | 1.07 | b | 0.31 | a |
| ww-GS-o | GS | 39.4 | ab | 57.7 | a | 22.7 | a | 6.4 | a | 2.16 | ab | 0.36 | a |
| ww/fs-GS-fx | GS | 17.8 | b | 57.7 | a | 21.1 | a | 4.2 | a | 1.07 | b | 0.31 | a |
| ww/fs-GS-fl | GS | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| LSD | | 23.2 | | 2.2 | | 2.0 | | 3.4 | | 1.26 | | 0.28 | |

| | | 2015 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Yield | | Test weight | | Seed weight | | PAW | | WUE | | PSE | |
| | | lb/a | $P < 0.05$ | lb/bu | $P < 0.05$ | g/1,000 seed | $P < 0.05$ | Inches in 6 ft depth | $P < 0.05$ | lb/a inch$^{-1}$ | $P < 0.05$ | % | $P < 0.05$ |
| ww-GS-fx[¶] | GS | 96.4 | ab | 60.8 | ab | 26.3 | a | 7.3 | ab | 5.53 | a | 0.27 | a |
| ww-GS-fl | GS | 108.9 | a | 60.9 | a | 27.0 | a | 9.0 | a | 5.91 | a | 0.35 | a |
| ww/fs-GS-o[‡] | GS | 59.4 | c | 59.8 | b | 21.6 | b | 6.0 | b | 3.68 | b | 0.25 | a |
| ww-GS-o | GS | 84.1 | b | 60.3 | ab | 25.8 | a | 7.9 | ab | 4.83 | ab | 0.34 | a |
| ww/fs-GS-fx | GS | 59.4 | c | 59.8 | b | 21.6 | b | 6.0 | b | 3.68 | b | 0.25 | a |
| ww/fs-GS-fl | GS | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| LSD | | 19.2 | | 1.0 | | 3.5 | | 2.4 | | 1.20 | | 0.10 | |

*continued*

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

| | | 2016 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Yield | | Test weight | | Seed weight | | PAW | | WUE | | PSE | |
| Rotation†* | Crop | lb/a | $P < 0.05$ | lb/bu | $P < 0.05$ | g/1,000 seed | $P < 0.05$ | Inches in 6 ft depth | $P < 0.05$ | lb/a inch$^{-1}$ | $P < 0.05$ | % | $P < 0.05$ |
| ww-GS-fx¶ | GS | 58.4 | ab§ | 58.8 | a | 58.8 | a | 7.2 | a | 3.19 | a | 0.22 | a |
| ww-GS-fl | GS | 64.6 | a | 59.2 | a | 59.2 | a | 7.4 | a | 3.47 | a | 0.21 | a |
| ww/fs-GS-o‡ | GS | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ww-GS-o | GS | 55.7 | ab | 59.6 | a | 59.6 | a | 6.2 | a | 3.11 | a | 0.18 | a |
| ww/fs-GS-fx | GS | 51.0 | ab | 59.1 | a | 59.1 | a | 3.9 | b | 3.08 | a | 0.22 | a |
| ww/fs-GS-fl | GS | 43.7 | b | 58.6 | a | 58.6 | a | 3.2 | b | 2.64 | a | 0.19 | a |
| LSD | | 17.7 | | 2.4 | | 2.4 | | 1.5 | | 1.05 | | 0.13 | |

| | | Average | | | | | |
|---|---|---|---|---|---|---|---|
| | | Yield | Test weight | Seed weight | PAW | | PSE |
| | | lb/a | lb/bu | g/1,000 seed | Inches in 6 ft depth | lb/a inch$^{-1}$ | % |
| ww-GS-fx¶ | GS | 67.4 | 59.2 | 35.48 | 6.3 | 3.89 | 0.24 |
| ww-GS-fl | GS | 74.4 | 59.8 | 36.29 | 7.0 | 4.12 | 0.25 |
| ww/fs-GS-o‡ | GS | 38.6 | 58.7 | 21.32 | 5.1 | 2.38 | 0.28 |
| ww-GS-o | GS | 59.7 | 59.2 | 36.02 | 6.9 | 3.37 | 0.29 |
| ww/fs-GS-fx | GS | 42.7 | 58.8 | 33.89 | 4.7 | 2.61 | 0.26 |
| ww/fs-GS-fl | GS | 43.7 | 58.6 | 58.55 | 3.2 | 2.64 | 0.19 |
| LSD | | | | | | | |

† WW is winter wheat, fs is forage sorghum, GS is grain sorghum, and o is spring oat.
‡ Beginning in 2013, treatment 12 replaced treatment 5.
* Data are for the abbreviated crop phase in large caps.
§ Means in columns followed by different letters are statistically different at $P \leq 0.05$.
¶ Flex-fallow was planted in 2012, 2013, and 2016.

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

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

*continued*

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

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

*continued*

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

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

*continued*

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

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

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

‡ Beginning in 2013, treatment 12 replaced treatment 5.

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

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

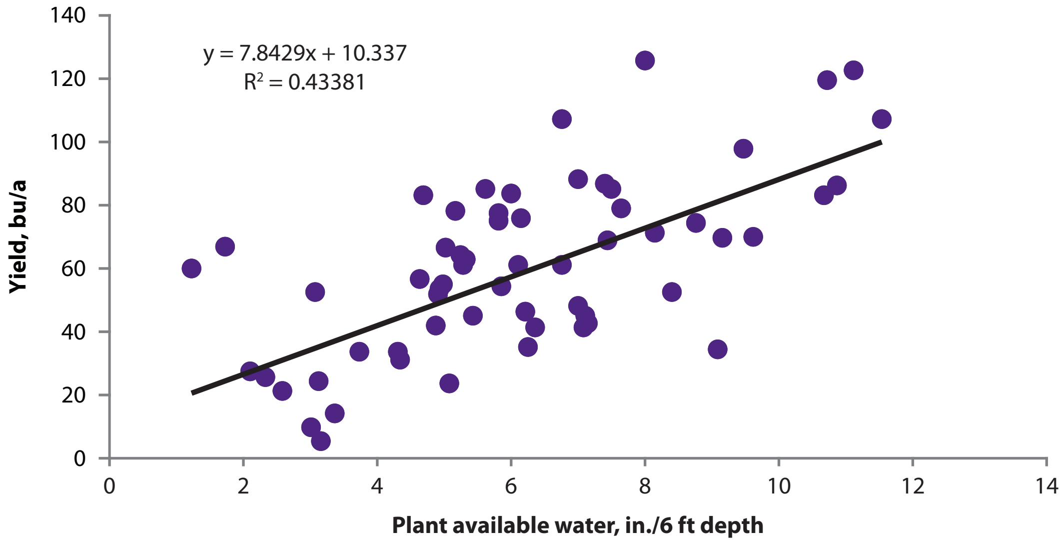


**Figure 1. Grain sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2016.**

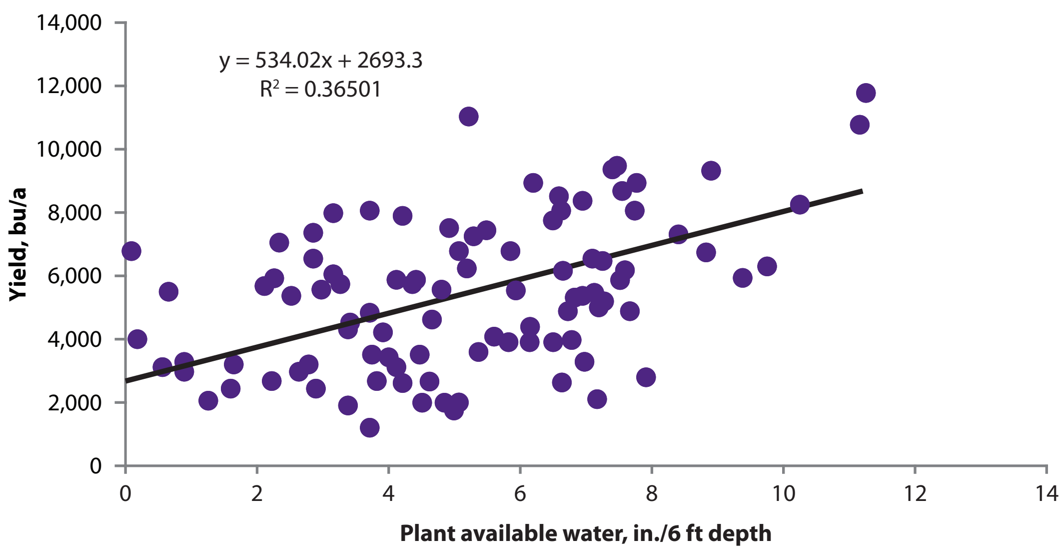


**Figure 2. Forage sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2016.**

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

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

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

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

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

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

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

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

## Results and Discussion

### *Winter Triticale*

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

### *Spring Triticale*

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

### *Forage Sorghum*

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

## References

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

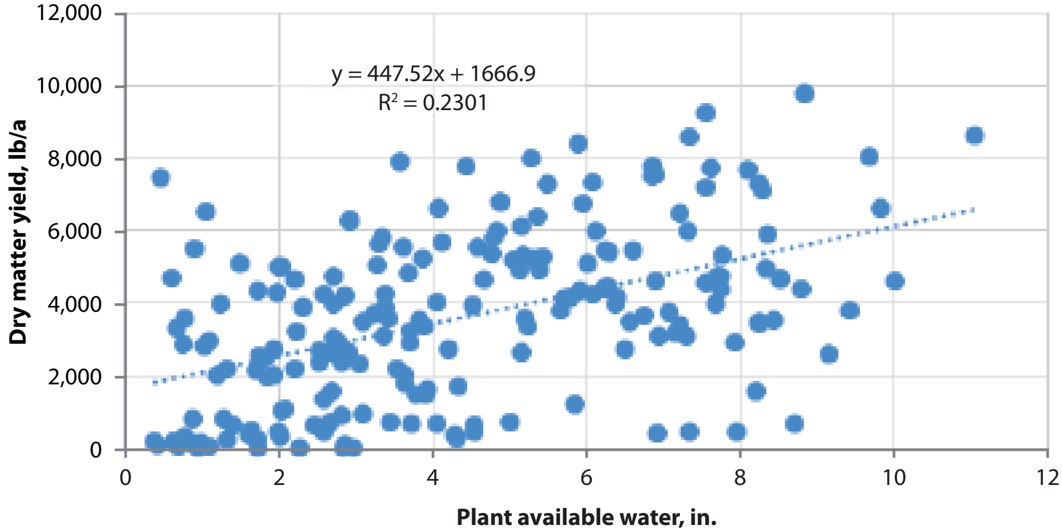


**Figure 1. Winter triticale yield response to plant available water at planting.**

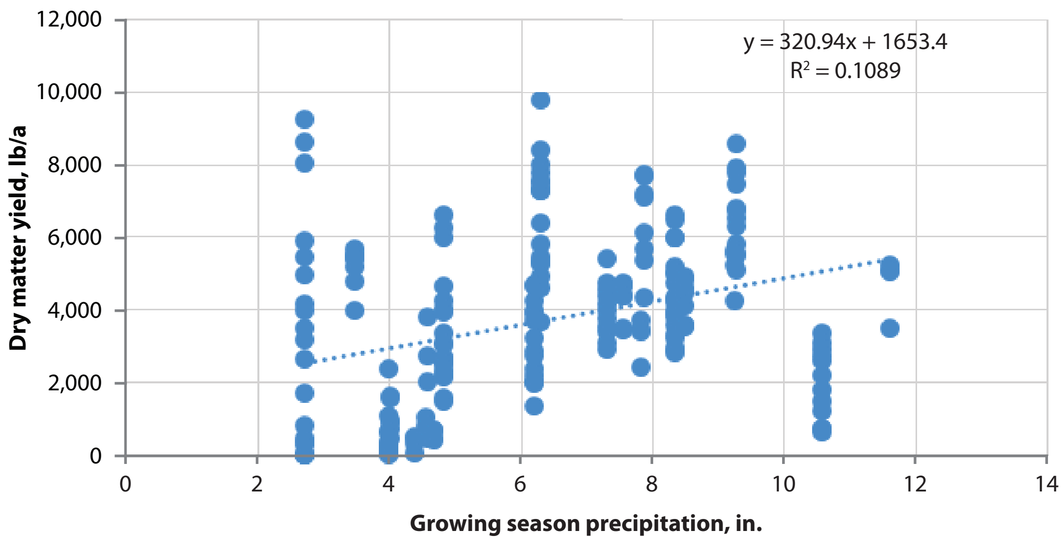


**Figure 2. Winter triticale yield response to growing season precipitation.**

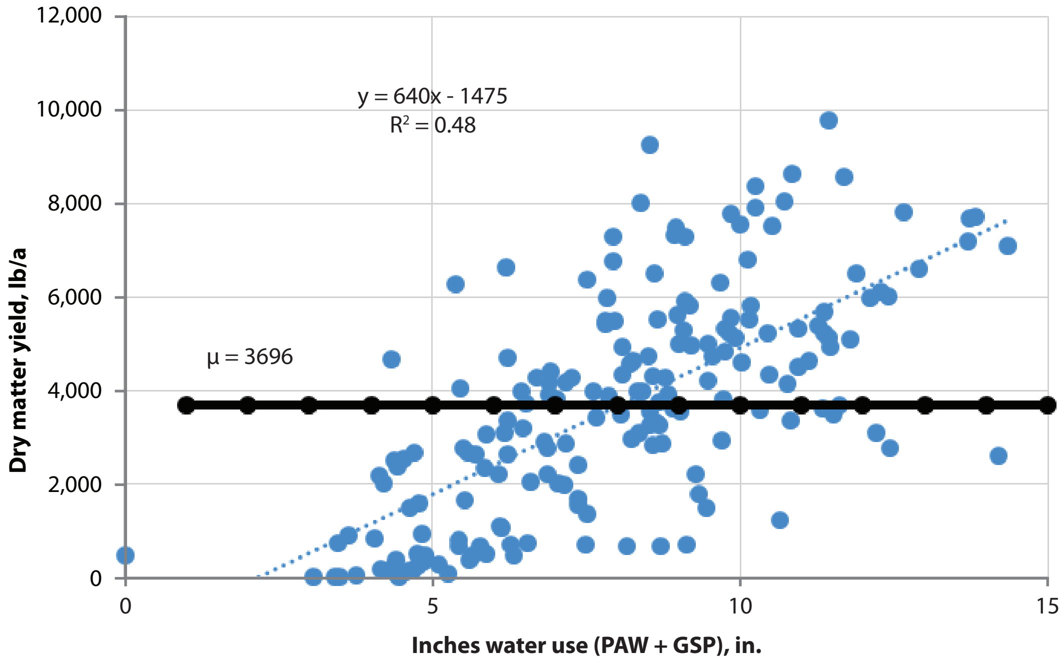


**Figure 3. Winter triticale yield response to water use (soil water plus growing season precipitation) and average yield (bold line) across the study period. PAW = plant available water at planting. GSP = growing season precipitation.**

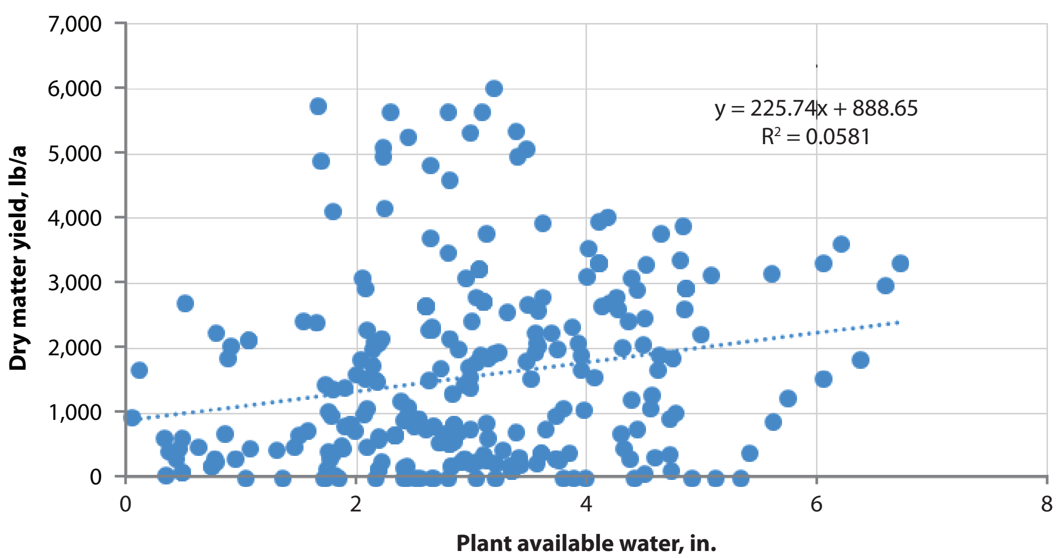


**Figure 4. Spring triticale yield response to plant available water at planting.**

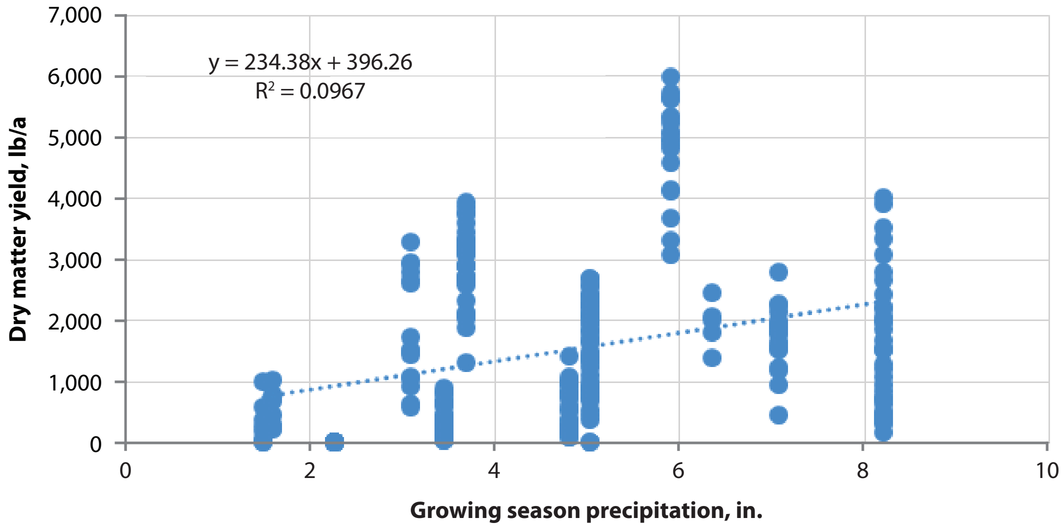


**Figure 5. Spring triticale yield response to growing season precipitation.**

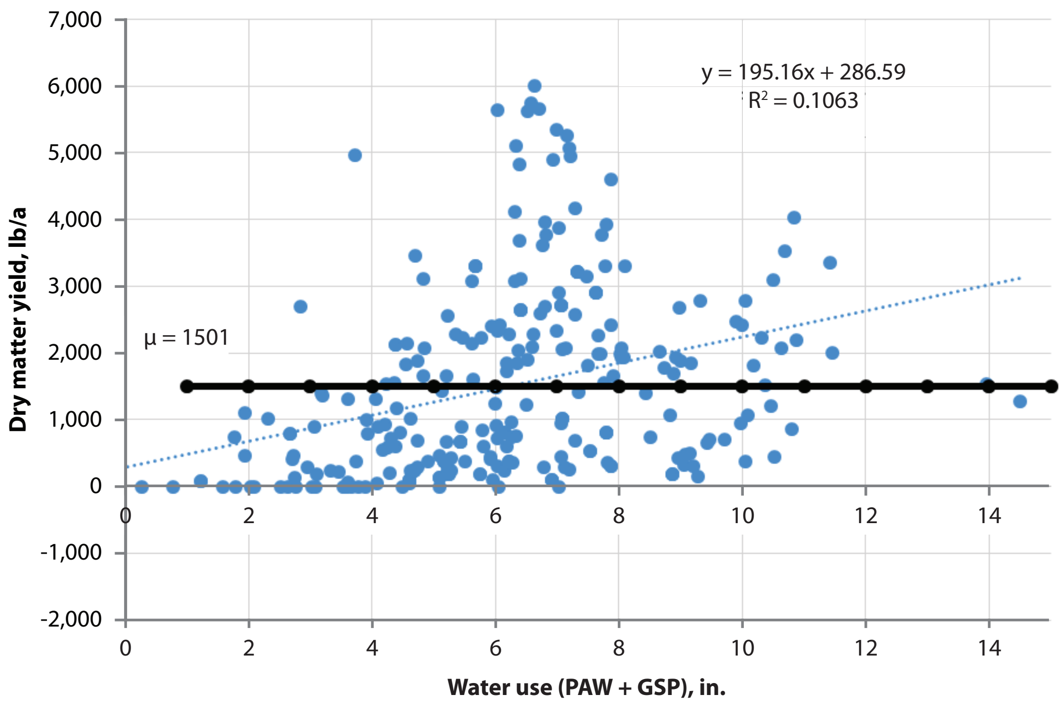


**Figure 6. Spring triticale yield response to water use (soil water plus growing season precipitation) and average yield (bold line) across the study period. PAW = plant available water at planting. GSP = growing season precipitation.**

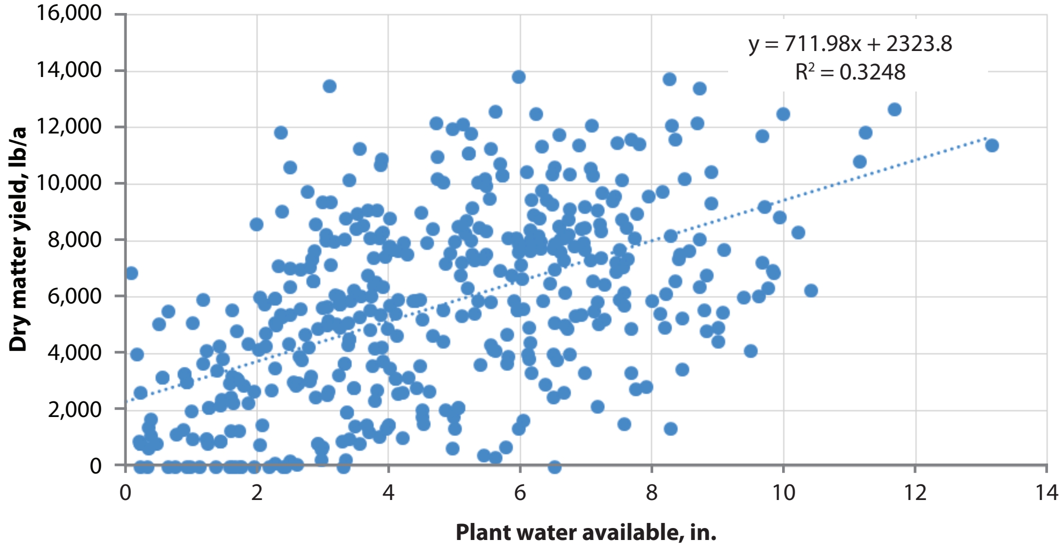


**Figure 7. Forage sorghum yield response to plant available water at planting.**

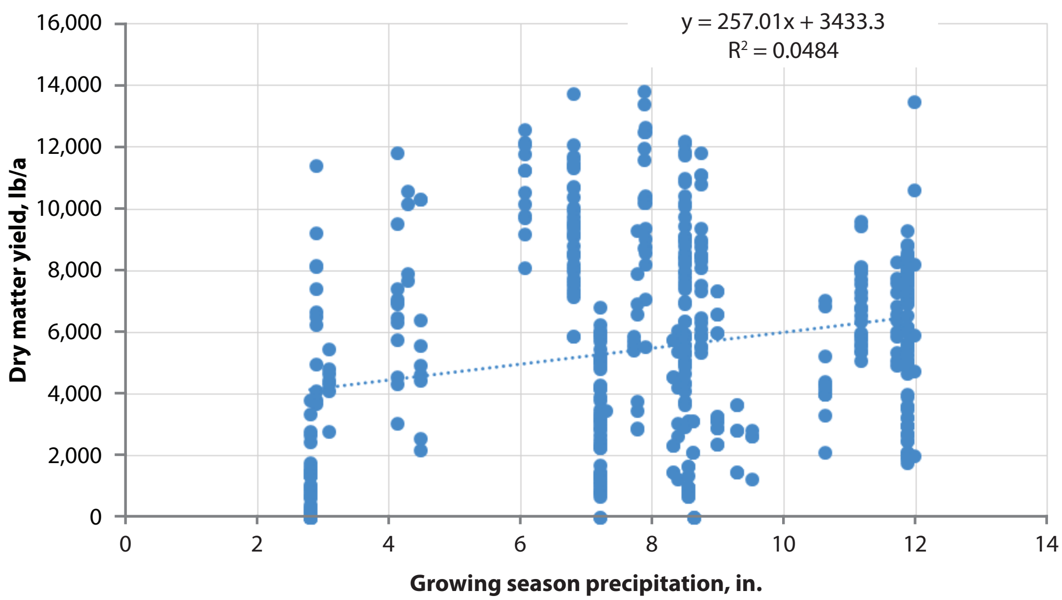


**Figure 8. Forage sorghum yield response to growing season precipitation.**

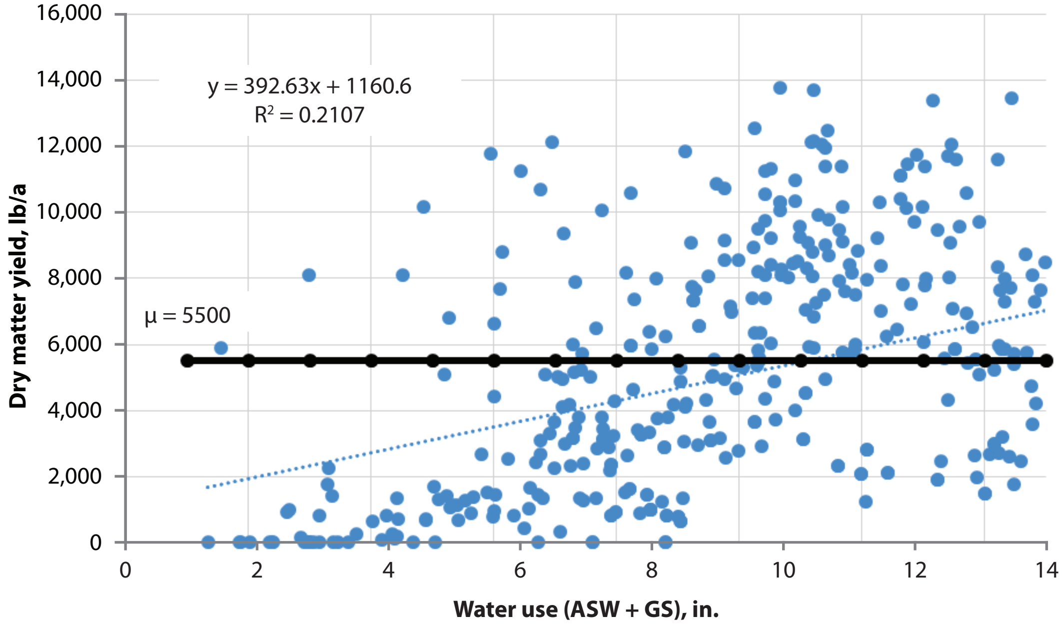


**Figure 9. Forage sorghum yield response to water use (soil water plus growing season precipitation) and average yield (bold line) across the study period.**

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

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

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

## Introduction
Interest in replacing fallow with a cash crop or cover crop has necessitated research on soil, water, and wheat yields following a shortened fallow period. Fallow stores moisture, which helps stabilize crop yields and reduces the risk of crop failure; however, only 25 to 30% of the precipitation received during the fallow period of a no-tillage wheat-fallow rotation is stored. The remaining 75 to 70% of precipitation is lost, primarily due to evaporation. Moisture storage in fallow is more efficient earlier in the fallow period, when the soil is dry, and during the winter months when the evaporation rate is lower. It may be possible to increase cropping intensity without reducing winter wheat yield. This study evaluated replacing part of the fallow period with a cover, annual forage, or short-season grain crop, measuring plant available water at wheat planting and winter wheat yield.

## Experimental Procedures

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

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

In experiment 2 (2012-2014) spring crops were grown the year following grain sorghum. Grain sorghum is harvested late in the year and most years does not allow growing a winter crop during the fallow period. Spring planted treatments included spring grain pea, spring pea plus spring oat (*Avena sativa* L.), spring pea plus spring triticale, spring oat, spring triticale, and a six species "cocktail" mixture of spring oat, spring triticale, spring pea, buckwheat var. Mancan (*Fagopyrum esculentum* Moench), purple top turnip (*Brassica campestris* L.), and forage radish (*Raphanus sativus* L.). In addition, spring grain pea, spring oat, and safflower (*Carthamus tinctorius* L.) were grown for grain. Safflower was only grown in 2012, and that treatment was replaced with spring oat grown for grain beginning in 2013. Additional treatments initiated in 2013 were yellow sweetclover planted with grain sorghum and allowed to grow into the fallow year, daikon radish (*Brassica rapa* L.) planted with winter wheat in a wheat-grain sorghum-fallow rotation, shogoin turnip (*Raphanus sativus* L.) planted with winter wheat in a wheat-grain sorghum-fallow rotation, and spring oats or a cocktail planted in a "flex-fallow" system (Table 1). The flex-fallow treatment was planted when a minimum of 4 inches of PAW (12 inches in 2013) was determined using a Paul Brown moisture probe at spring planting; otherwise, the treatment was left fallow. The flex-fallow treatment was intended to take advantage of growing a crop during the fallow period in wet years and fallowing in dry years. Crops grown for grain were grain peas, spring oat, and triticale. Crops grown in place of fallow were compared with a wheat-grain sorghum-fallow rotation for a total of 16 treatments (Table 1). The study design was a split-split-plot randomized complete block design with four replications; crop phase (wheat-grain sorghum-fallow) was the main plot, fallow replacement was the split-plot, and fallow replacement method (forage, grain, or cover) was the split-split-plot. The main plot was 330-ft wide and 120-ft long, the split-plot was 30-ft wide and 120-ft long, and the split-split plot was 15-ft wide and 120-ft long.

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

Volumetric soil moisture content was measured at planting and harvest of winter wheat, grain sorghum, and fallow using a Giddings Soil Probe by 1-ft increments to a 6-ft soil depth. In addition, volumetric soil content was measured in the 0-3-in. soil depth at wheat planting to quantify moisture in the seed planting depth. Grain yield was adjusted to 13.5% moisture content, and test weight was measured using a grain analysis computer. Grain samples were analyzed for nitrogen content.

## Results and Discussion

### *Year*

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

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

### *Winter Wheat Yield in Wheat-Grain Sorghum-Fallow*

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

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

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

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

### *Grain Sorghum Yield in Wheat-Grain Sorghum-Fallow*

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

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

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

### *Cover vs. Annual Forage*

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

### *Conclusions*

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

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

## References

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

**Table 1. Fallow treatments 2007-2016**

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

† Oat, triticale, pea, buckwheat, forage brassica and forage radish.
†† Flex: Plant when soil moisture is 14 inches (12 inches in 2013) or > and precipitation outlook is neutral or favorable. Flex-fallow was planted in 2013 and 2016, but was not planted in 2014 and 2015.
x = treatment present. - = treatment not present.

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

| Year | Month | Precipitation | Precipitation average† (30 yr) |
|---|---|---|---|
| | | ------------------ in. | ------------------ |
| 2012 | January | 0.00 | 0.46 |
| | February | 0.59 | 0.55 |
| | March | 1.92 | 1.31 |
| | April | 1.77 | 1.74 |
| | May | 0.30 | 2.98 |
| | June | 1.03 | 3.12 |
| | July | 2.41 | 2.80 |
| | August | 1.22 | 2.51 |
| | September | 1.19 | 1.42 |
| | October | 0.98 | 1.21 |
| | November | 0.00 | 0.55 |
| | December | 0.73 | 0.59 |
| | Total | 12.14 | 19.24 |
| | Wheat growing season (October-June) | 8.50 | 12.51 |
| | Grain sorghum growing season (June-October) | 6.83 | 11.06 |
| | Fallow preceding wheat (November-September) | 16.17 | 18.03 |
| | Fallow preceding grain sorghum (July-May) | 10.81 | 16.12 |
| 2013 | January | 0.48 | 0.46 |
| | February | 1.54 | 0.55 |
| | March | 0.13 | 1.31 |
| | April | 0.28 | 1.74 |
| | May | 1.25 | 2.98 |
| | June | 1.84 | 3.12 |
| | July | 2.23 | 2.80 |
| | August | 6.09 | 2.51 |
| | September | 1.83 | 1.42 |
| | October | 0.88 | 1.21 |
| | November | 0.74 | 0.55 |
| | December | 0.00 | 0.59 |
| | Total | 17.29 | 19.24 |
| | Wheat growing season (October-June) | 7.23 | 12.51 |
| | Grain sorghum growing season (June-October) | 12.87 | 11.06 |
| | Fallow preceding wheat (November-September) | 16.40 | 18.03 |
| | Fallow preceding grain sorghum (July-May) | 10.21 | 16.12 |

*continued*

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

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

*continued*

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

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

†30-year average (1984-2014).
Growing season amounts are those amounts accumulated between crop planting and termination.

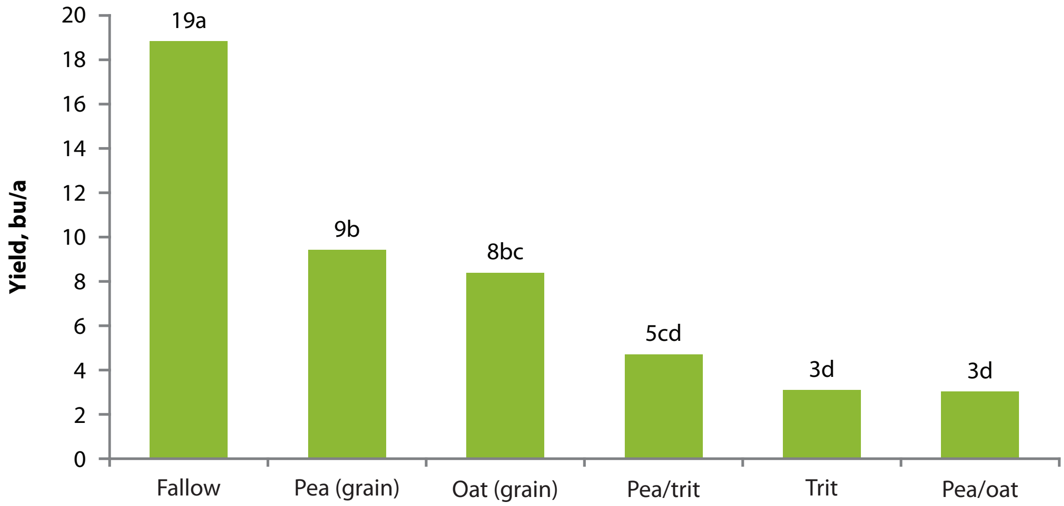


**Figure 1. Winter wheat yield (bu/a) in 2013 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$. Trit = triticale.**

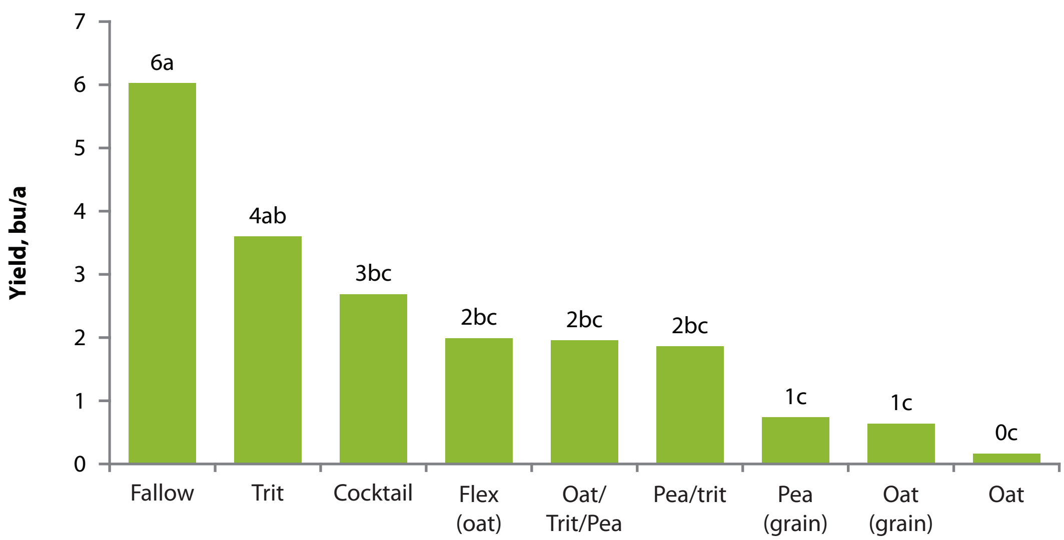


**Figure 2. Winter wheat yield (bu/a) in 2014 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$. Trit = triticale.**

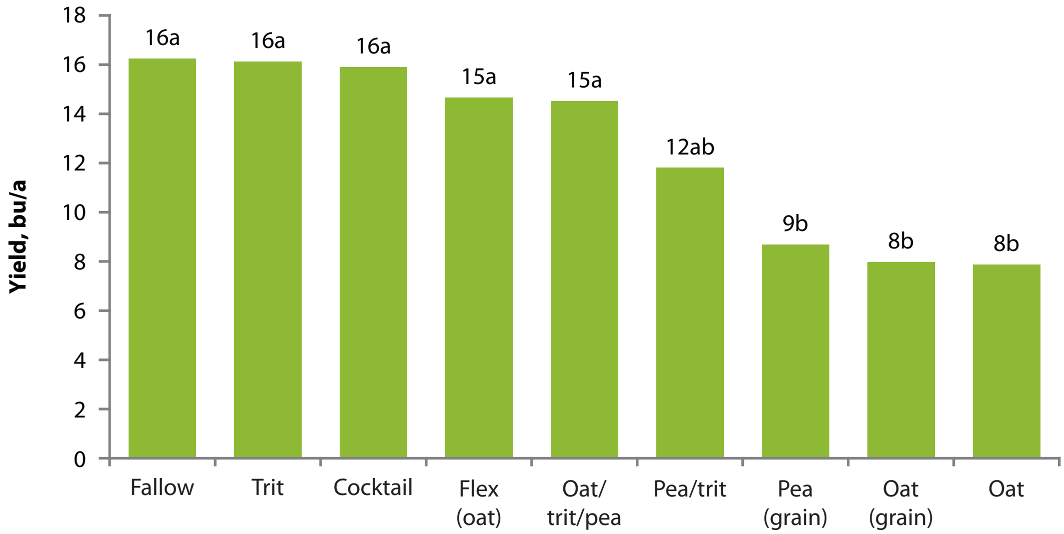


**Figure 3. Winter wheat yield (bu/a) in 2015 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$. Trit = triticale.**

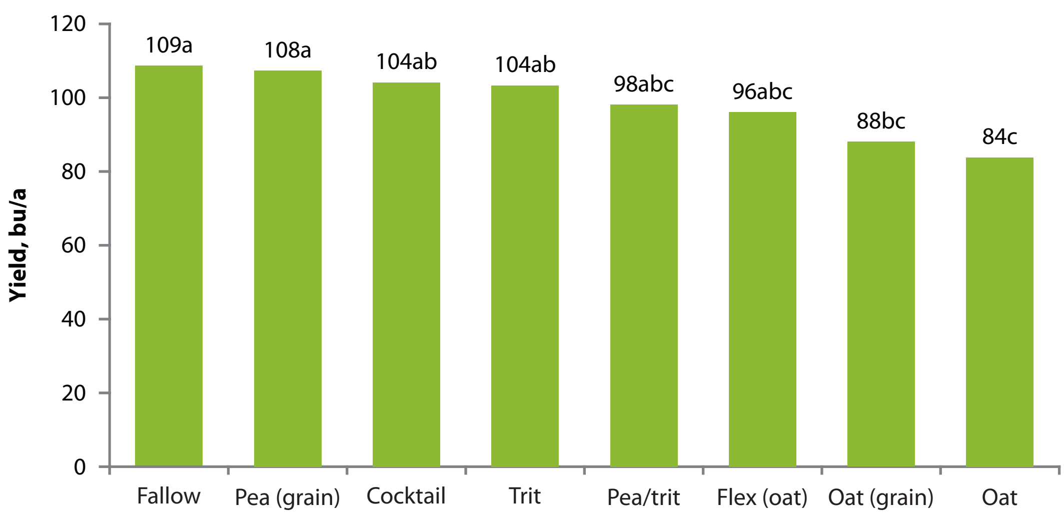


**Figure 4. Grain sorghum yield in 2015 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$. Trit = triticale.**

# Large-Scale Dryland Cropping Systems

*A. Schlegel and L. Haag*

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

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

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

## Results and Discussion

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

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

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

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

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

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

## Acknowledgments

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

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

| Crop | Rotation | Fallow accumulation | Fallow efficiency | Profile ASW at planting[2] | Crop water use |
|---|---|---|---|---|---|
| | | inch | % | ------------- inch | ------------- |
| Wheat | Wf[1] | 6.41a | 28a | 9.32a | 17.31a |
| | Wsf | 2.79bc | 19b | 6.07b | 13.44b |
| | Wcf | 2.33c | 15c | 5.79b | 13.36b |
| | Wscf | 3.09b | 19b | 6.03b | 13.59b |
| | Wcsf | 2.79bc | 17b | 6.15b | 13.46b |
| $LSD_{0.05}$ | | 0.50 | 3 | 0.61 | 0.52 |
| | | | | | |
| Corn | wCf | 2.36a | 17b | 5.46a | 13.64a |
| | wCsf | 2.14a | 16b | 5.36a | 13.54a |
| | wsCf | 1.38b | 24a | 4.38b | 12.87b |
| $LSD_{0.05}$ | | 0.38 | 3 | 0.62 | 0.40 |
| | | | | | |
| Grain sorghum | wSf | 2.27b | 15b | 5.54a | 12.86a |
| | wScf | 2.76a | 18ab | 5.91a | 13.19a |
| | wcSf | 1.26c | 16b | 4.66b | 12.18b |
| | SS | 1.62c | 20a | 4.75b | 12.16b |
| $LSD_{0.05}$ | | 0.38 | 3 | 0.61 | 0.39 |

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

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

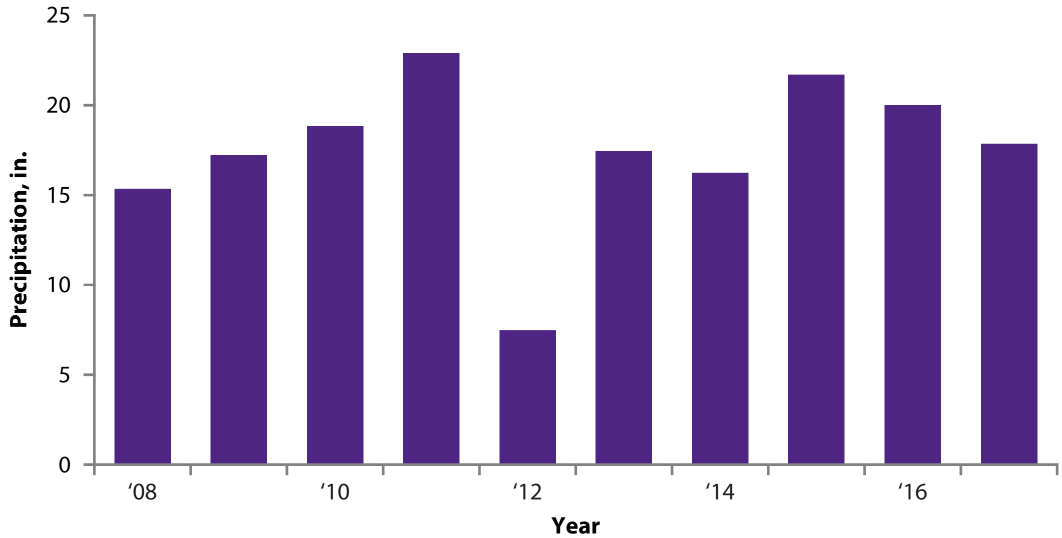


**Figure 1. Annual (2008-2016) and normal precipitation (1981-2010, last bar), Tribune, KS.**

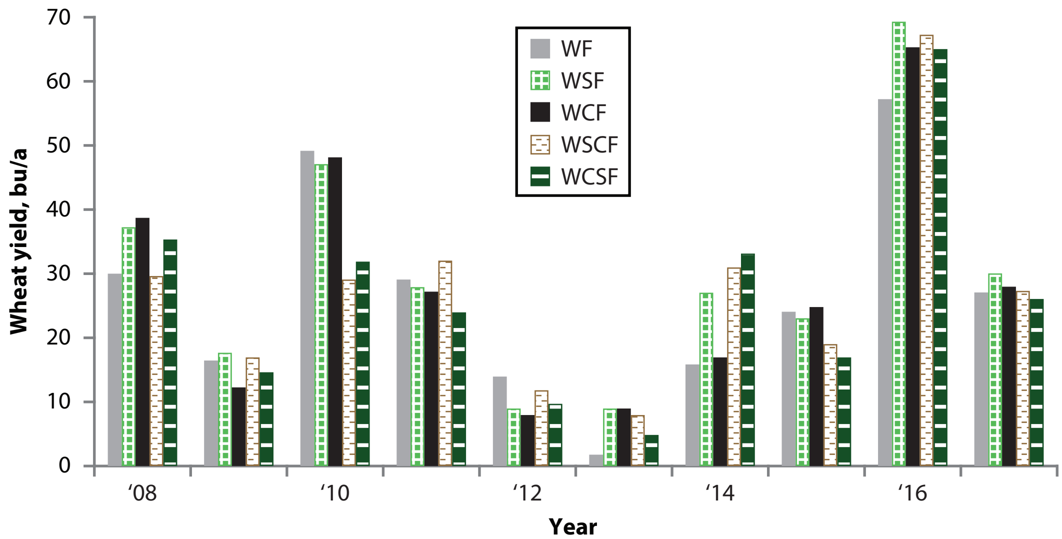


**Figure 2. Wheat yields by cropping system, 2008-2016. Last set of columns are treatment means. Wheat-fallow (WF), wheat-sorghum-fallow (WSF), wheat-corn-fallow (WCF), wheat-corn-sorghum-fallow (WCSF), and wheat-sorghum-corn-fallow (WSCF).**

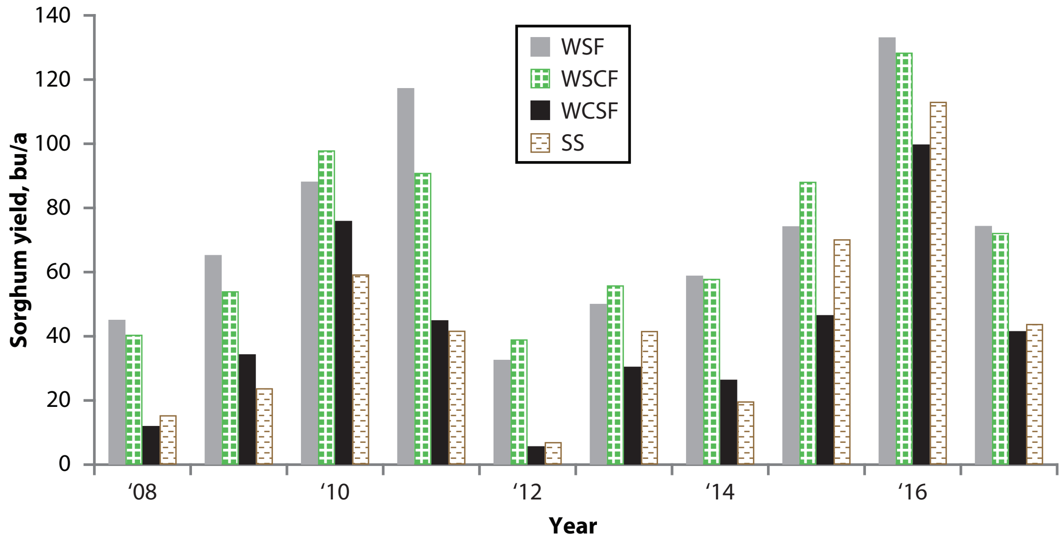


**Figure 3. Grain sorghum yields by cropping system, 2008-2016. Last set of columns are treatment means. tWheat-sorghum-fallow (WSF), wheat-sorghum-corn-fallow (WSCF), wheat-corn-sorghum-fallow (WCSF), and continuous grain sorghum (SS).**

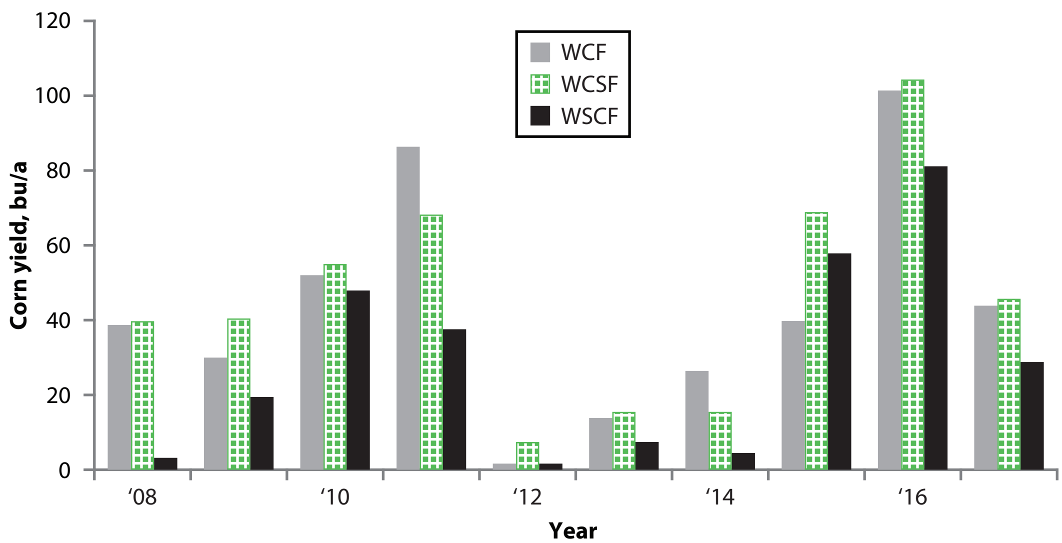


**Figure 4. Corn yields by cropping system, 2008-2016. Last set of columns are treatment means. Wheat-corn-fallow (WCF), wheat-corn-sorghum-fallow (WCSF), and wheat-sorghum-corn-fallow (WSCF).**

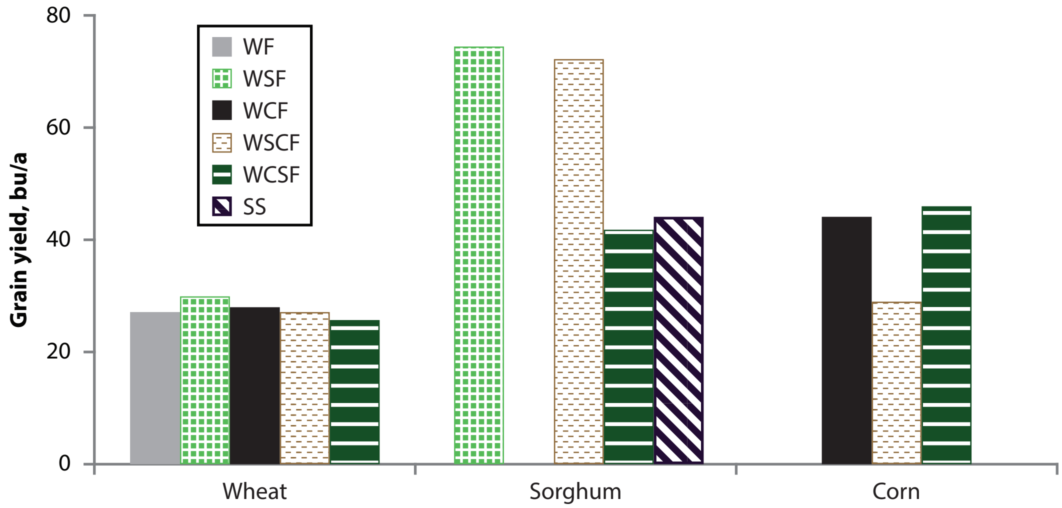


**Figure 5. Average grain yields by cropping system, 2008-2016. Wheat-fallow (WF), wheat-sorghum-fallow (WSF), wheat-corn-fallow (WCF), wheat-sorghum-corn-fallow (WSCF), wheat-corn-sorghum-fallow (WCSF), and continuous grain sorghum (SS).**

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

*A. Schlegel*


## Summary

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


## Experimental Procedures

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

## Results and Discussion

### *Soil Water*

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

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

### *Grain Yields*

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

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

## Acknowledgment

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

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

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

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

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

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

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

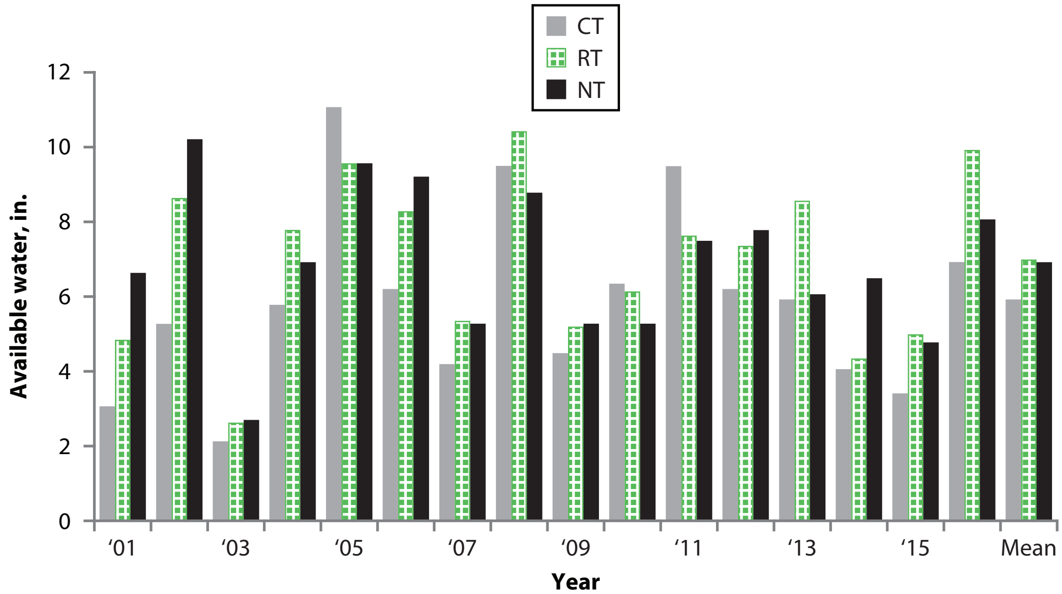


**Figure 1. Available soil water in 8-ft profile at planting of wheat in a wheat-sorghum-fallow rotation as affected by tillage intensity, Tribune, KS, 2001–2016. The last set of bars (Mean) is the average across years. CT = conventional tillage, RT = reduced tillage, NT = no-tillage.**

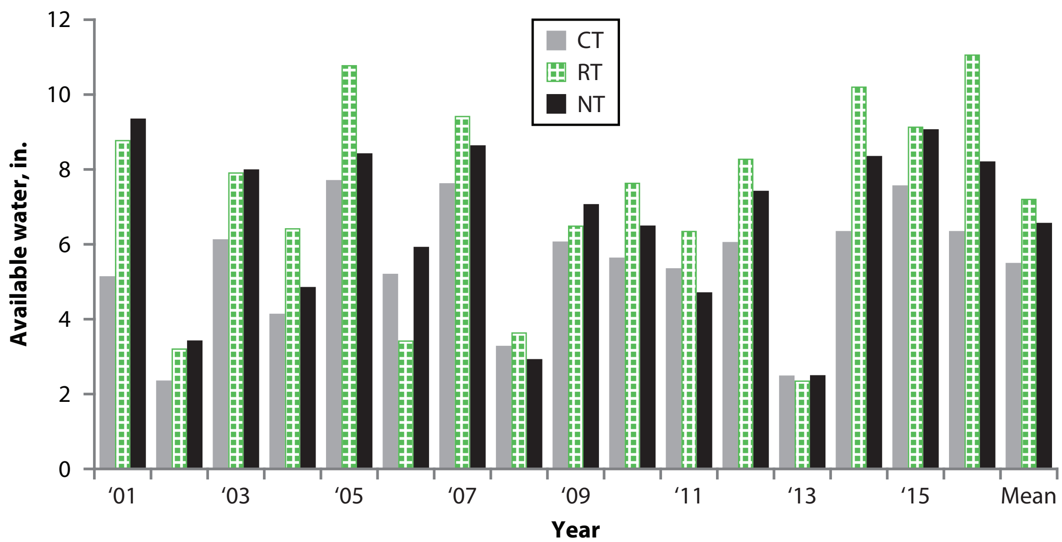


**Figure 2. Available soil water in 8-ft profile at planting of grain sorghum in a wheat-sorghum-fallow rotation as affected by tillage intensity, Tribune, KS, 2001–2016. The last set of bars (Mean) is the average across years. CT = conventional tillage, RT = reduced tillage, NT = no-tillage.**

# Wheat Stubble Height on Subsequent Corn and Grain Sorghum Crops

*A. Schlegel and L. Haag*


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


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

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

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

## Results and Discussion

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

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

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

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

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

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

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

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

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

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

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

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

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

[1] Water use efficiency (lb of grain/inch of water use).
[2] 2015 values not included in average - no samples collected.
LSD = least significant difference.
ANOVA = analysis of variance.

# Wheat and Grain Sorghum in Four-Year Rotations

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

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

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

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

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

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

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

### *Grain Yields*

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

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

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

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

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

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

ANOVA = analysis of variance.

LSD = least significant difference.

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

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

[1] W, wheat; S, sorghum; capital letters denote current year's crop.
Wheat-sorghum-sorghum-fallow (WSSF) and wheat-wheat-sorghum-fallow (WWSF).
ANOVA = analysis of variance.
LSD = least significant difference.

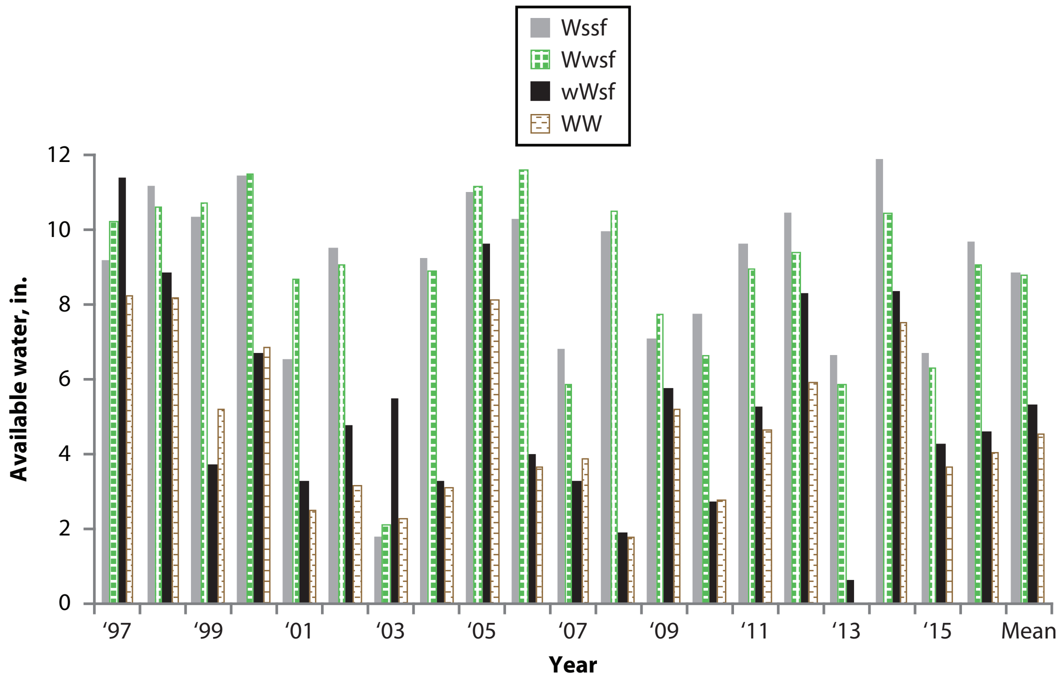


**Figure 1. Available soil water in 6-ft profile at planting of wheat in several rotations at Tribune, KS, 1997–2016. Capital letter denotes current crop in rotation (W, wheat; S, sorghum). The last set of bars (Mean) is the average across years. Wheat-sorghum-sorghum-fallow (WSSF), wheat-wheat-sorghum-fallow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

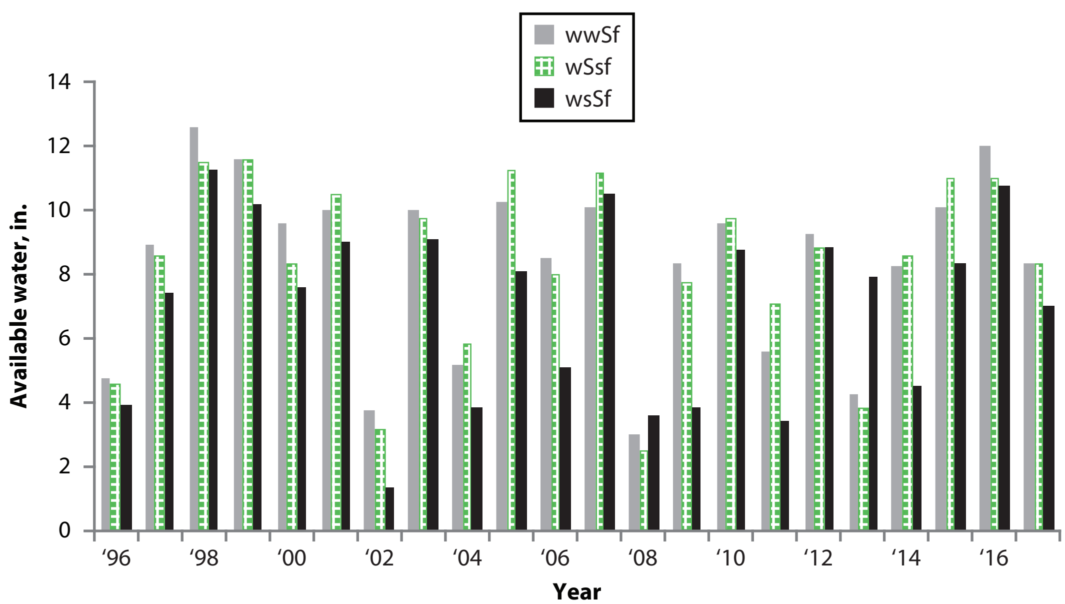


**Figure 2. Available soil water in 6-ft profile at planting of sorghum in several rotations at Tribune, KS, 1996–2016. Capital letter denotes current crop in rotation (W, wheat; S, sorghum). The last set of bars (Mean) is the average across years. Wheat-sorghum-sorghum-fallow (WSSF) and wheat-wheat-sorghum-fallow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

# Seeding Rate for Dryland Wheat

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

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

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

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

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

## Results and Discussion

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

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

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

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

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

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

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

*continued*

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

| | | Grain yield | | | |
|---|---|---|---|---|---|
| Variety | Seeding rate | Tribune | Garden City | Colby | Average |
| | lb/a | bu/a | | | |
| ANOVA (P>F) | | | | | |
| Variety | | 0.001 | 0.001 | 0.001 | 0.001 |
| Seeding rate | | 0.001 | 0.001 | 0.001 | 0.001 |
| Variety × seeding rate | | 0.046 | 0.001 | 0.731 | 0.124 |
| Location | | - - - | - - - | - - - | 0.001 |
| Location × variety | | - - - | - - - | - - - | 0.001 |
| Location × seeding rate | | - - - | - - - | - - - | 0.743 |
| Location × variety × seeding rate | | - - - | - - - | - - - | 0.001 |
| MEANS[1] | | | | | |
| Variety | | | | | |
| Byrd | | 55b | 47b | 26b | 43c |
| T158 | | 65a | 72a | 53a | 63a |
| TAM 111 | | 43c | 44bc | 28b | 38d |
| Winterhawk | | 65a | 43c | 29b | 46b |
| $LSD_{0.05}$ | | 2 | 3 | 3 | 2 |
| Seeding rate (lb/a) | | | | | |
| 30 | | 51c | 44c | 27c | 41c |
| 45 | | 55b | 49b | 32b | 45b |
| 60 | | 59a | 54a | 35ab | 49a |
| 75 | | 59a | 56a | 37a | 50a |
| 90 | | 61a | 55a | 38a | 51a |
| $LSD_{0.05}$ | | 3 | 4 | 4 | 2 |

[1] Means within a column with the same letter are not statistically different at $P = 0.05$.
ANOVA = analysis of variance.
LSD = least significant difference.

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

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

*continued*

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

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

[1] Means within a column with the same letter are not statistically different at $P = 0.05$.
ANOVA = analysis of variance.
LSD = least significant difference.

# Occasional Tillage in a Wheat-Sorghum-Fallow Rotation

*A. Schlegel and J. Holman*

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

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

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

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

At Garden City, wheat yields were greater in 2016 than earlier years (Table 3). Wheat yields in 2014 were severely reduced by hail. There were no significant yield differences among tillage treatments in any year or averaged across years. Favorable growing conditions caused grain sorghum yields in 2016 to be about twice the yields of 2014 and 2015 (Table 4). Similar to wheat, there were no significant yield differences among tillage treatments in any year or averaged across years.

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

## Reference

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

## Acknowledgment

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

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

ANOVA = analysis of variance.

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

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

ANOVA = analysis of variance.

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

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

ANOVA = analysis of variance.

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

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

ANOVA = analysis of variance.

# Alternative Cropping Systems with Limited Irrigation

*A. Schlegel*

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

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

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

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


## Acknowledgment

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

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

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

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

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

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

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

Note: All crops received ~10 inches of irrigation.
In season rainfall for corn (4/28/16 – 9/15/16) = 17.91 inches; grain sorghum (6/01/16 – 10/20/16) = 12.61 inches; and wheat (9/29/15 – 7/08/16) = 20.29 inches.
C = corn.
W = wheat.
GS = grain sorghum.
LSD = least significant difference.
ANOVA = analysis of variance.
[1] Means within a column with the same letter are not statistically different at $P = 0.05$.

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

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

Note: All crops received ~10 inches of irrigation each year.
C = corn.
W = wheat.
GS = grain sorghum.
LSD = least significant difference.
ANOVA = analysis of variance.
[1] Means within a column with the same letter are not statistically different at $P = 0.05$.

# 2015 Kansas Summer Annual Forage Hay and Silage Variety Trial

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

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

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

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

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

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

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

Management guidelines were provided to cooperators; however, previous growing experience influenced final management decisions. All trials were planted in small research plots (approximately 225 $ft^2$) with three replications. Cultural practices (Table 3), growing season temperature, and precipitation (Figures 1-5) are provided for each site. Emergence date was determined when plant stand was visibly apparent. Stand vigor and percent stand establishment were determined two weeks after planting using a visual assessment. Stand vigor was rated on a scale of 1 through 10, with 10 being the most vigorous and percent stand establishment was rated on a scale of 0 through 100. Lodging was determined by visual assessment. Days to heading and days to soft dough were determined when 50% of stand reached maturity. All hay entries were harvested when the earliest variety reached heading. Silage entries were harvested when they reached soft dough. Late maturing silage varieties and photoperiod sensitive varieties (PPS) were harvested at the last silage harvest. Results are listed alphabetically by seed supplier. Forage samples were dried, ground, and analyzed for nutrient contents using NIR (near infrared reflectance) by SDK Laboratories in Hutchinson, KS.

### *2015 Growing Conditions*

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

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

## Results and Discussion

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

### *Hay Test*

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

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

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

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

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

### *Silage Test*

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

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

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

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

### *Recommendation*

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

## Acknowledgments

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

**Table 1. 2015 Hay test entries**

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

*Abbreviations: Forage Sorghum (FS), Sorghum Sudan (SS), Sorghum (S), Brown Mid-Rib (BMR), and Photoperiod Sensitive (PS).
** Maturity Groups: Early (E), Medium Early (ME), Medium (M), Medium Late (ML), Late (L), and Full (F).
Hybrid information was provided by seed companies.

**Table 2. 2015 Silage test entries**

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

*Abbreviations: Forage Sorghum (FS), Sorghum Sudan (SS), Brown Mid-Rib (BMR), and Photoperiod Sensitive (PS).
** Maturity Groups: Early (E), Medium Early (ME), Medium (M), Medium Late (ML), Late (L), and Full (F).
Hybrid information was provided by seed companies.

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

| Location | Irrigation | Planting date | 1st harvest date | 2nd harvest date | 3rd harvest date | Seeding rate | Harvest area | Fertilizer N/a | Fertilizer $P_2O_5$/a |
|---|---|---|---|---|---|---|---|---|---|
| | in. | | | | | | ft$^2$ | --------- lb --------- | |
| Hay Test | | | | | | | | | |
| Garden City | 10.03 | 16-Jun | 17-Aug | 26-Oct | -* | 15 (lb/a) | 90 | 160 | 0 |
| Hays | - | 11-Jun | 10-Aug | - | - | 15 (lb/a) | 90 | 50 | 30 |
| Hutchinson | - | 14-Jul | 27-Oct | - | - | 20 (lb/a) | 42 | 50 | 0 |
| Mound Valley | - | 5-Jun | 26-Jul | 27-Aug | 16-Oct | 20 (lb/a) | 80 | 150 | 60 |
| Scandia | - | 24-Jun | 1-Sep | - | - | 20 (lb/a) | 60 | 50 | 0 |
| Silage Test | | | | | | | | | |
| Garden City | 10.03 | 17-Jun | -** | - | - | 60,000 (seeds/a) | 202.5 | 160 | 0 |
| Hays | - | 11-Jun | - | - | - | 50,000 (seeds/a) | 12.5 | 50 | 30 |
| Hutchinson*** | - | - | - | - | - | - | - | - | - |
| Mound Valley | - | 5-Jun | - | - | - | 100,000 (seeds/a) | 100 | 150 | 60 |
| Scandia | - | 25-Jun | - | - | - | 92,400 (seeds/a) | 12.5 | 50 | 0 |

*Based on growing conditions and plant regrowth, some sites were cut more than others.
**Silage entries harvested at soft dough or end of season for varieties that did not reach soft dough.
***Hutchinson did not have a silage test.

**Table 4. Hay performance test near Garden City**

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

*continued*

Plant date: 6/16/2015

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

**Table 4. Hay performance test near Garden City, continued**

| | | Forage quality | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brand | Name | ADF | aNDF | IVTDMD @48 | Lignin | NDFD @48 | NDFn | NEG | NEL | NEM | NFC | Protein crude | RFQ | TDN |
| | | Sorghum sudan | | | | | | | | | | | | |
| Alta Seeds | AS5201 | 42.39 | 62.29 | 69.23 | 4.31 | 52.33 | 57.93 | 0.20 | 0.50 | 0.53 | 18.58 | 8.89 | 83.84 | 50.19 |
| Alta Seeds | AS6201 | 39.30 | 59.11 | 73.97 | 3.55 | 58.53 | 54.97 | 0.23 | 0.53 | 0.56 | 17.76 | 11.17 | 97.46 | 52.50 |
| Alta Seeds | AS6401 | 40.66 | 59.84 | 75.20 | 3.33 | 58.60 | 55.65 | 0.22 | 0.52 | 0.55 | 16.31 | 11.64 | 92.42 | 51.59 |
| Alta Seeds | AS6402 | 39.87 | 60.37 | 76.50 | 2.86 | 60.78 | 56.14 | 0.23 | 0.53 | 0.56 | 15.42 | 12.19 | 96.01 | 52.35 |
| Alta Seeds | AS6501 | 39.81 | 59.27 | 77.40 | 2.83 | 62.60 | 55.12 | 0.24 | 0.53 | 0.56 | 16.40 | 11.41 | 97.54 | 52.81 |
| Alta Seeds | AS9301 | 40.55 | 59.92 | 72.20 | 3.71 | 56.40 | 55.73 | 0.22 | 0.52 | 0.55 | 18.05 | 10.47 | 92.41 | 51.61 |
| Alta Seeds | AS9302 | 40.92 | 59.95 | 75.48 | 3.05 | 59.65 | 55.76 | 0.23 | 0.53 | 0.56 | 17.16 | 11.05 | 93.93 | 52.19 |
| CERES, Inc. | CB7290 | 41.60 | 62.52 | 71.30 | 3.29 | 54.73 | 58.15 | 0.14 | 0.37 | 0.39 | 16.48 | 9.65 | 84.74 | 36.95 |
| CERES, Inc. | F2P134 | 43.44 | 64.22 | 69.27 | 4.05 | 52.33 | 59.73 | 0.17 | 0.48 | 0.50 | 15.81 | 8.98 | 75.97 | 47.85 |
| Gayland Ward Seed | Sweet Forever BMR | 41.01 | 63.93 | 74.30 | 3.24 | 58.53 | 59.45 | 0.21 | 0.51 | 0.53 | 14.42 | 10.18 | 88.12 | 50.40 |
| Gayland Ward Seed | Sweet Six BMR | 41.69 | 60.73 | 72.07 | 3.86 | 55.40 | 56.48 | 0.23 | 0.53 | 0.56 | 19.58 | 9.51 | 91.04 | 52.17 |
| | | Forage sorghum | | | | | | | | | | | | |
| KSU | Rox Orange | 38.47 | 58.63 | 75.13 | 2.65 | 59.18 | 54.52 | 0.25 | 0.54 | 0.58 | 20.07 | 10.94 | 102.90 | 53.84 |
| KSU | Sumac | 41.24 | 60.56 | 72.27 | 3.62 | 55.53 | 56.32 | 0.23 | 0.53 | 0.56 | 20.62 | 8.81 | 92.44 | 52.50 |
| | Average | 40.84 | 60.87 | 73.41 | 3.41 | 57.28 | 56.61 | 0.22 | 0.51 | 0.54 | 17.44 | 10.38 | 91.45 | 50.54 |
| | LSD (0.05) | | | | | | | | | | | | | |

**Table 5. Hay performance test near Hays**

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

*continued*

Plant Date: 6/11/2015 *Days to harvest: *57

**Table 5. Hay performance test near Hays, continued**

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

**Table 6. Hay performance test near Hutchinson**

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

*continued*

Plant Date: 7/14/2015 *Days to harvest: *105

**Table 6. Hay performance test near Hutchinson, continued**

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

**Table 7. Hay performance test near Mound Valley**

| Brand | Name | Yield 1 | Yield 2 | Yield 3 | Total | Rust* |
|---|---|---|---|---|---|---|
| | | ------------------------ lb DM/a | | ------------------------ | | 0-10 |
| | | | | Sorghum sudan | | |
| Alta Seeds | AS5201 | 3,388 | 2,815 | 3,469 | 9,672 | 1.3 |
| Alta Seeds | AS6201 | 3,038 | 2,124 | 1,952 | 7,114 | 2.3 |
| Alta Seeds | AS6401 | 2,321 | 1,993 | 3,273 | 7,587 | 3.0 |
| Alta Seeds | AS6402 | 2,478 | 1,856 | 1,965 | 6,299 | 1.7 |
| Alta Seeds | AS6501 | 2,333 | 2,104 | 1,109 | 5,546 | 4.7 |
| Alta Seeds | AS9301 | 2,915 | 2,544 | 2,456 | 7,915 | 2.0 |
| Alta Seeds | AS9302 | 3,115 | 2,288 | 3,520 | 8,923 | 2.0 |
| Browning Seed | Sweet Sioux WMR | 2,585 | 2,947 | 3,678 | 9,210 | 3.3 |
| Browning Seed | Sweet Sioux BMR | 2,762 | 2,597 | 1,393 | 6,752 | 3.7 |
| Browning Seed | B-52 | 2,929 | 2,180 | 2,311 | 7,420 | 1.3 |
| Browning Seed | 747 | 3,494 | 2,124 | 2,379 | 7,996 | 3.0 |
| Browning Seed | Wondergreen | 3,035 | 2,348 | 950 | 6,333 | 4.0 |
| Gayland Ward Seed | Sweet Six BMR | 3,213 | 2,119 | 2,497 | 8,528 | 2.0 |
| KSU | Kansas Orange | 2,504 | 2,349 | 865 | 5,718 | 6.0 |
| | | | | Forage sorghum | | |
| KSU | Rox Orange | 1,511 | 1,560 | 1090 | 4161 | 4.7 |
| KSU | Sumac | 1,933 | 1,714 | 870 | 4517 | 5.3 |
| | Average | 2,722 | 2,229 | 2111 | 7106 | 3.1 |
| | LSD (0.05) | 986 | | | | |

*continued*

Plant date: 6/5/2015 Days to harvest: Yield 1 = *41; Yield 2 = 32; Yield 3 = 50

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

**Table 7. Hay performance test near Mound Valley, continued**

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

**Table 8. Hay performance test near Scandia**

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

Plant date: 6/24/2015 *Days to harvest: 62

**Table 8. Hay performance test near Scandia, continued**

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

**Table 9. Silage performance test near Garden City**

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

*continued*

Planting Date: 6/17/15 Emergence Date: 6/22/15

**Table 9. Silage performance test near Garden City, continued**

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

**Table 10. Silage performance test near Hays**

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

*continued*

Plant Date: 6/11/2015

**Table 10. Silage performance test near Hays, continued**

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

**Table 11. Silage performance test near Mound Valley**

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

Plant Date: 6/5/2015

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

**Table 12. Silage performance test near Scandia**

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

Plant Date: 6/25/15 Emergence Date: 7/1/15

| | | Forage quality | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Brand | Variety | ADF | aNDF | IVTDMD @48 | Lignin | Milk | NDFD @48 | NDFn | NEL | NFC | Protein crude | RFQ | TDN | Total starch |
| | | % | % | % | % | lb/ton | % | % | % | % | | | | |
| Alta Seeds | AF7101 | 41.04 | 59.70 | 73.37 | 3.21 | 1983.67 | 55.00 | 55.52 | 0.50 | 24.41 | 8.06 | 101.52 | 54.23 | 7.59 |
| Alta Seeds | AF7102 | 38.20 | 56.48 | 77.33 | 2.91 | 2238.33 | 59.70 | 52.53 | 0.54 | 24.85 | 9.40 | 120.03 | 58.30 | 8.19 |
| Alta Seeds | AF7201 | 40.47 | 57.41 | 73.37 | 2.89 | 2002.00 | 52.50 | 53.39 | 0.51 | 27.79 | 7.52 | 100.99 | 54.03 | 9.43 |
| Alta Seeds | AF7202 | 36.20 | 53.04 | 78.03 | 2.67 | 2232.67 | 58.00 | 49.32 | 0.54 | 28.70 | 9.80 | 123.73 | 57.97 | 10.03 |
| Alta Seeds | AF7301 | 37.69 | 56.65 | 76.50 | 2.92 | 2255.67 | 58.43 | 52.68 | 0.54 | 26.72 | 9.06 | 118.28 | 58.37 | 9.75 |
| Alta Seeds | AF7401 | 38.78 | 54.02 | 76.03 | 2.83 | 2152.67 | 54.90 | 50.24 | 0.53 | 30.77 | 8.00 | 114.75 | 56.50 | 11.38 |
| Alta Seeds | AF8301 | 42.07 | 61.10 | 69.93 | 4.10 | 1823.67 | 48.33 | 56.82 | 0.48 | 26.16 | 6.36 | 85.78 | 50.97 | 8.31 |
| KSU | Kansas Orange | 39.52 | 59.41 | 69.07 | 3.68 | 1953.33 | 46.17 | 55.25 | 0.50 | 30.03 | 6.61 | 87.85 | 52.17 | 12.30 |
| Ward Seed | GW 600 BMR | 41.51 | 61.12 | 73.33 | 3.82 | 2007.00 | 56.60 | 56.85 | 0.50 | 24.60 | 6.56 | 102.21 | 54.90 | 7.56 |
| Ward Seed | Silo Pro BMR | 35.54 | 54.40 | 77.20 | 2.62 | 2271.33 | 57.57 | 50.59 | 0.54 | 29.51 | 8.55 | 121.31 | 58.37 | 11.99 |
| | Average | 39.10 | 57.33 | 74.42 | 3.16 | 2092.03 | 54.72 | 53.32 | 0.52 | 27.35 | 7.99 | 107.64 | 55.58 | 9.65 |
| | LSD (0.05) | | | | | | | | | | | | | |

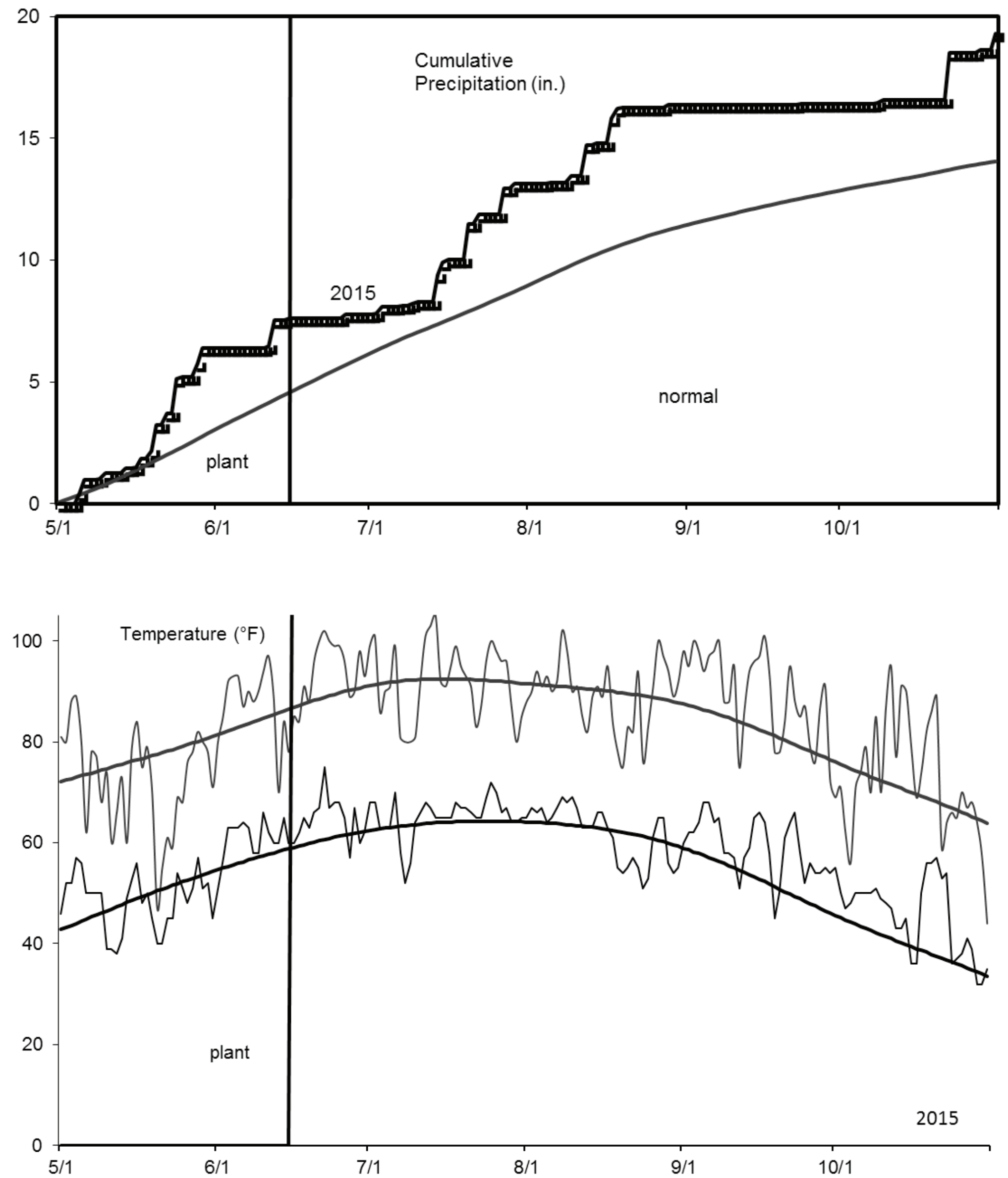



**Figure 1. Precipitation and temperature during the growing season near Garden City, KS. Top pane: daily and mean (1981 to 2010) cumulative precipitation. Bottom pane: daily and mean (1981 to 2010) high and low temperature.**

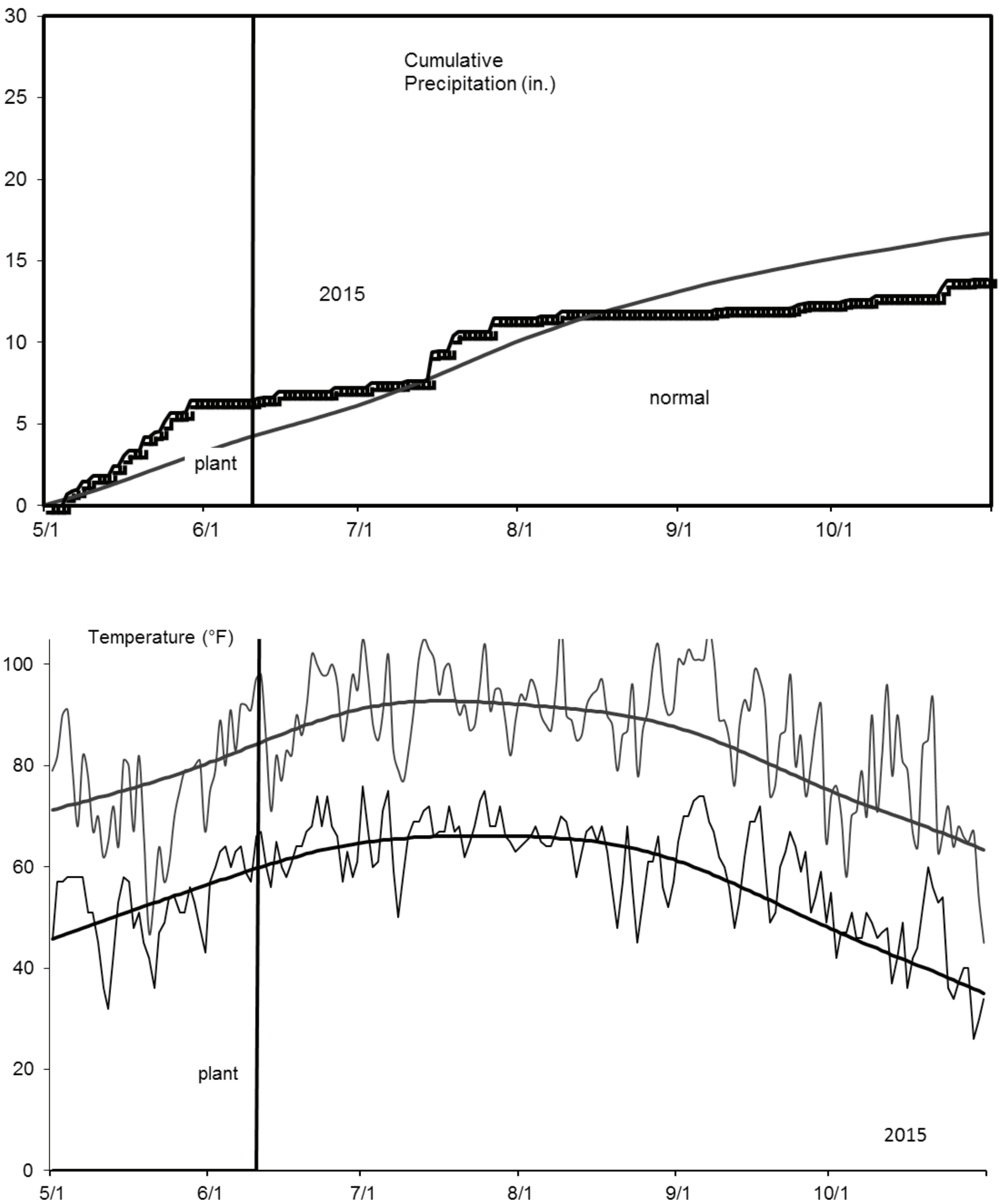
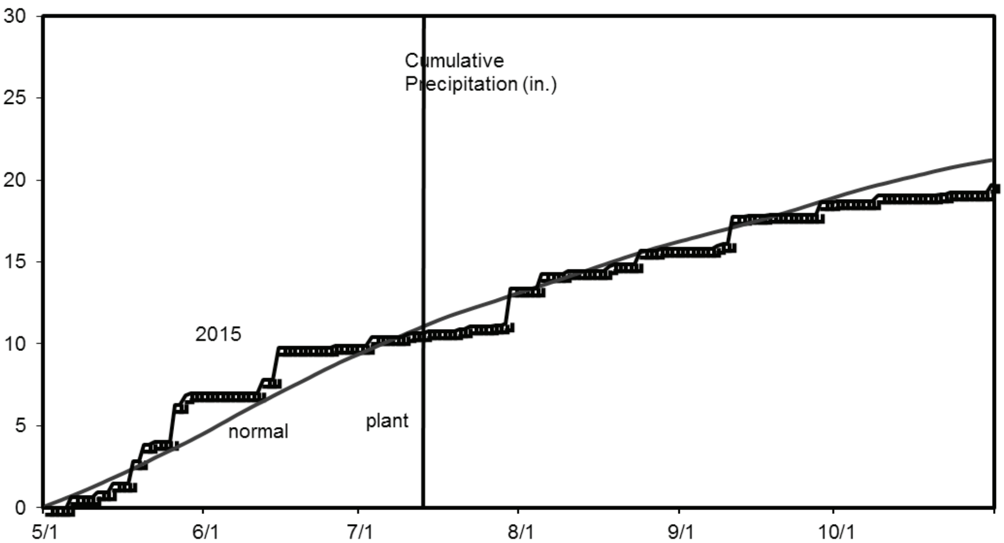



**Figure 2. Precipitation and temperature during the growing season near Hays, KS. Top pane: daily and mean (1981 to 2010) cumulative precipitation. Bottom pane: daily and mean (1981 to 2010) high and low temperature.**



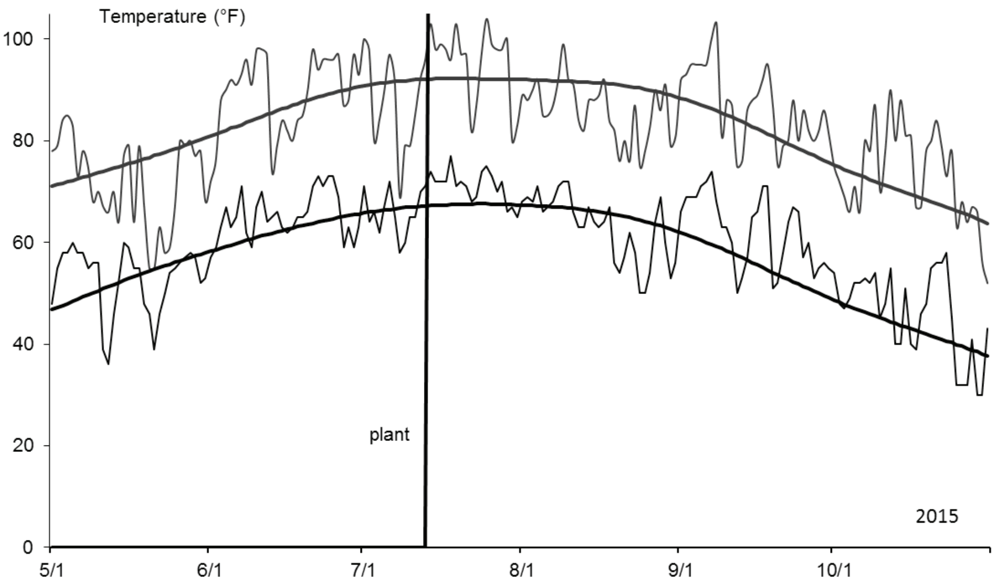




**Figure 3. Precipitation and temperature during the growing season near Hutchinson, KS. Top pane: daily and mean (1981 to 2010) cumulative precipitation. Bottom pane: daily and mean (1981 to 2010) high and low temperature.**

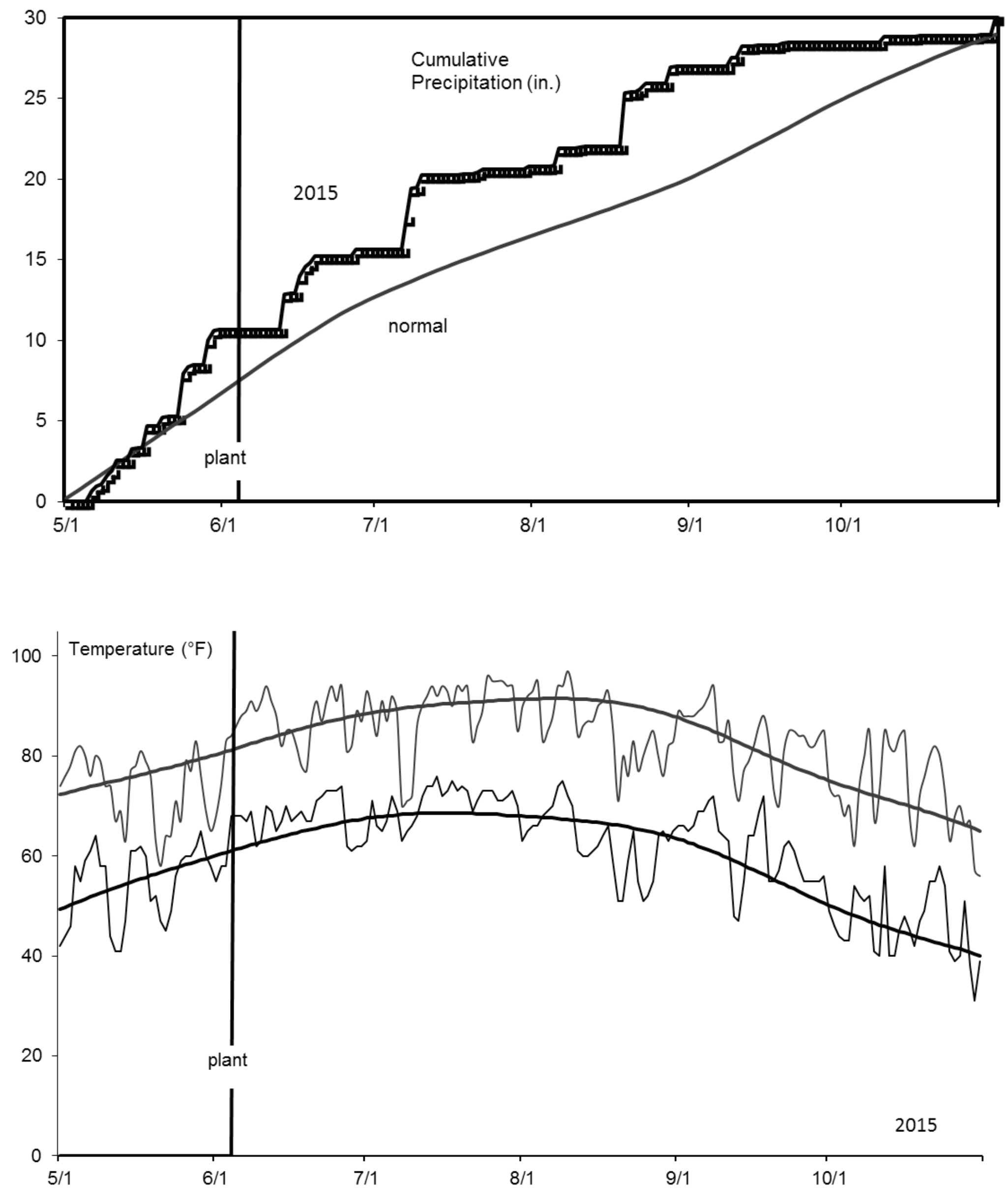



**Figure 4. Precipitation and temperature during the growing season near Mound Valley, KS. Top pane: daily and mean (1981 to 2010) cumulative precipitation. Bottom pane: daily and mean (1981 to 2010) high and low temperature.**

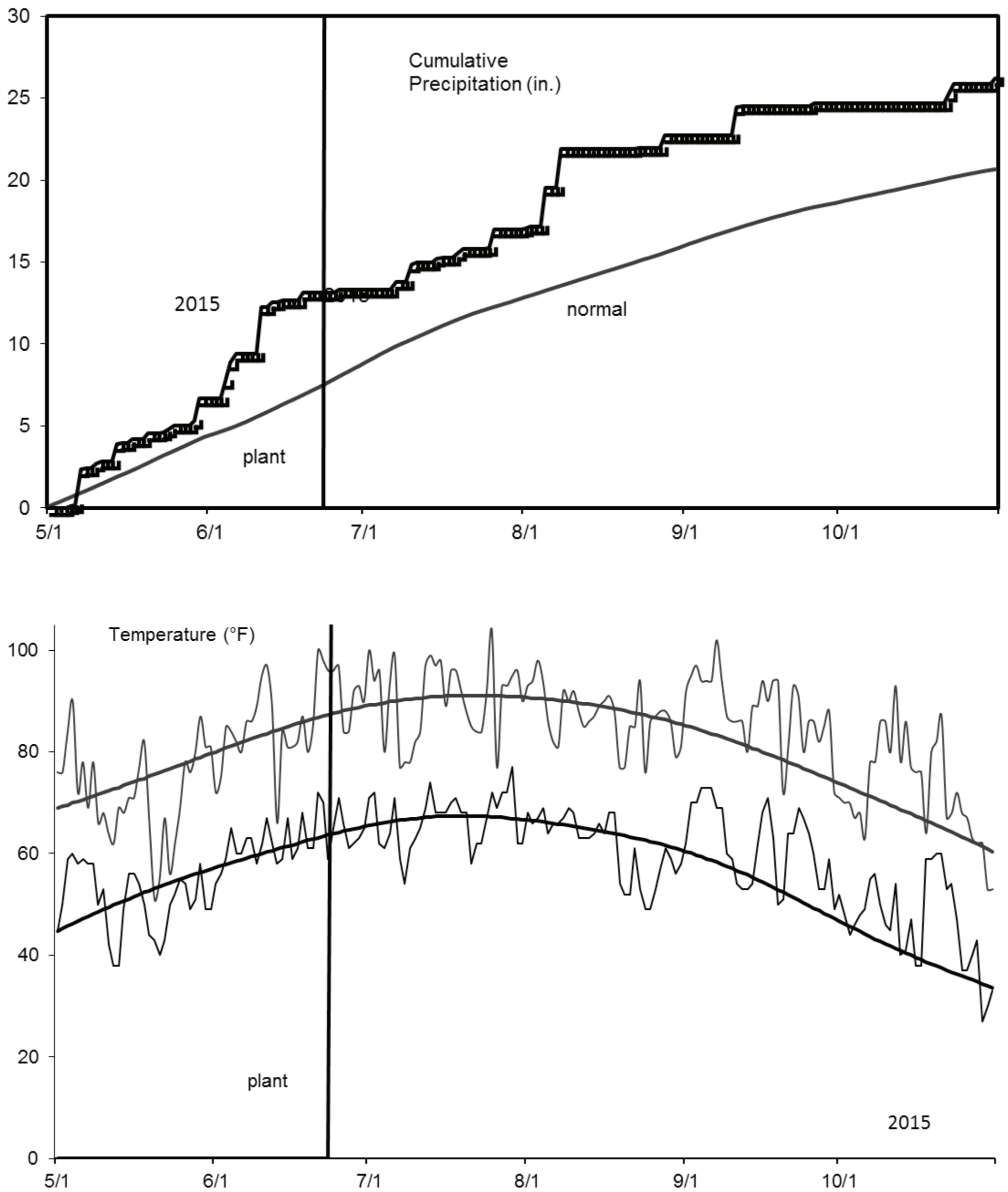



**Figure 5. Precipitation and temperature during the growing season near Scandia, KS. Top pane: daily and mean (1981 to 2010) cumulative precipitation. Bottom pane: daily and mean (1981 to 2010) high and low temperature.**

# 2016 Kansas Summer Annual Forage Hay and Silage Variety Trial

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

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

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

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

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

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

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

Management guidelines were provided to cooperators; however, previous growing experience influenced final management decisions. All trials were planted in small research plots (approximately 225 $ft^2$) with three replications. Cultural practices (Table 4), growing season temperature, and precipitation (Figures 1-5) are provided for each site. Results are listed alphabetically by seed supplier. Forage samples were dried, ground, and analyzed for nutrient contents using NIR (near infrared reflectance) by SDK Laboratories in Hutchinson, KS. Nutrient contents measured were acid detergent fiber (ADF), neutral detergent fiber (NDF), in vitro true dry matter digestibility after 48 hours (IVTDMD@48hr), lignin, percent of NDF digestible after 48 hours (NDFD@48hr), nitrogen free NDF (NDFn), net energy for gain (NEG), net energy for lactation (NEL), net energy for maintenance (NEM), non-fibrous carbohydrates (NFC), crude protein, relative forage quality (RFQ), total digestible nutrients (TDN), and starch (silage only).

### *2016 Growing Conditions*

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

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

## Results and Discussion

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

### *Hay Test*

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

At Garden City, Sweetleaf II, Grazex BMR 301, and Super Sugar DM were in the top LSD (Least Significant Difference at $P \leq 0.05$) group in the first cutting (Table 6). In the second cutting more separation occurred between entries, and Sweetleaf II, Canex, Sordan Headless, Grazex BMR 301, Grazex BMR 801, 121 BMR, and Super Sugar were in the highest yielding LSD group. Crude protein averaged 9.6% and TDN was 48.6%.

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

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

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

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

### *Silage Test*

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

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

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

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

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

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

### *Recommendation*

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

## Acknowledgments

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

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

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

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

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

*continued*

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

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

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

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

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

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

*continued*

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

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

[1] Abbreviations: Forage sorghum (FS), sorghum sudan (SS), sorghum (S).

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

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

| Location | Irrigation | Planting date | 1st harvest date | 2nd harvest date | 3rd harvest date | Seeding rate | Harvest area | Fertilizer N | Fertilizer $P_2O_5$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | lb/a | ft² | --------- lb/a --------- | |
| Hay test | | | | | | | | | |
| Garden City | 10.49 | 3-Jun | 4-Aug | 22-Sep | -* | 20 | 225 | 180 | 0 |
| Hays | - | 6-Jun | 18-Aug | 17-Oct | - | 15 | 90 | 50 | 30 |
| Hutchinson | - | 10-Jun | 10-Aug | 19-Sep | - | 20 | 54 | 50 | 0 |
| Mound Valley | - | 9-Jun | 13-Jul | 18-Aug | 4-Oct | 20 | 45 | 150 | 60 |
| Scandia | - | 10-Jun | 10-Aug | - | - | 30 | 60 | 50 | 0 |

| Location | Irrigation | Planting date | 1st harvest date | 2nd harvest date | 3rd harvest date | Seeding rate | Harvest area | Fertilizer N | Fertilizer $P_2O_5$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | seeds/a | ft² | --------- lb/a --------- | |
| Silage test | | | | | | | | | |
| Garden City | 10.49 | 15-Jun | -** | - | - | 80,000 | 225 | 180 | 0 |
| Hays | - | 7-Jun | - | - | - | 50,000 | 12.5 | 50 | 30 |
| Hutchinson | - | 10-Jun | - | - | - | 50,000 | 87 | 100 | 0 |
| Mound Valley | - | 9-Jun | - | - | - | 100,000 | 100 | 150 | 60 |
| Scandia | - | 9-Jun | - | | | 92,400 | 12.5 | 50 | 0 |

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

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

**Table 5. Hay performance across locations summary**

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

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

**Table 6a. Hay performance test near Garden City**

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

*continued*

**Table 6a. Hay performance test near Garden City**

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

Plant date: 6/3/2016

Days to harvest: 62 49

**Table 6b. Hay performance test near Garden City**

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

*continued*

**Table 6b. Hay performance test near Garden City**

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

**Table 7a. Hay performance test near Hays**

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

*continued*

**Table 7a. Hay performance test near Hays**

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

Plant date: 6/6/2016

Days to harvest: 73 60

**Table 7b. Hay performance test near Hays**

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

*continued*

**Table 7b. Hay performance test near Hays**

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

**Table 8a. Hay performance test near Hutchinson**

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

Plant date: 6/9/2016

| | | | |
|---|---|---|---|
| Days to harvest: | | 91 | 42 |

**Table 8b. Hay performance test near Hutchinson**

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

**Table 9a. Hay performance test near Mound Valley**

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

### Table 9b. Hay performance test near Mound Valley

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

Plant date: 6/9/2016

**Table 10a. Hay performance test near Scandia**

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

Plant date: 6/10/16

Days to harvest: 61

**Table 10b. Hay performance test near Scandia**

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

*continued*

**Table 10b. Hay performance test near Scandia**

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

**Table 11. Silage performance across locations summary**

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

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

**Table 12a. Silage performance test near Garden City**

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

*continued*

**Table 12a. Silage performance test near Garden City**

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

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

**Table 12b. Silage performance test near Garden City**

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

*continued*

**Table 12b. Silage performance test near Garden City**

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

**Table 13a. Silage performance test near Hays**

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

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

**Table 13b. Silage performance test near Hays**

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

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

**Table 14. Silage performance test near Hutchinson**

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

Planting Date: 6/10/16
Emergence Date: 6/15/16

**Table 15a. Silage performance test near Mound Valley**

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

Planting Date: 6/9/16
Emergence Date: 6/15/16
*Starch content was low due to little or no grain production.

**Table 15b. Silage performance test near Mound Valley**

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

Planting Date: 6/9/16
Emergence Date: 6/15/16
*Starch content was low due to little or no grain production.

**Table 16a. Silage performance test near Scandia**

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

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

**Table 16b. Silage performance test near Scandia**

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

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

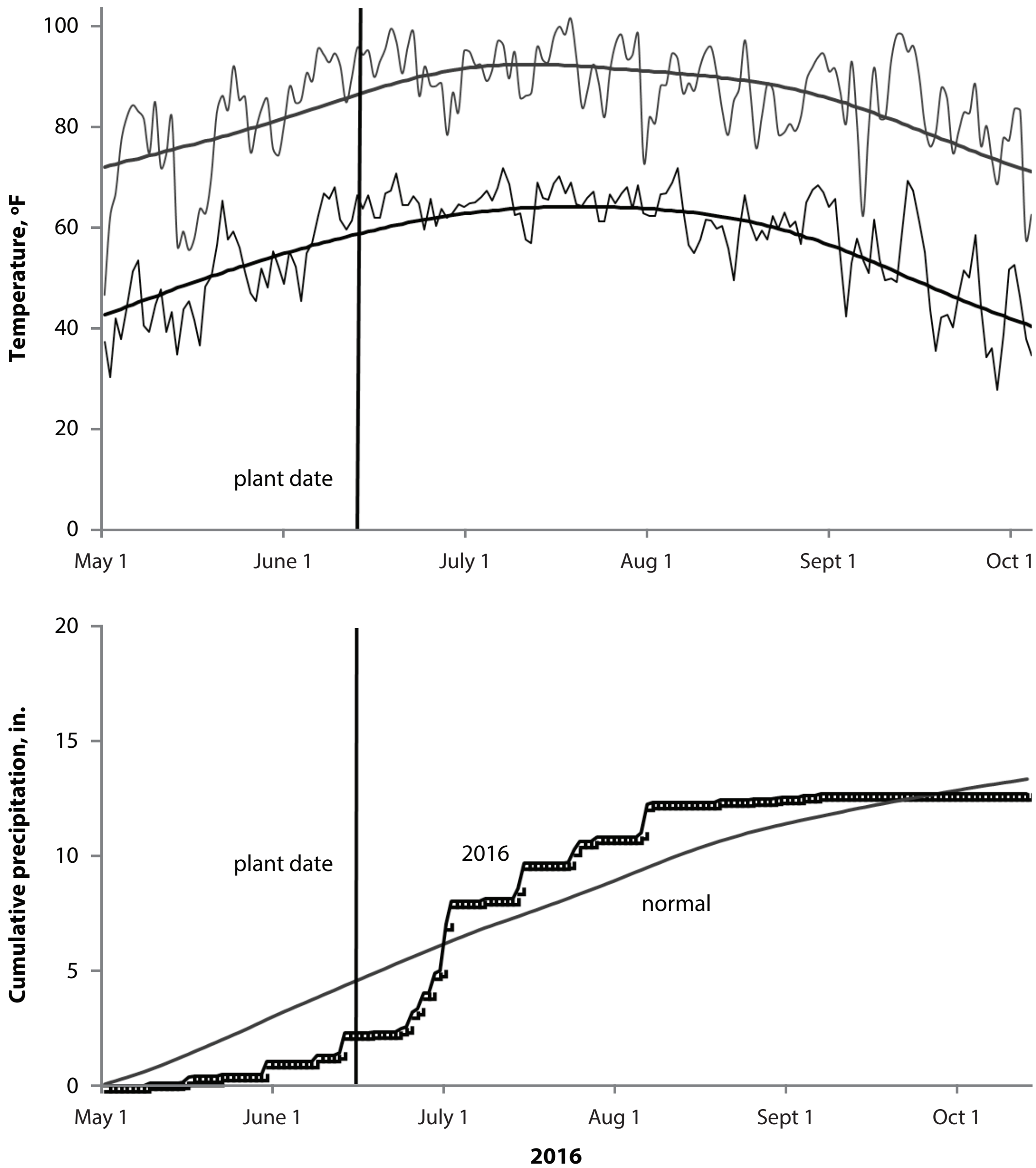



**Figure 1. Precipitation and temperature during the growing season near Garden City, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.**

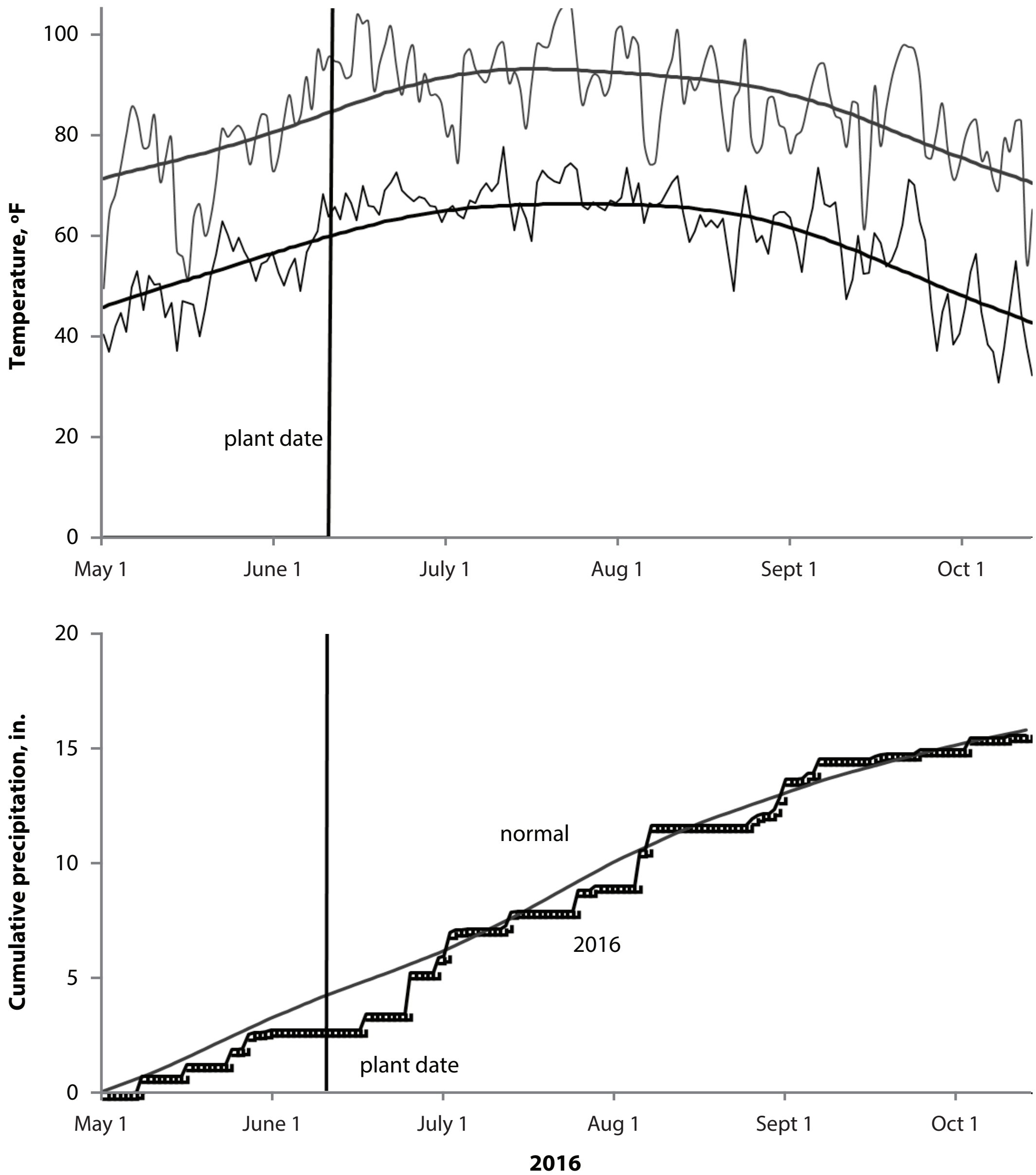



**Figure 2. Precipitation and temperature during the growing season near Hays, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.**

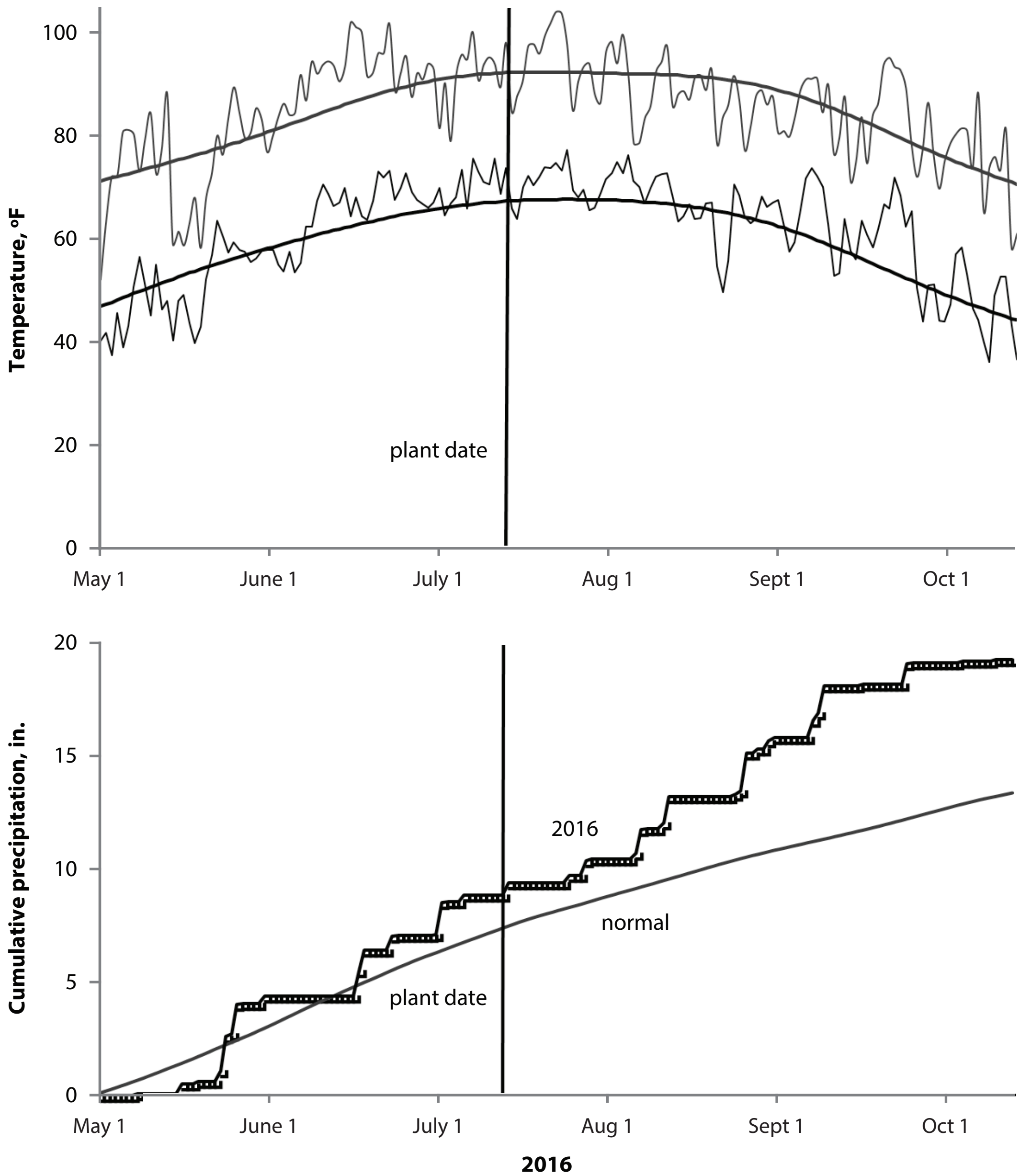



**Figure 3. Precipitation and temperature during the growing season near Hutchinson, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.**

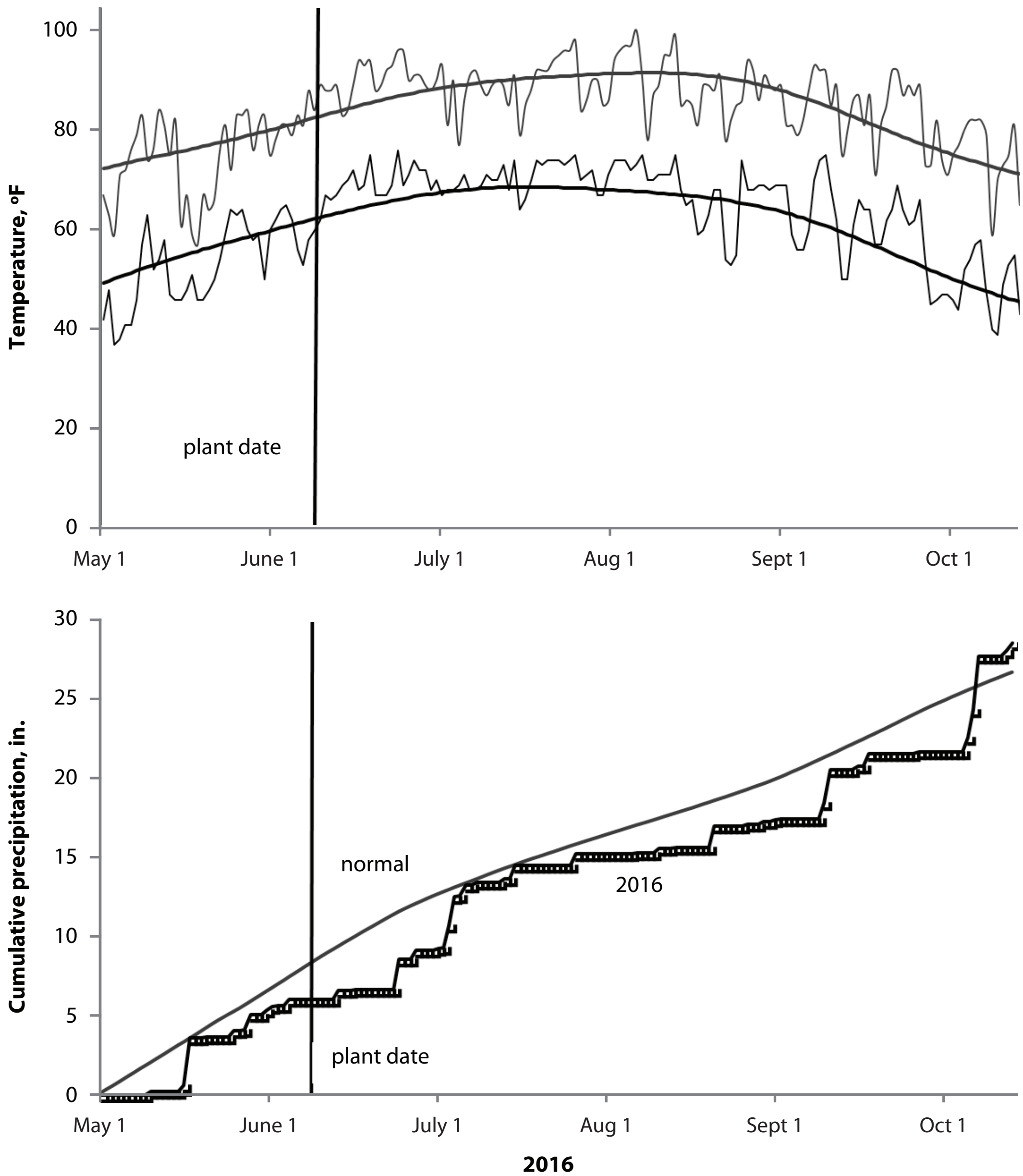



**Figure 4. Precipitation and temperature during the growing season near Mound Valley, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.**

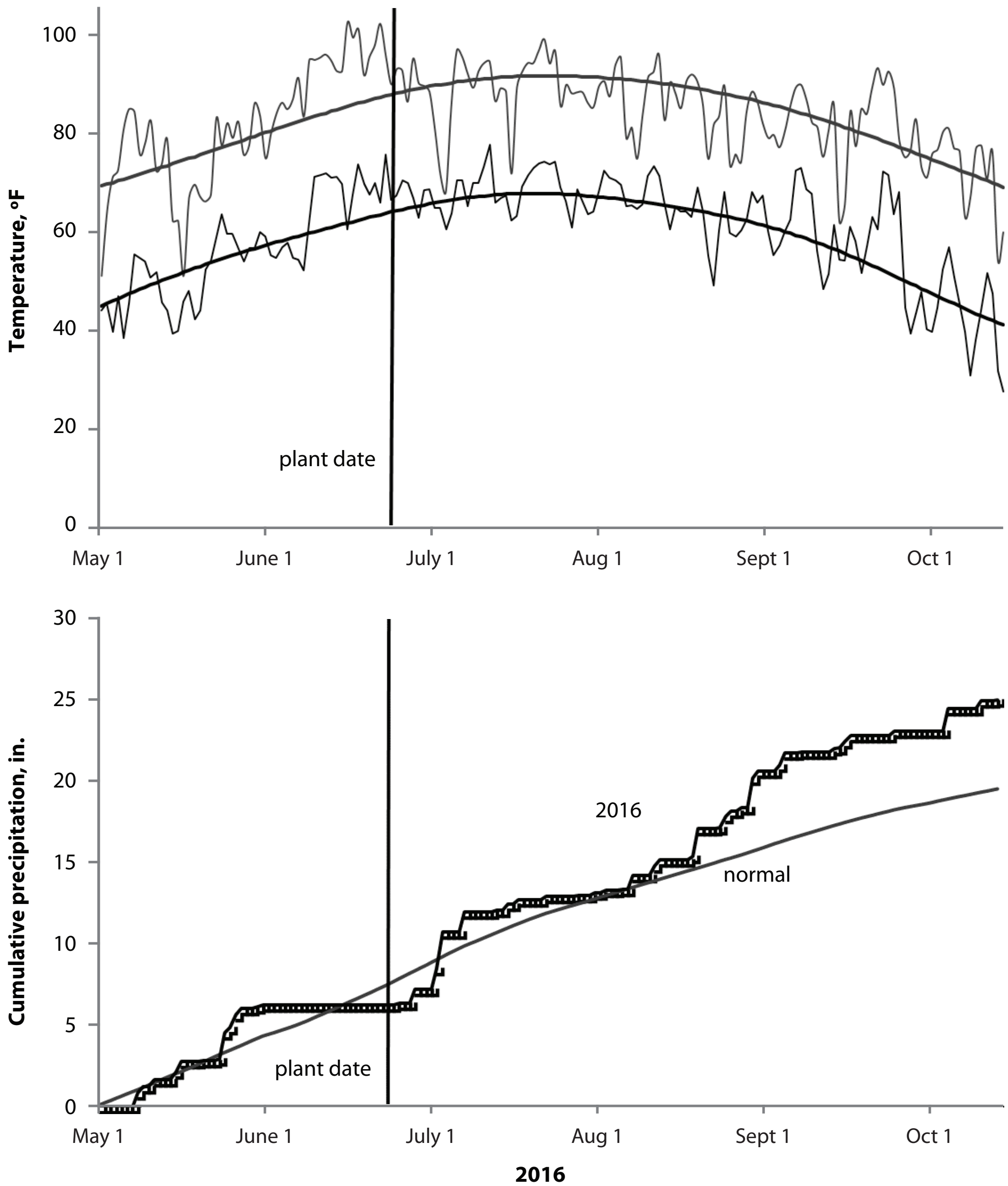



**Figure 5. Precipitation and temperature during the growing season near Scandia, KS. Top pane: daily and mean (1981 to 2010) high and low temperature. Bottom pane: daily and mean (1981 to 2010) cumulative precipitation.**

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

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

## Summary

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

## Introduction

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

## Experimental Procedures

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

### *Planting Dates and Plot Layout*

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

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

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

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

### *Data Collection and Analysis*

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

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

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

## Results and Discussion

### *Garden City*

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

### *Tribune*

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

### *Assessing Canopy Coverage/Canopy Closure*

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

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

| | Garden City | | | |
|---|---|---|---|---|
| | Days after planting | | | |
| Seeding rate | 29 | 36 | 47 | 54 |
| seeds/a | | | | |
| STAND_27[1] | 0.428 | 0.768 | 0.823 | 0.848 |
| 67,500 | 0.392 | 0.631 | 0.793 | 0.839 |
| 54,000 | 0.324 | 0.549 | 0.753 | 0.819 |
| 40,500 | 0.288 | 0.424 | 0.650 | 0.792 |
| 27,000 | 0.288 | 0.417 | 0.642 | 0.748 |
| LSD[3] | 0.077 | 0.110 | 0.100 | 0.063 |
| CV[4] | 26 | 15.6 | 6.4 | 3.6 |

| | Tribune | | | | |
|---|---|---|---|---|---|
| | Days after planting | | | | |
| Seeding rate | 23 | 32 | 38 | 45 | 65 |
| seeds/a | | | | | |
| STAND_40[2] | 0.214 | 0.347 | 0.537 | 0.749 | 0.787 |
| 80,000 | 0.223 | 0.411 | 0.634 | 0.796 | 0.803 |
| 60,000 | 0.210 | 0.338 | 0.560 | 0.756 | 0.795 |
| 40,000 | 0.209 | 0.285 | 0.520 | 0.689 | 0.771 |
| 20,000 | 0.209 | 0.248 | 0.426 | 0.664 | 0.759 |
| LSD | 0.02 | 0.064 | 0.12 | 0.076 | 0.024 |
| CV | 6.3 | 15.9 | 12.04 | 7.16 | 2 |

[1]Sorghum planted with a planter on 30 in.-row spacing at seeding rate of 27,000 seeds/a.
[2]Sorghum planted with a planter on 30 in.-row spacing at seeding rate of 40,000 seeds/a.
[3]LSD = least significant difference.
[4]CV = coefficient of variation.

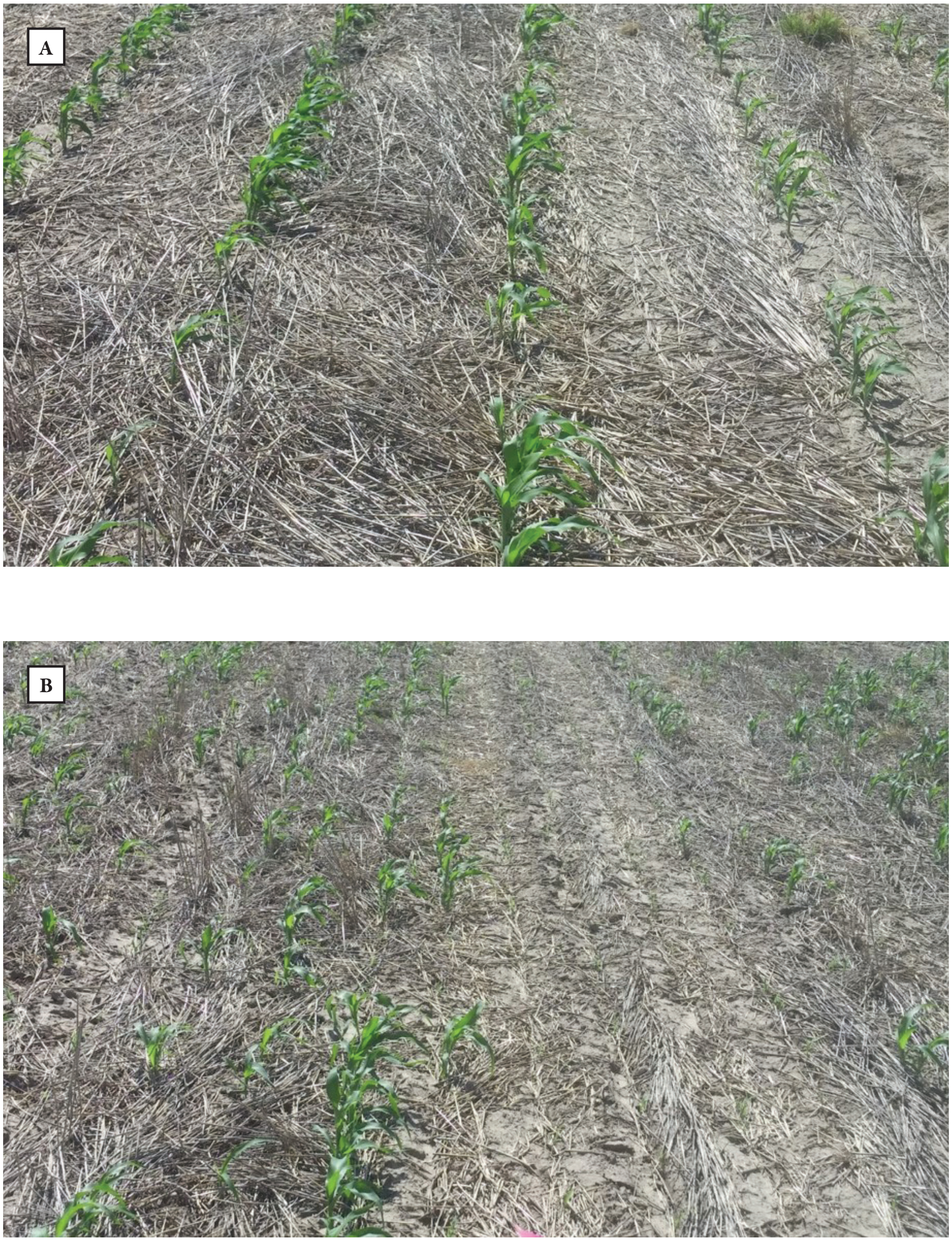


**Figure 1. Emergence of drilled and planted sorghum. A) Sorghum planted using a no-tillage air seeder drill. B) Sorghum planted using a standard 30 in. planter.**

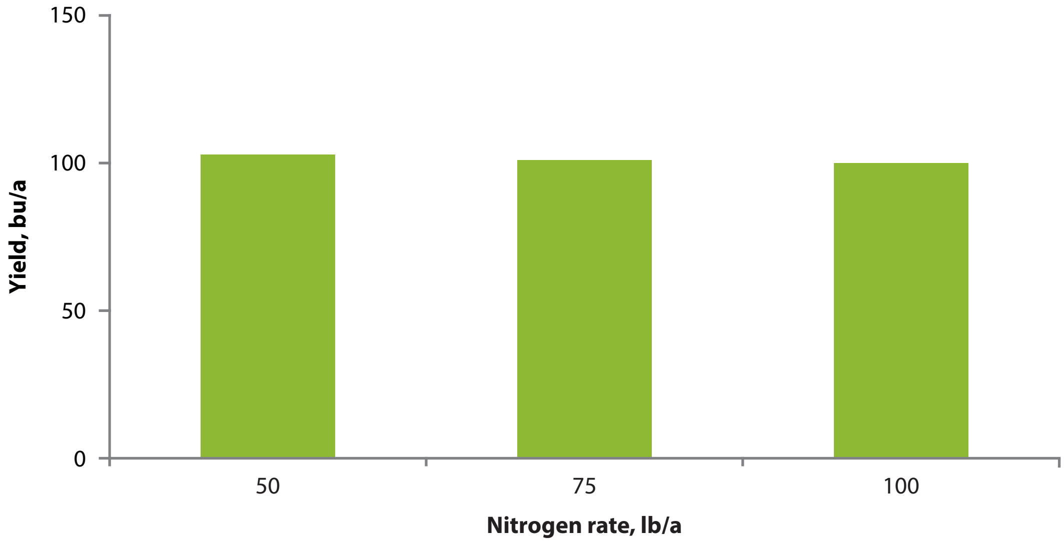


**Figure 2. Grain sorghum yield affected by nitrogen rate under four drilled seeding rates and the standard planting rate in Garden City, KS (least significant difference = 6).**

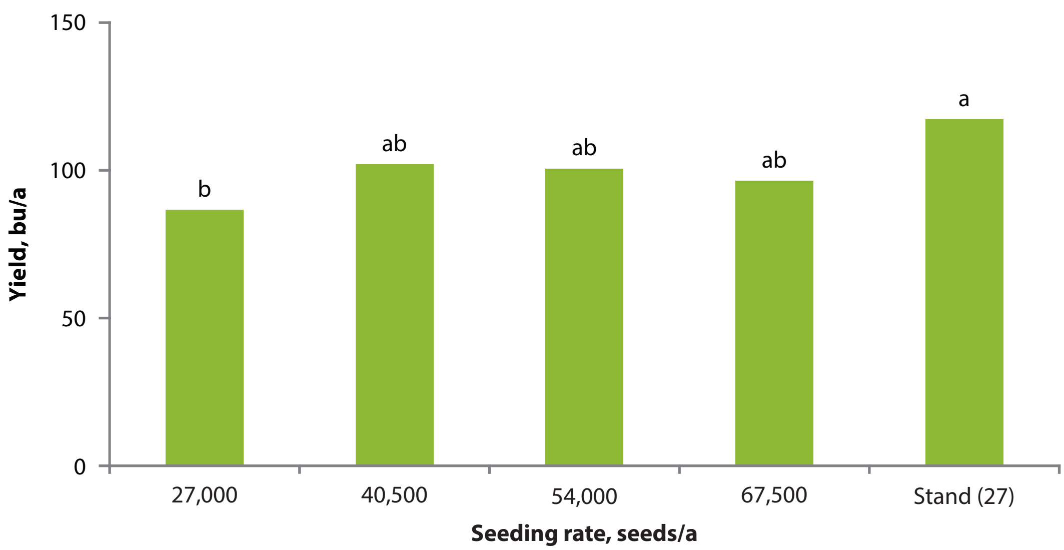


**Figure 3. Grain sorghum yield affected by four drilled seeding rates and the standard planting rate at three different nitrogen rates in Garden City, KS.**
**[ab]Means followed by same letter are not significantly different (least significant difference = 24).**

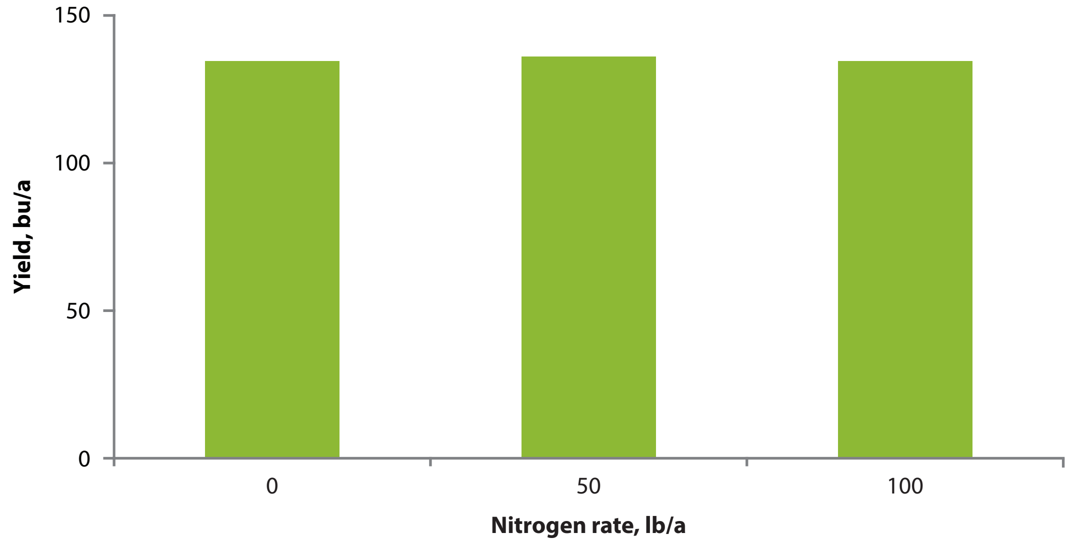


**Figure 4. Grain sorghum yield affected by N rate under four drilled seeding rates and the standard planting rate in Tribune, KS (least significant difference = 4).**

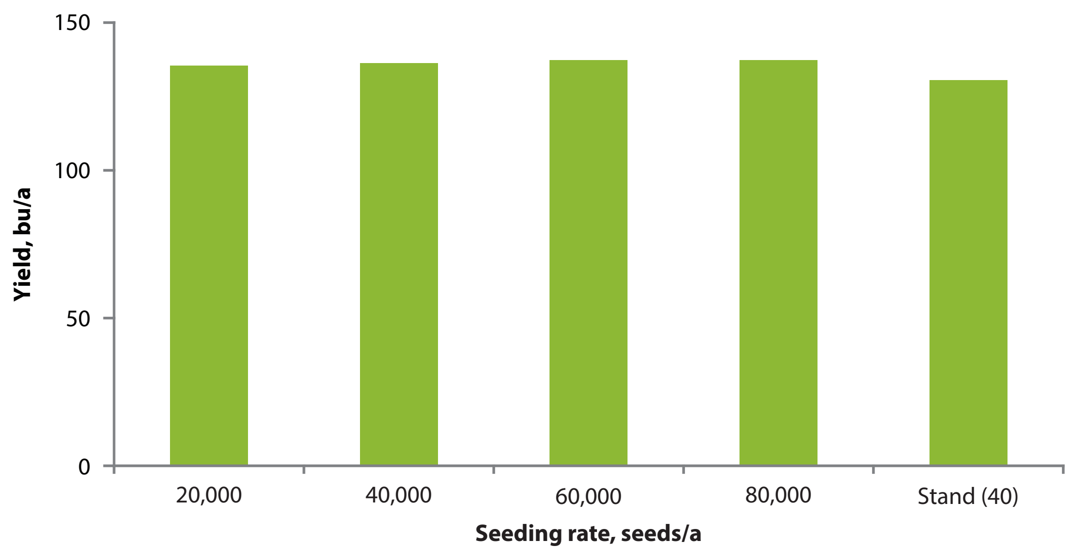


**Figure 5. Grain sorghum yield affected by four drilled seeding rates and the standard planting rate averaged across three different N rates at Tribune, KS (least significant difference = 7).**

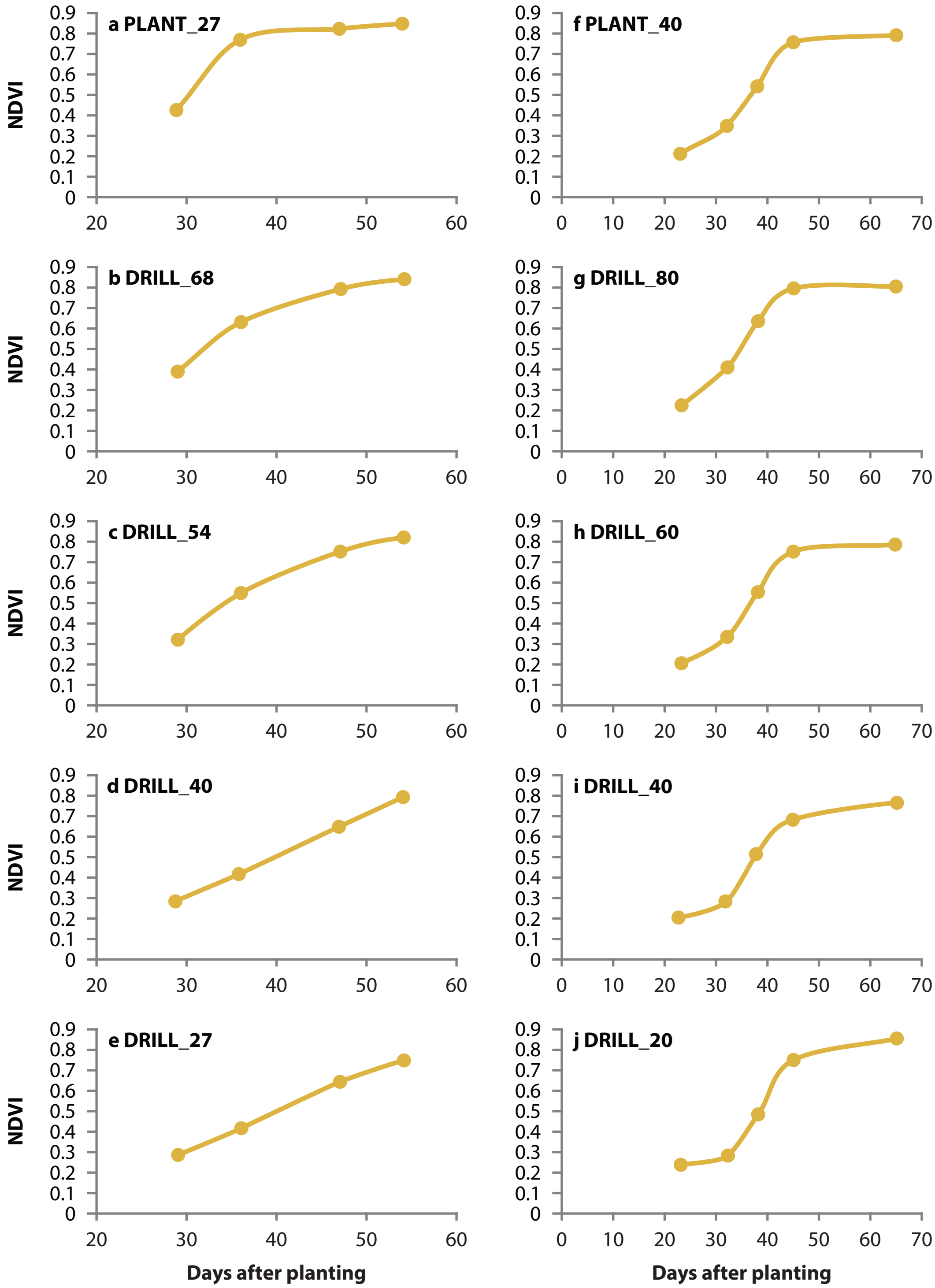


**Figure 5. Normalized difference vegetation index and days after planting in relation to drilled vs. planted sorghum for both Garden City and Tribune locations used for determining the rate of canopy closure. Garden City: (a) planted sorghum at 27,000 seeds/a, (b) drilled at 67,500 seeds/a, (c) drilled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

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

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

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

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

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

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

## Experimental Procedures

### *Treatments*

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

### *Design*

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

### *Cultural Practice*

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

### *Measurements*

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

***Plant nutrient analysis:*** 15 of the uppermost, fully expanded leaves were collected at random from each plot at tasseling (VT) and analyzed to determine the levels of primary nutrients (N, P, and K), secondary nutrients (Ca, Mg, S, and chlorine), and for micronutrients (Zn, Cu, Fe, Mn, boron (B), molybdenum (Mo), and aluminum (Al)).
***Plant health and N status:*** Sensor readings were collected within each plot using a GreenSeeker (Ntech Industries, Inc, Ukiah, CA) handheld at different growth stages and at the time of leaf sampling.

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

### *Data Analysis*

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

## Results and Discussion

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

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

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

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

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

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

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

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

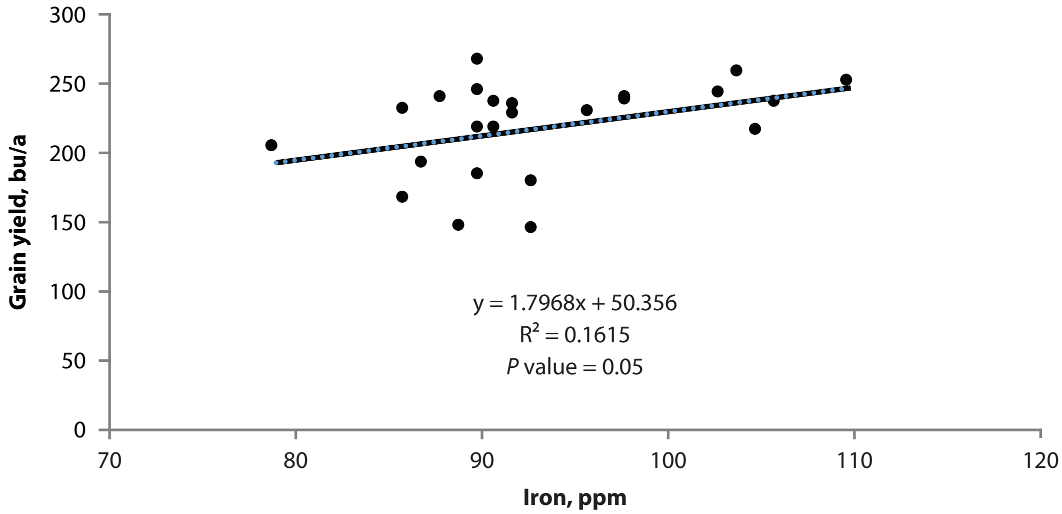


**Figure 1. Relationship between grain yield and plant iron concentration for corn grown under five irrigation capacities (0.25, 0.17, 0.13, 0.10, and 0.08 in./d) and dryland at the Kansas State University Southwest Research–Extension Center Finnup Farm near Garden City, KS.**

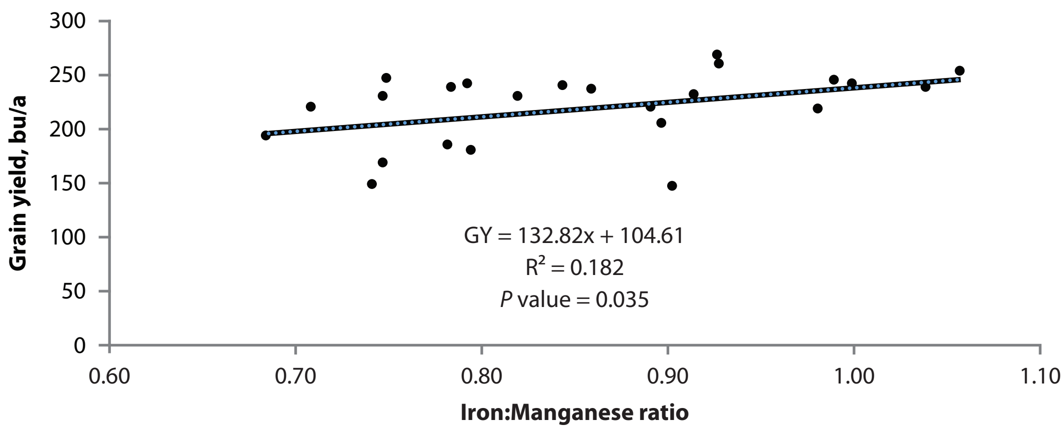


**Figure 2. Relationship between grain yield and plant Fe/Mn ratio for corn grown under five irrigation capacities (0.25, 0.17, 0.13, 0.10, and 0.08 in./d) and dryland at the Kansas State University Southwest Research–Extension Center Finnup Farm near Garden City, KS.**

# Irrigated Corn Response to Long-Term Nitrogen and Phosphorus Fertilization

*A. Schlegel and D. Bond*


## Summary

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize the production of irrigated corn in western Kansas. In 2016, N applied alone increased yields by 85 bu/a, whereas P applied alone increased yields by only 12 bu/a. Nitrogen and P applied together increased yields up to 164 bu/a. This is 20 bu/a greater than the 10-year average, where N and P fertilization increased corn yields up to 144 bu/a. Application of 120 lb/a N (with the highest P rate) produced about 94% of maximum yield in 2016, which is similar to the 10-year average. Application of 80 instead of 40 lb $P_2O_5$/a increased average yields 6 bu/a. Average grain N content reached a maximum of 0.6 lb/bu, while grain P content reached a maximum of 0.15 lb/bu (0.34 lb $P_2O_5$/bu). At the highest N and P rate, apparent fertilizer nitrogen recovery (grain) ($AFNR_g$) was 44% and apparent fertilizer phosphorus recovery (grain) ($AFPR_g$) was 62%.


## Introduction

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

## Experimental Procedures

This field study is conducted at the Tribune unit of the Kansas State University Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a without P and K; with 40 lb/a $P_2O_5$ and zero K; and with 40 lb/a $P_2O_5$ and 40 lb/a $K_2O$. The treatments were changed in 1992; the K variable was replaced by a higher rate of P (80 lb/a $P_2O_5$). All fertilizers were broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. The corn hybrids [Pioneer 33B54 (2007), Pioneer 34B99 (2008), DeKalb 61-69 (2009), Pioneer 1173H (2010), Pioneer 1151XR (2011), Pioneer 0832 (2012-2013), Pioneer 1186AM (2014), Pioneer 35F48 AM1 (2015), and Pioneer 1197 (2016)] were planted at about 32,000 seeds/a in late April or early May. Hail damaged the 2008 and 2010 crops. The corn was irrigated to minimize water stress. Sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 15.5% moisture. Grain samples were collected at harvest, dried, ground and analyzed for N and P concentrations. Grain N and P content (lb/bu) and removal (lb/a) were calculated. Apparent fertilizer N recovery in the grain ($AFNR_g$) was calculated as N uptake in treatments receiving N fertilizer minus N uptake in the unfertilized control divided by N rate. The same approach was used to calculate apparent fertilizer P recovery in the grain ($AFPR_g$).

## Results and Discussion

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

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

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

| Fertilizer | | Yield | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen | $P_2O_5$ | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Mean |
| ---- lb/a ---- | | ---- bu/a ---- | | | | | | | | | | |
| 0 | 0 | 49 | 36 | 85 | 20 | 92 | 86 | 70 | 86 | 92 | 74 | 69 |
| 0 | 40 | 50 | 57 | 110 | 21 | 111 | 85 | 80 | 95 | 103 | 78 | 79 |
| 0 | 80 | 51 | 52 | 106 | 28 | 105 | 94 | 91 | 98 | 104 | 86 | 81 |
| 40 | 0 | 77 | 62 | 108 | 23 | 114 | 109 | 97 | 106 | 113 | 105 | 91 |
| 40 | 40 | 112 | 105 | 148 | 67 | 195 | 138 | 125 | 153 | 164 | 145 | 135 |
| 40 | 80 | 116 | 104 | 159 | 61 | 194 | 135 | 126 | 149 | 162 | 135 | 134 |
| 80 | 0 | 107 | 78 | 123 | 34 | 136 | 128 | 112 | 117 | 131 | 118 | 108 |
| 80 | 40 | 163 | 129 | 179 | 85 | 212 | 197 | 170 | 187 | 195 | 196 | 171 |
| 80 | 80 | 167 | 139 | 181 | 90 | 220 | 194 | 149 | 179 | 193 | 193 | 171 |
| 120 | 0 | 106 | 65 | 117 | 28 | 119 | 134 | 114 | 115 | 124 | 109 | 103 |
| 120 | 40 | 194 | 136 | 202 | 90 | 222 | 213 | 204 | 213 | 212 | 212 | 190 |
| 120 | 80 | 213 | 151 | 215 | 105 | 225 | 211 | 194 | 216 | 216 | 223 | 197 |
| 160 | 0 | 132 | 84 | 139 | 49 | 157 | 158 | 122 | 128 | 144 | 142 | 125 |
| 160 | 40 | 220 | 150 | 210 | 95 | 229 | 227 | 199 | 211 | 215 | 226 | 198 |
| 160 | 80 | 227 | 146 | 223 | 95 | 226 | 239 | 217 | 233 | 216 | 238 | 206 |
| 200 | 0 | 159 | 99 | 155 | 65 | 179 | 170 | 139 | 144 | 162 | 159 | 143 |
| 200 | 40 | 224 | 152 | 207 | 97 | 218 | 225 | 198 | 204 | 214 | 216 | 196 |
| 200 | 80 | 232 | 157 | 236 | 104 | 231 | 260 | 220 | 238 | 221 | 235 | 213 |

*continued*

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

| Fertilizer | | Yield | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen | $P_2O_5$ | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Mean |
| ---------------- lb/a ---------------- | | ---------- bu/a ---------- | | | | | | | | | | |
| Analysis of variance (ANOVA) (P >F) | | | | | | | | | | | | |
| Nitrogen | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Linear | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Quadratic | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Phosphorus | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Linear | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Quadratic | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Nitrogen × Phosphorus | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Means[1] | | | | | | | | | | | | |
| Nitrogen, lb/a | | | | | | | | | | | | |
| 0 | | 50f | 48e | 100e | 23e | 103d | 88f | 80e | 93e | 100e | 79e | 76e |
| 40 | | 102e | 91d | 138d | 50d | 167c | 127e | 116d | 136d | 146d | 129d | 120d |
| 80 | | 146d | 115c | 161c | 70c | 189b | 173d | 143c | 161c | 173c | 169c | 150c |
| 120 | | 171c | 118c | 178b | 74bc | 189b | 186c | 171b | 181b | 184b | 182b | 163b |
| 160 | | 193b | 127b | 191a | 80ab | 204a | 208b | 179ab | 190ab | 192ab | 202a | 177a |
| 200 | | 205a | 136a | 199a | 89a | 209a | 218a | 186a | 196a | 199a | 203a | 184a |
| Least significant difference$_{(0.05)}$ | | 11 | 9 | 12 | 9 | 13 | 10 | 10 | 10 | 9 | 10 | 8 |
| $P_2O_5$, lb/a | | | | | | | | | | | | |
| 0 | | 105b | 71b | 121c | 36b | 133b | 131c | 109b | 116c | 128b | 118b | 107c |
| 40 | | 160a | 122a | 176b | 76a | 198a | 181b | 163a | 177b | 184a | 179a | 162b |
| 80 | | 168a | 125a | 187a | 81a | 200a | 189a | 166a | 186a | 185a | 185a | 167a |
| Least significant difference$_{(0.05)}$ | | 8 | 6 | 9 | 7 | 9 | 7 | 7 | 7 | 6 | 7 | 5 |

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

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

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

| Fertilizer | | Grain | | | | Grain removal | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nitrogen | $P_2O_5$ | N | P | N | P | N | P | *$AFNR_g$ | *$AFPR_g$ |
| ---------- lb/a ---------- | | ---------- % ---------- | | ---------- lb/bu ---------- | | ---------- lb/a ---------- | | ---------- % ---------- | |
| 0 | 0 | 0.99 | 0.230 | 0.47 | 0.109 | 31 | 7 | --- | --- |
| 0 | 40 | 0.95 | 0.312 | 0.45 | 0.147 | 35 | 12 | --- | 24 |
| 0 | 80 | 0.96 | 0.321 | 0.45 | 0.152 | 36 | 12 | --- | 14 |
| | | | | | | | | | |
| 40 | 0 | 1.15 | 0.182 | 0.55 | 0.086 | 49 | 8 | 45 | --- |
| 40 | 40 | 0.97 | 0.301 | 0.46 | 0.143 | 61 | 19 | 75 | 67 |
| 40 | 80 | 0.98 | 0.323 | 0.46 | 0.153 | 61 | 21 | 75 | 37 |
| | | | | | | | | | |
| 80 | 0 | 1.26 | 0.177 | 0.60 | 0.084 | 64 | 9 | 40 | --- |
| 80 | 40 | 1.05 | 0.257 | 0.50 | 0.122 | 84 | 21 | 66 | 74 |
| 80 | 80 | 1.03 | 0.310 | 0.49 | 0.147 | 82 | 25 | 63 | 49 |
| | | | | | | | | | |
| 120 | 0 | 1.25 | 0.170 | 0.59 | 0.081 | 61 | 8 | 24 | --- |
| 120 | 40 | 1.14 | 0.226 | 0.54 | 0.107 | 102 | 20 | 58 | 71 |
| 120 | 80 | 1.10 | 0.297 | 0.52 | 0.140 | 102 | 28 | 59 | 57 |
| | | | | | | | | | |
| 160 | 0 | 1.25 | 0.176 | 0.59 | 0.083 | 73 | 10 | 26 | --- |
| 160 | 40 | 1.18 | 0.242 | 0.56 | 0.114 | 110 | 22 | 49 | 84 |
| 160 | 80 | 1.17 | 0.281 | 0.56 | 0.133 | 114 | 27 | 51 | 55 |
| | | | | | | | | | |
| 200 | 0 | 1.24 | 0.186 | 0.59 | 0.088 | 83 | 12 | 26 | --- |
| 200 | 40 | 1.20 | 0.239 | 0.57 | 0.113 | 110 | 22 | 39 | 82 |
| 200 | 80 | 1.19 | 0.295 | 0.56 | 0.140 | 119 | 30 | 44 | 62 |

*continued*

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

| Fertilizer | | Grain | | | | Grain removal | | | |
|---|---|---|---|---|---|---|---|---|---|
| Nitrogen | $P_2O_5$ | N | P | N | P | N | P | *$AFNR_g$ | *$AFPR_g$ |
| ---------- lb/a ---------- | | ------ % ------ | | ------ lb/bu ------ | | ------ lb/a ------ | | ------ % ------ | |
| Analysis of variance (ANOVA) (P >F) | | | | | | | | | |
| Nitrogen | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Linear | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | --- | 0.001 |
| Quadratic | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | --- | 0.001 |
| Phosphorus | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Linear | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | --- |
| Quadratic | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | --- |
| Nitrogen × phosphorus | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.036 | 0.126 |
| Means [1] | | | | | | | | | |
| Nitrogen, lb/a | | | | | | | | | |
| 0 | | 0.97e | 0.288a | 0.46e | 0.136a | 34f | 10e | --- | 19d |
| 40 | | 1.04d | 0.269b | 0.49d | 0.127b | 57e | 16d | 65a | 52c |
| 80 | | 1.11c | 0.248c | 0.53c | 0.117c | 77d | 18c | 56b | 62b |
| 120 | | 1.16b | 0.231d | 0.55b | 0.109d | 88c | 19c | 47c | 64ab |
| 160 | | 1.20a | 0.233d | 0.57a | 0.110d | 99b | 20b | 42d | 70ab |
| 200 | | 1.21a | 0.240cd | 0.57a | 0.114cd | 104a | 21a | 36e | 72a |
| Least significant difference$_{(0.05)}$ | | 0.02 | 0.011 | 0.01 | 0.005 | 4 | 1 | 5 | 8 |
| $P_2O_5$, lb/a | | | | | | | | | |
| 0 | | 1.19a | 0.187c | 0.56a | 0.088c | 60b | 9c | 32b | --- |
| 40 | | 1.08b | 0.263b | 0.51b | 0.124b | 84a | 19b | 57a | 67a |
| 80 | | 1.07b | 0.304a | 0.51b | 0.144a | 86a | 24a | 58a | 46b |
| Least significant difference$_{(0.05)}$ | | 0.01 | 0.008 | 0.01 | 0.004 | 3 | 1 | 4 | 5 |

*$AFNR_g$ and $AFPR_g$ = Apparent Fertilizer N Recovery (grain) and Apparent Fertilizer P Recovery (grain).

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

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

*A. Schlegel and D. Bond*


## Summary

Long-term research shows that phosphorus (P) and nitrogen (N) fertilizer must be applied to optimize production of irrigated grain sorghum in western Kansas. In 2016, N applied alone increased yields 71 bu/a, whereas N and P applied together increased yields up to 93 bu/a. Averaged across the past 10 years, N and P fertilization increased sorghum yields up to 77 bu/a. Application of 80 lb/a N (with P) was sufficient to produce 89% of maximum yield in 2016, which is slightly less than the 10-yr average. Application of potassium (K) has had no effect on sorghum yield throughout the study period. Average grain N content reached a maximum of ~0.7 lb/bu while grain P content reached a maximum of 0.15 lb/bu (0.34 lb $P_2O_5$/bu) and grain K content reached a maximum of 0.19 lb/bu (0.23 lb $K_2O$/bu). At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 33% for N, 69% for P, and 40% for K.


## Introduction

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

## Experimental Procedures

This field study is conducted at the Tribune unit of the Southwest Research-Extension Center. Fertilizer treatments initiated in 1961 are N rates of 0, 40, 80, 120, 160, and 200 lb/a N without P and K; with 40 lb/a $P_2O_5$ and zero K; and with 40 lb/a $P_2O_5$ and 40 lb/a $K_2O$. All fertilizers are broadcast by hand in the spring and incorporated before planting. The soil is a Ulysses silt loam. Sorghum (Pioneer 8505 in 2007, Pioneer 85G46 in 2008-2011, Pioneer 84G62 in 2012-2014, Pioneer 86G32 in 2015, and Pioneer 84G62 in 2016) was planted in late May or early June. Irrigation is used to minimize water stress. Sprinkler irrigation has been used since 2001. The center two rows of each plot are machine harvested after physiological maturity. Grain yields are adjusted to 12.5% moisture. Grain samples were collected at harvest, dried, ground and analyzed for N, P, and K concentrations. Grain N, P, and K content (lb/bu) and removal (lb/a) were calculated. Apparent fertilizer N recovery in the grain ($AFNR_g$) was calculated as N uptake in treatments receiving N fertilizer minus N uptake in the unfertilized control divided by N rate. The same approach was used to calculate apparent fertilizer P recovery in the grain ($AFPR_g$) and apparent fertilizer K recovery ($AFKR_g$).

## Results and Discussion

Grain sorghum yields in 2016 were 10% greater than the 10-year average (Table 1). Nitrogen alone increased yields 71 bu/a while P alone increased yields 11 bu/a. However, N and P applied together increased yields up to 93 bu/a. Averaged across the past 10 years, N and P applied together increased yields up to 77 bu/a. In 2016, 40 lb/a N (with P) produced about 82% of maximum yield, which is slightly less than the 10-year average of 84%. The 10-year average for 80 lb/a N (with P) and 120 lb/a N (with P) was 93 and 96% of maximum yield, respectively. Sorghum yields were not affected by K fertilization, which has been the case throughout the study period.

The 10-year average grain N concentration (%) increased with N rates but tended to decrease when P was also applied, presumably because of higher grain yields diluting N content (Table 2). Grain N content reached a maximum of ~0.7 lb/bu. Maximum N removal (lb/a) was obtained with 160 lb N/a or greater with P. Similar to N, average P concentration increased with P application but decreased with higher N rates. Grain P content (lb/bu) of ~0.15 lb P/bu (0.34 lb $P_2O_5$/bu) was similar for all N rates when P was applied. Grain P removal was similar for all N rates of 40 lb/a or greater, with P removal ranging from 19 to 23 lb/a. Average K concentration (%) and content (lb/bu) tended to decrease with increased N rates. Similar to P, K removal was similar for all N rates of 40 lb/a or greater plus K, ranging from 23 to 27 lb/a. At the highest N, P, and K rate, apparent fertilizer recovery in the grain was 33% for N, 69% for P, and 40% for K.

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

| Fertilizer | | | Grain sorghum yield | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen | $P_2O_5$ | $K_2O$ | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Mean |
| lb/a | | | bu/a | | | | | | | | | | |
| 0 | 0 | 0 | 80 | 66 | 64 | 51 | 75 | 78 | 62 | 90 | 89 | 80 | 74 |
| 0 | 40 | 0 | 97 | 60 | 70 | 51 | 83 | 90 | 77 | 94 | 102 | 91 | 82 |
| 0 | 40 | 40 | 94 | 65 | 76 | 55 | 88 | 93 | 72 | 96 | 97 | 91 | 83 |
| 40 | 0 | 0 | 123 | 92 | 84 | 66 | 106 | 115 | 94 | 115 | 122 | 106 | 102 |
| 40 | 40 | 0 | 146 | 111 | 118 | 77 | 121 | 140 | 114 | 144 | 160 | 142 | 127 |
| 40 | 40 | 40 | 145 | 105 | 109 | 73 | 125 | 132 | 110 | 142 | 155 | 137 | 123 |
| 80 | 0 | 0 | 138 | 114 | 115 | 73 | 117 | 132 | 102 | 120 | 133 | 120 | 116 |
| 80 | 40 | 0 | 159 | 128 | 136 | 86 | 140 | 163 | 136 | 151 | 173 | 154 | 143 |
| 80 | 40 | 40 | 166 | 126 | 108 | 84 | 138 | 161 | 133 | 164 | 178 | 160 | 142 |
| 120 | 0 | 0 | 138 | 106 | 113 | 70 | 116 | 130 | 100 | 116 | 127 | 108 | 112 |
| 120 | 40 | 0 | 164 | 131 | 130 | 88 | 145 | 172 | 137 | 162 | 177 | 164 | 147 |
| 120 | 40 | 40 | 165 | 136 | 136 | 90 | 147 | 175 | 142 | 170 | 178 | 170 | 151 |
| 160 | 0 | 0 | 146 | 105 | 108 | 74 | 124 | 149 | 117 | 139 | 150 | 135 | 125 |
| 160 | 40 | 0 | 170 | 138 | 128 | 92 | 152 | 178 | 146 | 171 | 181 | 173 | 153 |
| 160 | 40 | 40 | 167 | 133 | 140 | 88 | 151 | 174 | 143 | 176 | 179 | 161 | 151 |
| 200 | 0 | 0 | 154 | 120 | 110 | 78 | 128 | 147 | 119 | 139 | 155 | 151 | 130 |
| 200 | 40 | 0 | 168 | 137 | 139 | 84 | 141 | 171 | 136 | 165 | 177 | 167 | 149 |
| 200 | 40 | 40 | 170 | 135 | 129 | 87 | 152 | 175 | 138 | 170 | 179 | 170 | 151 |

*continued*

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

| Fertilizer | | | Grain sorghum yield | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen | $P_2O_5$ | $K_2O$ | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Mean |
| ------------------ lb/a ------------------ | | | ---------- bu/a ---------- | | | | | | | | | | |
| Analysis of variance (ANOVA) (P > F) | | | | | | | | | | | | | |
| Nitrogen | | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Linear | | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Quadratic | | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| P-K | | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Zero P vs. P | | | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| P vs. P-K | | | 0.992 | 0.745 | 0.324 | 0.892 | 0.278 | 0.826 | 0.644 | 0.117 | 0.806 | 0.943 | 0.974 |
| N × P-K | | | 0.965 | 0.005 | 0.053 | 0.229 | 0.542 | 0.186 | 0.079 | 0.012 | 0.002 | 0.001 | 0.012 |
| Means [1] | | | | | | | | | | | | | |
| Nitrogen, lb/a | | | | | | | | | | | | | |
| 0 | | | 91d | 64d | 70c | 52c | 82d | 87d | 70d | 94e | 96d | 87d | 79d |
| 40 | | | 138c | 103c | 104b | 72b | 117c | 129c | 106c | 134d | 146c | 129c | 118c |
| 80 | | | 155b | 123b | 120a | 81a | 132b | 152b | 124b | 145c | 161b | 145b | 134b |
| 120 | | | 156ab | 124ab | 126a | 82a | 136ab | 159ab | 126b | 149bc | 161b | 147b | 137b |
| 160 | | | 161ab | 125ab | 125a | 84a | 142a | 167a | 135a | 162a | 170a | 156a | 143a |
| 200 | | | 164a | 131a | 126a | 83a | 141a | 165a | 131ab | 158ab | 170a | 163a | 143a |
| Least significant difference$_{(0.05)}$ | | | 9 | 7 | 11 | 5 | 8 | 9 | 8 | 9 | 8 | 8 | 6 |
| $P_2O_5$-$K_2O$, lb/a | | | | | | | | | | | | | |
| 0 - 0 | | | 130b | 101b | 99b | 68b | 111b | 125b | 99b | 120b | 129b | 117b | 110b |
| 40 - 0 | | | 151a | 117a | 120a | 80a | 130a | 152a | 124a | 148a | 162a | 149a | 133a |
| 40 - 40 | | | 151a | 117a | 116a | 79a | 133a | 152a | 123a | 153a | 161a | 148a | 133a |
| Least significant difference$_{(0.05)}$ | | | 6 | 5 | 7 | 4 | 6 | 6 | 5 | 6 | 5 | 6 | 4 |

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

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

| Fertilizer | | | Grain | | | | | | Grain removal | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | $P_2O_5$ | $K_2O$ | N | P | K | N | P | K | N | P | K | *$AFNR_g$ | *$AFPR_g$ | *$AFKR_g$ |
| lb/a | | | % | | | lb/bu | | | lb/acre | | | % | | |
| 0 | 0 | 0 | 1.04 | 0.267 | 0.370 | 0.51 | 0.131 | 0.181 | 37 | 9 | 13 | --- | --- | --- |
| 0 | 40 | 0 | 1.02 | 0.314 | 0.389 | 0.50 | 0.154 | 0.191 | 41 | 13 | 16 | --- | 18 | --- |
| 0 | 40 | 40 | 1.02 | 0.312 | 0.386 | 0.50 | 0.153 | 0.189 | 41 | 13 | 16 | --- | 18 | 7 |
| 40 | 0 | 0 | 1.14 | 0.239 | 0.344 | 0.56 | 0.117 | 0.169 | 57 | 12 | 17 | 49 | --- | --- |
| 40 | 40 | 0 | 1.11 | 0.318 | 0.377 | 0.54 | 0.156 | 0.185 | 69 | 20 | 24 | 79 | 59 | --- |
| 40 | 40 | 40 | 1.11 | 0.311 | 0.373 | 0.54 | 0.152 | 0.183 | 67 | 19 | 23 | 73 | 53 | 28 |
| 80 | 0 | 0 | 1.35 | 0.226 | 0.339 | 0.66 | 0.111 | 0.166 | 76 | 13 | 19 | 49 | --- | --- |
| 80 | 40 | 0 | 1.23 | 0.299 | 0.360 | 0.60 | 0.146 | 0.176 | 85 | 21 | 25 | 60 | 65 | --- |
| 80 | 40 | 40 | 1.20 | 0.311 | 0.367 | 0.59 | 0.153 | 0.180 | 83 | 22 | 25 | 57 | 69 | 37 |
| 120 | 0 | 0 | 1.40 | 0.213 | 0.335 | 0.69 | 0.104 | 0.164 | 77 | 12 | 18 | 33 | --- | --- |
| 120 | 40 | 0 | 1.33 | 0.287 | 0.354 | 0.65 | 0.141 | 0.174 | 95 | 21 | 26 | 48 | 63 | --- |
| 120 | 40 | 40 | 1.33 | 0.309 | 0.360 | 0.65 | 0.151 | 0.176 | 98 | 23 | 27 | 50 | 76 | 40 |
| 160 | 0 | 0 | 1.43 | 0.233 | 0.345 | 0.70 | 0.114 | 0.169 | 87 | 14 | 21 | 31 | --- | --- |
| 160 | 40 | 0 | 1.39 | 0.309 | 0.362 | 0.68 | 0.151 | 0.177 | 104 | 23 | 27 | 42 | 78 | --- |
| 160 | 40 | 40 | 1.36 | 0.288 | 0.355 | 0.66 | 0.141 | 0.174 | 100 | 21 | 26 | 39 | 67 | 39 |
| 200 | 0 | 0 | 1.43 | 0.239 | 0.348 | 0.70 | 0.117 | 0.171 | 91 | 15 | 22 | 27 | --- | --- |
| 200 | 40 | 0 | 1.39 | 0.288 | 0.361 | 0.68 | 0.141 | 0.177 | 101 | 21 | 26 | 32 | 66 | --- |
| 200 | 40 | 40 | 1.40 | 0.294 | 0.361 | 0.69 | 0.144 | 0.177 | 103 | 22 | 27 | 33 | 69 | 40 |

*continued*

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

| Fertilizer | Grain | | | | | | Grain removal | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N $P_2O_5$ $K_2O$ | N | P | K | N | P | K | N | P | K | *$AFNR_g$ | *$AFPR_g$ | *$AFKR_g$ |
| ---------------- lb/a ---------------- | --------------- % --------------- | | | ------------- lb/bu ------------- | | | ------------ lb/acre ------------ | | | ----------------- % ----------------- | | |
| Analysis of variance (ANOVA) (P > F) | | | | | | | | | | | | |
| Nitrogen | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Linear | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Quadratic | 0.001 | 0.014 | 0.001 | 0.001 | 0.014 | 0.001 | 0.001 | 0.001 | 0.001 | 0.054 | 0.001 | 0.001 |
| P-K | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.790 | --- |
| Zero P vs. P | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | --- | --- | --- |
| P vs. P-K | 0.435 | 0.707 | 0.963 | 0.435 | 0.707 | 0.963 | 0.672 | 0.822 | 0.991 | --- | --- | --- |
| N × P-K | 0.407 | 0.014 | 0.083 | 0.407 | 0.014 | 0.083 | 0.101 | 0.001 | 0.007 | 0.001 | --- | --- |
| Means[1] | | | | | | | | | | | | |
| Nitrogen, lb/a | | | | | | | | | | | | |
| 0 | 1.03e | 0.298a | 0.382a | 0.50e | 0.146a | 0.187a | 40e | 12c | 15d | --- | 18c | 7c |
| 40 | 1.12d | 0.289ab | 0.365b | 0.55d | 0.142ab | 0.179b | 64d | 17b | 21c | 67a | 56b | 28b |
| 80 | 1.26c | 0.279bc | 0.355cd | 0.62c | 0.137bc | 0.174cd | 82c | 18a | 23b | 55b | 67a | 37a |
| 120 | 1.35b | 0.269c | 0.350d | 0.66b | 0.132c | 0.171d | 90b | 18a | 24b | 44c | 69a | 40a |
| 160 | 1.39ab | 0.277bc | 0.354cd | 0.68ab | 0.136bc | 0.174cd | 97a | 19a | 25a | 37d | 72a | 39a |
| 200 | 1.41a | 0.274c | 0.357c | 0.69a | 0.134c | 0.175c | 98a | 19a | 25a | 30e | 67a | 40a |
| Least significant difference$_{(0.05)}$ | 0.04 | 0.012 | 0.006 | 0.02 | 0.006 | 0.003 | 4 | 1 | 1 | 6 | 8 | 4 |
| $P_2O_5$-$K_2O$, lb/a | | | | | | | | | | | | |
| 0 - 0 | 1.30a | 0.236b | 0.347b | 0.64a | 0.116b | 0.170b | 71b | 13b | 19b | 38b | --- | --- |
| 40 - 0 | 1.25b | 0.303a | 0.367a | 0.61b | 0.148a | 0.180a | 82a | 20a | 24a | 52a | 58 | --- |
| 40 - 40 | 1.24b | 0.304a | 0.367a | 0.61b | 0.149a | 0.180a | 82a | 20a | 24a | 51a | 59 | --- |
| Least significant difference$_{(0.05)}$ | 0.03 | 0.009 | 0.004 | 0.01 | 0.004 | 0.002 | 3 | 1 | 1 | 4 | 5 | --- |

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

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

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

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

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

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

## Experimental Procedures
An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to examine the efficacy of fall and spring preemergence herbicides in fallow. Fall applications were applied December 3, 2015, and spring treatments were applied March 3, 2016. All herbicides were applied using a tractor-mounted, $CO_2$-pressurized plot sprayer, delivering 20 gallons per acre (GPA) at 30 psi and 4.1 mph. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and a cation exchange capacity of 18.4. Plots were 10- by 35-feet. The experimental design was a randomized complete block and treatments were replicated four times. Visual kochia control was determined on April 6, May 26, and July 28, 2016, which was 5, 12, and 21 weeks after spring applications (WAST), respectively.

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

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

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

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

*continued*

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

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

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

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

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

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

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

## Experimental Procedures
An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to examine the efficacy of single and sequential herbicide treatments in fallow. Application, environmental, and weed information are given in Table 1. All herbicides were applied using a compressed-$CO_2$ backpack sprayer, delivering 20 GPA at 3.0 mph and 27 psi. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Plots were 10- by 35-feet, arranged in a randomized complete block design with four replications. Control of kochia, Palmer amaranth, and Russian thistle were visually determined on June 9 and July 6, 2016, which were 15 and 42 days after the May 25 application, respectively.

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

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

**Table 1. Application information**

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

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

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

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

# Preemergence and Post-Harvest Kochia Control in Wheat

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

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

## Introduction
A scheduled approach of herbicides before and after wheat harvest is needed for effective season-long weed control. Clarity, Distinct, Prowl $H_2O$ (pendimethalin), Rave (dicamba + triasulfuron), and Zidua (pyroxasulfone) have all shown activity on the normal weed spectrum seen in this region. The various combinations and timings of application to achieve effective weed control with these herbicides are not known. Therefore, it was the objective of this study to explore various combinations and timings of these compounds for season-long weed control.

## Experimental Procedures
An experiment was conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, to examine the efficacy of preemergence and/or post-harvest dicamba tank mixtures in winter wheat. Herbicides were applied March 3, 2016 (preemergence to kochia), and July 11, 2016 (postemergence following wheat harvest). Treatments were applied using a $CO_2$-compressed, tractor-mounted or backpack sprayer, delivering 20 GPA at 3.0 mph and 27 or 30 psi. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Plot size was 10- by 40-feet and arranged in a split-plot design replicated four times, with preemergence herbicide as the main plot and post-harvest herbicides as the subplots. Wheat was removed from the experiment June 20, 2016, but no yield data were collected. Kochia control was evaluated visually on March 4, July 11, July 25, and August 12, 2016. These dates were 29 and 130 days after the preemergence treatments and 14 and 32 days after the post-harvest treatments, respectively.

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

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

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

| | | | Kochia | | | |
|---|---|---|---|---|---|---|
| Herbicide[a] | Rate | Timing | March 4 | July 11 | July 25 | August 12 |
| | oz/a | | --- % control --- | | | |
| Glyphosate | 32 | POST-Harvest | --- | --- | 60 | 85 |
| Distinct | 6 | POST-Harvest | | | | |
| COC | 1% | POST-Harvest | | | | |
| AMS | 2% | POST-Harvest | | | | |
| Clarity | 4 | Preemergence | 80 | 25 | 25 | 20 |
| MCPA ester | 8 | Preemergence | | | | |
| Zidua | 2 | Preemergence | | | | |
| NIS | 0.125% | Preemergence | | | | |
| Clarity | 4 | Preemergence | 80 | 25 | 70 | 86 |
| MCPA ester | 8 | Preemergence | | | | |
| Zidua | 2 | Preemergence | | | | |
| NIS | 0.125% | Preemergence | | | | |
| Glyphosate | 32 | POST-Harvest | | | | |
| Distinct | 6 | POST-Harvest | | | | |
| COC | 1% | POST-Harvest | | | | |
| AMS | 2% | POST-Harvest | | | | |
| Clarity | 4 | Preemergence | 83 | 33 | 20 | 20 |
| MCPA ester | 8 | Preemergence | | | | |
| Prowl $H_2O$ | 32 | Preemergence | | | | |
| NIS | 0.125% | Preemergence | | | | |
| Clarity | 4 | Preemergence | 83 | 33 | 70 | 85 |
| MCPA ester | 8 | Preemergence | | | | |
| Prowl $H_2O$ | 32 | Preemergence | | | | |
| NIS | 0.125% | Preemergence | | | | |
| Glyphosate | 32 | POST-Harvest | | | | |
| Distinct | 6 | POST-Harvest | | | | |
| COC | 1% | POST-Harvest | | | | |
| AMS | 2% | POST-Harvest | | | | |
| Clarity | 4 | Preemergence | 84 | 30 | 28 | 28 |
| MCPA ester | 8 | Preemergence | | | | |
| Prowl $H_2O$ | 32 | Preemergence | | | | |
| Zidua | 2 | Preemergence | | | | |
| NIS | 0.125% | Preemergence | | | | |

*continued*

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

| Herbicide[a] | Rate | Timing | Kochia | | | |
|---|---|---|---|---|---|---|
| | | | March 4 | July 11 | July 25 | August 12 |
| | oz/a | | % control | | | |
| Clarity | 4 | Preemergence | 84 | 30 | 73 | 85 |
| MCPA ester | 8 | Preemergence | | | | |
| Prowl $H_2O$ | 32 | Preemergence | | | | |
| Zidua | 2 | Preemergence | | | | |
| NIS | 0.125% | Preemergence | | | | |
| Glyphosate + | 32 | POST-Harvest | | | | |
| Distinct | 6 | POST-Harvest | | | | |
| COC | 1% | POST-Harvest | | | | |
| AMS | 2% | POST-Harvest | | | | |
| Rave | 4 | Preemergence | 73 | 28 | 23 | 23 |
| NIS | 0.125% | Preemergence | | | | |
| Rave | 4 | Preemergence | 73 | 28 | 68 | 84 |
| NIS | 0.125% | Preemergence | | | | |
| Glyphosate | 32 | POST-Harvest | | | | |
| Distinct | 6 | POST-Harvest | | | | |
| COC | 1% | POST-Harvest | | | | |
| AMS | 2% | POST-Harvest | | | | |
| Untreated | --- | --- | 0 | 0 | 0 | 0 |
| Least significant difference (0.05) | | | 4 | 8 | 4 | 4 |

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

# Winter and Early Spring Herbicides for Kochia Control in Fallow

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


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


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

## Experimental Procedures
An experiment at the Kansas State University Southwest Research-Extension Center near Garden City, KS, examined the efficacy of winter and early spring herbicide applications for kochia control in fallow. Herbicides were applied December 3, 2015, and March 14, 2016. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Plots were 10- by 35-feet and arranged in a randomized complete block replicated four times. A tractor-mounted, compressed-$CO_2$ sprayer delivering 20 GPA at 3.0 mph and 30 psi was used to apply all herbicides. Kochia plants in the spring averaged less than 0.5-inch tall and 100 plants/10 $ft^2$ on March 14. Visual weed control was determined on March 7, April 1, and June 8, 2016, which was 95 days after winter applications and 18 and 86 days after spring applications, respectively.

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

## Reference

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

**Table 1. Winter and spring herbicide applications for kochia control**

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

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

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


## Summary

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


## Introduction

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

## Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated the efficacy of preemergence (PRE), early postemergence (EPOST), and sequential (preemergence followed by postemergence) herbicides in corn. All herbicide treatments were applied using a compressed-$CO_2$ backpack sprayer, delivering 20 GPA at 3.0 mph and 27 psi. Application dates and environmental conditions are given in Table 1. Soil was a Ulysses silt loam with pH 8.0, 1.4% organic matter and cation exchange capacity of 18.4. Plot size was 10- by 35-feet. The experiment was a randomized complete block with each treatment replicated four times. Visual weed control was determined on June 3 and July 7, 2016, which was 9 days after early postemergence and 31 days after the postemergence treatments, respectively. Corn yields were determined September 26, 2016, by mechanically harvesting the center two rows of each plot and adjusting grain moisture to 15.5%.

## Results and Discussion

Control of quinoa and Russian thistle was 100% regardless of herbicide treatment or evaluation date (data not shown). Kochia control was 95% or more on June 3 regardless of herbicide treatment and 100% by July 7. Common sunflower control was 100% with all EPOST and sequential treatments on July 7, whereas green foxtail control was 95% or more on July 7, except with Corvus plus atrazine preemergence or the EPOST treatments containing Liberty 280. No visible corn injury was observed with any treatment except those containing Liberty 280. The intent of this study was to plant a corn variety resistant to glufosinate. However, a glufosinate-susceptible variety was mistakenly planted. Therefore, Liberty-containing treatments caused 68 to 70 and 88 to 91% corn injury June 3 and July 7, respectively (data not shown). The high degree of corn injury with the Liberty treatments severely limited corn yield. All other herbicide-treated corn yielded 21 to 45 bu/a more grain than untreated corn.

**Table 1. Application information**

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

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

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

*continued*

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

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

[a] AMS is ammonium sulfate, and NIS is nonionic surfactant.
[b] PRE is preemergence, POST is postemergence, and EPOST is early postemergence.
LSD = Least significant difference.

# Resicore and Glyphosate Application Timings in Corn

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

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

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

## Procedures
An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated the efficacy of preplant or preemergence followed by postemergence applications in corn. All herbicides were applied using a compressed $CO_2$ backpack sprayer, delivering 20 GPA at 3.0 mph and 27 psi. Application dates, timings, and environmental conditions are shown in Table 1. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Plots were 10- by 35-feet and arranged in a randomized complete block with four replications. Visual estimates of weed control were taken on May 26 and July 7, 2016. Corn yields were determined September 26, 2016, by mechanically harvesting the two center rows of each plot and adjusting weights to 15.5% moisture.

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

**Table 1. Application information**

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

**Table 2. Resicore and glyphosate timings in corn**

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

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

# Rates of Armezon Pro for Postemergence Weed Control in Fallow

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

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

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

## Experimental Procedures
An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated the efficacy of Armezon Pro rates for postemergence weed control in fallow. All treatments were applied May 16, 2016, when kochia averaged 10 inches tall and 10 plants/square foot and Russian thistle averaged 4 inches in height and 1 plant per square foot. Herbicides were applied using a compressed-$CO_2$ backpack sprayer calibrated to deliver 20 GPA at 3.0 mph and 27 psi. Plots were 10- by 35-feet, and arranged in a randomized complete block with four replications. Soil was a Ulysses silt loam with pH of 8.0, organic matter of 1.4%, and cation exchange capacity of 18.4. Visual weed control was determined on May 23, June 1, and June 14, 2016, which was 7, 16, and 29 days after treatment (DAT).

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

**Table 1. Armezon Pro rates for fallow weed control**

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

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

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

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


## Summary

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


## Introduction

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

## Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated the efficacy of single and sequential herbicide applications in corn. The entire plot area was over-seeded with foxtail, crabgrass, and Palmer amaranth, as well as the domestically cultivated sorghum 'Rox orange,' quinoa, and sunflowers. These serve as proxies for their wild relatives, shattercane, lambsquarters, and wild sunflowers, respectively. Treatments were applied preemergence followed by early postemergence (V4) or postemergence (V8) or as early postemergence (V4) alone. All herbicides were applied using a tractor-mounted, compressed-$CO_2$ sprayer, delivering 20 GPA at 3.0 mph and 30 psi. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Plots were 10 by 35 feet and arranged in a randomized complete block design with four replications. Visual weed control was determined July 13, 2016, which was 27 days after the V8 applications (DAPO). Grain yields were determined September 20, 2016, by mechanically harvesting the center two rows of each plot and adjusting the weights to 15.5% moisture.

## Results and Discussion

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

Table 1. Application information

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

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

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

*continued*

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

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

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

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

[c] DAPO is days after V8 applications.

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

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

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

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

## Results and Discussion

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

**Table 1. Application information**

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

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

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

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

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

[c] DALP is days after late post emergence applications.

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

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


## Summary

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


## Introduction

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

## Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated Kochiavore herbicide at three rates and with various adjuvants for weed control in fallow. All treatments were applied on May 10, 2016, when kochia averaged 5 inches tall and 10 plants per square foot, Russian thistle was 3 inches tall and 3 plants/10 $ft^2$, and flixweed was 15 inches tall and 1 plant per square foot. Herbicides were applied using a tractor-mounted, compressed-$CO_2$ sprayer, delivering 20 GPA at 3.0 mph and 30 psi. Plots were 10- by 35-feet, and treatments were arranged in a randomized complete block with four replications. Visual weed control was determined on May 24 and June 6, 2016, 14 and 27 days after herbicide treatment (DAT), respectively.

## Results and Discussion

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

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

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

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

# Efficacy of Preplant and Early Postemergence Herbicides in Corn

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

## Summary

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

## Introduction

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

## Experimental Procedures

An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated weed control with single and sequential herbicide treatments in corn. The entire plot area was over-seeded with foxtail, crabgrass, and Palmer amaranth, as well as the domestically cultivated sorghum 'Rox orange', quinoa and sunflowers. These serve as proxies for their wild relatives, shattercane, lambsquarters, and wild sunflowers, respectively. Single treatments were applied on May 23, 2016, which was 11 days prior to planting (11 DPP); sequential treatments consisted of 11 DPP treatments followed by early postemergence treatments applied on June 17, 2016. The early postemergence treatments were applied when corn had two true leaves (V2). All herbicides were applied using a tractor-mounted, compressed-$CO_2$ sprayer delivering 20 GPA at 3.0 mph and 30 psi. Plots were 10- by 35-feet, and treatments were arranged in a randomized complete block with four replications. Soil was a Ulysses silt loam with 1.4% organic matter, pH of 8.0, and cation exchange capacity of 18.4. Visual weed control was determined on June 2 and August 18, 2016, which was 10 days after the preplant applications (10 DAPP) and 62 days after the early postemergence applications (62 DAPO), respectively. Corn yield was determined September 29, 2016, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 15.5% moisture.

## Results and Discussion

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

**Table 1. Preplant and early postemergence herbicides in corn**

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

*continued*

**Table 1. Preplant and early postemergence herbicides in corn**

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

[a] AMS is ammonium sulfate and NIS is nonionic surfactant.
[b] 11 DPP is 11 days prior to corn planting and V2 is corn with 2 visible leaf collars.
[c] DAPP is days after DPP applications, and DAPO is days after V2 application.

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

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

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

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

## Experimental Procedures
An experiment conducted at the Kansas State University Southwest Research-Extension Center near Garden City, KS, evaluated early postemergence weed control in corn with resistance to glufosinate and glyphosate. The entire plot area was over-seeded with foxtail, crabgrass, and Palmer amaranth, as well as the domestically cultivated sorghum 'Rox orange,' quinoa and sunflowers. These serve as proxies for their wild relatives, shattercane, lambsquarters, and wild sunflowers, respectively. All treatments were applied on June 17, 2016, when corn had two true leaves. A tractor-mounted, compressed-$CO_2$ sprayer delivering 20 GPA at 3.0 mph and 30 psi was used to apply all treatments. Plots were 10- by 35-feet and arranged in a randomized complete block design with four replications. Soil was a Ulysses silt loam with pH of 8.0, 1.4% organic matter, and cation exchange capacity of 18.4. Weed control was determined visually on June 24 and August 18, 2016, which was 7 and 62 days after treatment (DAT), respectively. Corn yield was determined October 3, 2016, by mechanically harvesting the center two rows of each plot and adjusting grain weights to 15.5% moisture.

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

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

**Table 1. Postemergence herbicides in resistant corn**

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

[a] AMS is ammonium sulfate and NIS is nonionic surfactant.
[b] DAT is days after herbicide treatment.
LSD = Least significant difference.

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

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

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

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

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

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

# Experimental Procedures

## Experimental Site

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

## Experimental Design

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

## Plot Establishment and Management

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

## Data Collection

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

## Data Analysis

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

## Results and Discussion

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

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

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

*Significant at .1% probability level.

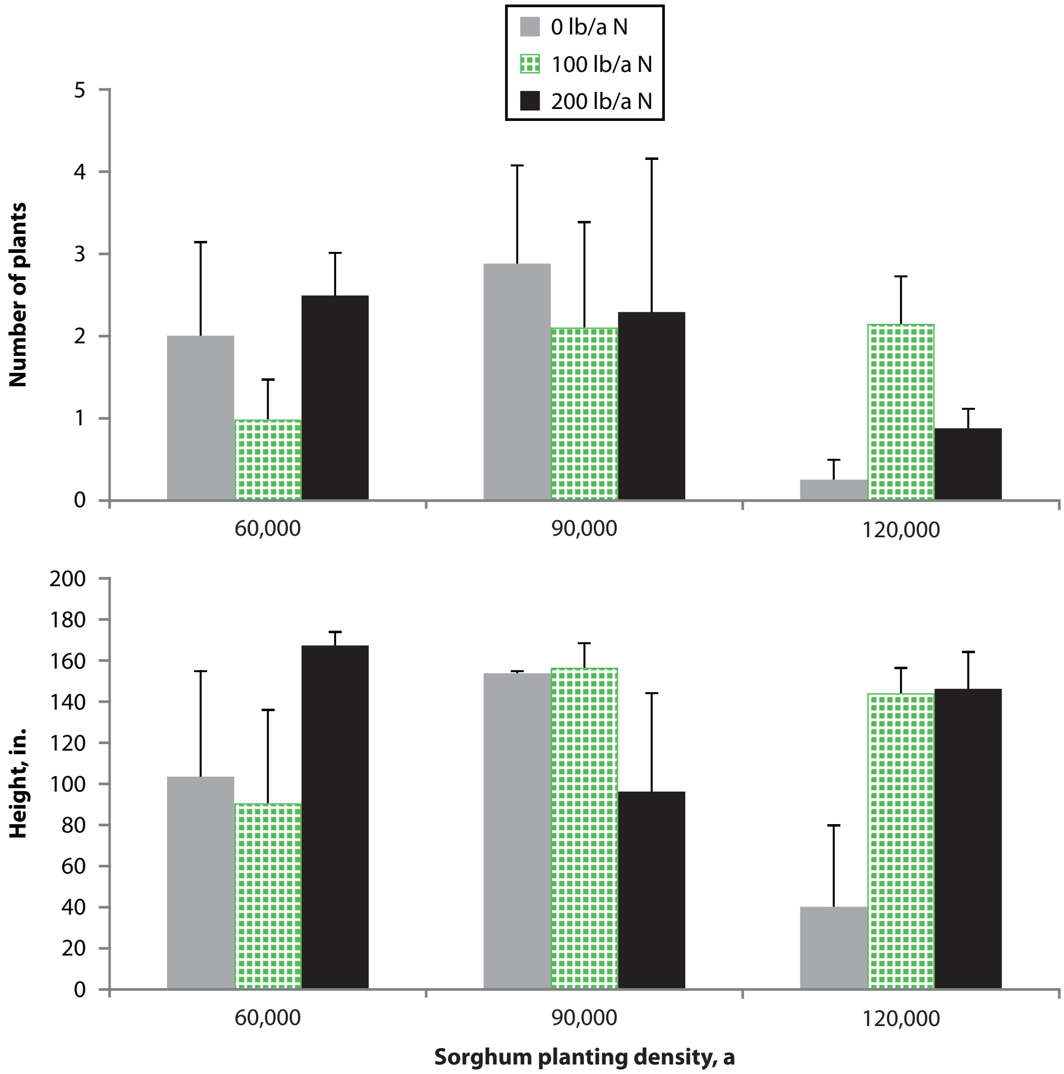


**Figure 1. Palmer amaranth number (A) and height (B) by sorghum planting density and nitrogen (N) rate.**

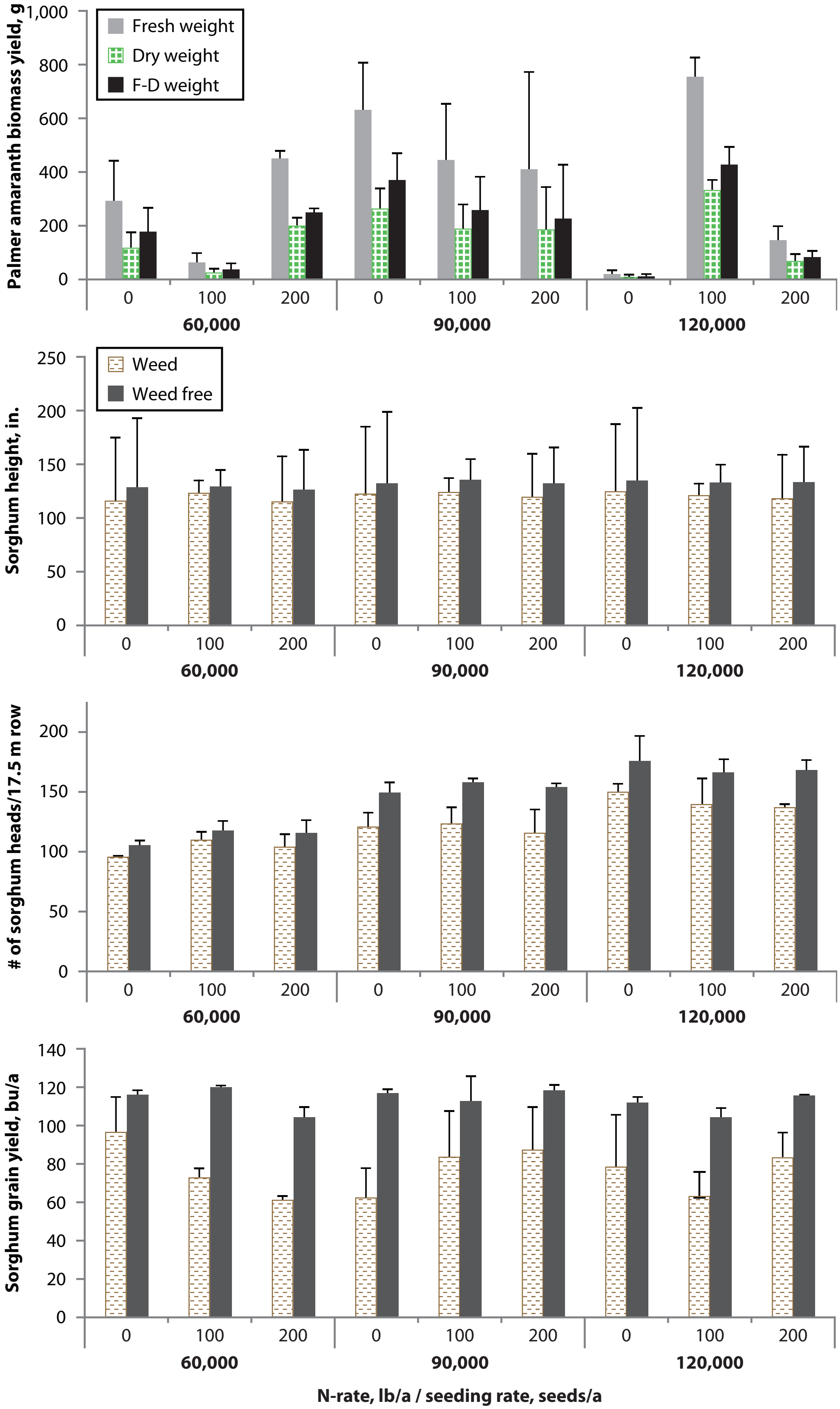


Figure 2. (A) Palmer amaranth biomass, (B) sorghum height, (C) headcount, and (D) grain yield by sorghum planting density and nitrogen rate.

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SOUTHWEST RESEARCH-EXTENSION CENTER

# Field Day 2017

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