Kansas Agricultural Experiment Station Research Reports

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

Article 1

January 2016

Determining Profitable Annual Forage Rotations

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

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

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

See next page for additional authors

Recommended Citation

Holman, J. D.; Roberts, T.; Maxwell, S.; and Kisekka, I. (2016) "Determining Profitable Annual Forage Rotations," *Kansas Agricultural Experiment Station Research Reports*: Vol. 2: Iss. 7. https://doi.org/10.4148/2378-5977.1246

Determining Profitable Annual Forage Rotations

Abstract

Producers are interested in growing annual forages, yet the region 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 2013 comparing several 1-, 3-, and 4-year forage rotations with no-till and minimum-till (min-till). Data presented are from 2013 through 2015. Winter triticale yields were increased by tillage. Double-crop forage sorghum yielded 23% 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 spring triticale or forage sorghum. Subsequent years will be used to compare forage rotations and profitability.

Keywords

annual forage rotations, profitable forage, annual forages, winter triticale, double crop forage sorghum, spring oat, triticale, forage sorghum

Authors

J. D. Holman, T. Roberts, S. Maxwell, and I. Kisekka

Determining Profitable Annual Forage Rotations

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

Summary
Producers are interested in growing annual forages, yet the region 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 2013 comparing several 1-, 3-, and 4-year forage rotations with no-till and minimum-till (min-till). Data presented are from 2013 through 2015. Winter triticale yields were increased by tillage. Double-crop forage sorghum yielded 23% 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 spring triticale or 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. Including 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), triticale or summer crop silage, or forage sorghum (FS) 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, and reduce weather risk. Growing forages throughout the year greatly reduces the risk of crop failure.

Double crop yields of WT and FS were 70% of annual cropping at Garden City, Kansas ($P \leq 0.05$), 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 successful crop rotations 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 a 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 was identified, and several other grasses (e.g. tumble windmill grass and red three-awn) are already tolerant of glyphosate. Although continuous no-till 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 impact of occasional tillage on forage yield. Yield of forage crops following tillage might not be impacted as much as in grain crops, since forages require less water.

Objectives

1. Improve precipitation use and fallow efficiency of dryland cropping systems by reducing fallow through the use of forage crops.
2. Test a number of forage crop rotations and tillage practices (no-till and min-till) to identify sustainable forage cropping systems.
3. Disseminate results to growers, crop advisors, and local extension agents through meetings and publications.

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 (oats), 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-till or min-till). 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.). Spring triticale was grown in place of spring oat beginning in 2015. Tillage was implemented after spring oat/triticale 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-till): (S-S)
2. Year 1: winter triticale/double crop forage sorghum; Year 2: forage sorghum; Year 3: spring oat/triticale (no-till): (T/S-S-O no-till)
3. Year 1: winter triticale/double crop forage sorghum; Year 2: forage sorghum; Year 3: spring oat/triticale (single tillage after spring oat, min-till): (T/S-S-O min-till)
4. Year 1: winter triticale/double crop forage sorghum; Year 2: forage sorghum; Year 3: forage sorghum; Year 4: spring oat/triticale (no-till): (T/S-S-S-O no-till)
5. Year 1: winter triticale/double crop forage sorghum; Year 2: forage sorghum; Year 3: forage sorghum; Year 4: spring oat/triticale (single tillage after spring oat, min-till): (T/S-S-S-O min-till)
6. Year 1: winter triticale; Year 2: forage sorghum; Year 3: spring oat/triticale (no-till): (T-S-O)

Winter triticale was planted the end of September, spring oat/triticale 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 (Haun scale 9.5). Winter triticale was harvested approximately May 15, spring oat/triticale 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 (from each plot) cut 3 in. high using a small plot Carter forage harvester. 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 at planting is 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 an accurate and 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 cost 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). Low crop yields and no spring oat yield were the results of a very dry year in 2013. In 2013, S-S produced the highest annual yield. In 2014, annualized yield was comparable across treatments except for T/S-S-O (no-till), which had lower yield than T/S-S-S-O (min-till) 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-till) yielded less than S-S, but more than T-S-O and comparable to all other treatments. T-S-O annual yield was less than all other treatments in 2015. Tillage increased the yield of triticale and thus the yield of T/S-S-O and T/S-S-S-O were improved with tillage, and annual yield of the three-year rotation was improved more than the four-year rotation due to triticale occurring more frequently in the rotation.

Forage yield per crop harvest was determined for each rotation since planting and harvest expenses are the major expenses to growing a crop. While 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-till) had lower average harvest yields than S-S or T/S-S-S-O (min-till) but was similar to T/S-S-O (min-till) and T/S-S-S-O (no-till). 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-till), but comparable to the other treatments. 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 similar 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, and 12% less in 2015. Across all years double crop (5,700 lb/a) averaged 23% less than full season forage sorghum (7,400 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-till (3,300 lb/a) yielded 217% more than no-till (1,500 lb/a). The only tillage in this study occurred in the fallow period before triticale and, in this study it 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; similar to winter wheat, it did not reduce yields but actually increased yields in the first 3 years of this study.

Oats failed to make a crop in 2013 due to drought conditions, and yields were low and similar amongst treatments in 2014 (400 lb/a) due to continued dry conditions. Oat yield was high in 2015 (4,900 lb/a) due to favorable spring precipitation and was similar across treatments. Oat yield was not affected by tillage or rotation.

Soil Moisture

Plant available moisture at planting was measured to a 6-foot soil depth, and moisture content varied by year and planting period. On average soil water was greatest at full season forage sorghum planting (4.65 inches) and was not different among the other planting periods, ranging from 3.19 to 3.44 inches (Table 2 and Figure 2).

Water use efficiency (WUE) was greatest in forage sorghum with full season producing 566 pounds per acre inch and double crop producing 428 pounds per acre inch. WUE for winter triticale averaged 356 pounds per acre inch, and oats was 314 pounds per acre inch. The yield potential and thus WUE was greater with forage sorghum than triticale or oat. However, when precipitation was favorable during a particular growing season, such as with 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 2% ahead of winter triticale to 34% for double cropped forage sorghum. Precipitation storage ahead of full season forage sorghum was 29% and ahead of oat planting was 21% (Table 2 and Figure 4).

References

Blanco, H. and J. Holman. 2012. Cover crops reduce wind and water erosion. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Report of Progress. 1070:7-11.

Hinkle, J.B., J.T. Vasconcelos, S.A. Furman, A.S. deMello, L.S. Senaratne, S. Pokharel, C.R. Calkins. 2010. Sensory attributes of beef from steers fed field peas. 2010 Nebraska Beef Report pg. 117-118. University of Nebraska-Lincoln, Dept. of Animal Science.

Holman, J., T., Dumler, T. Roberts, and S. Maxwell. 2012. Fallow replacement crop effects on wheat yield. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Report of Progress. 1070:24-29.

Table 1. Rotation treatment yields across years between 2013 and 2015.

Crop rotation	2013	2014	2015	Average†
	Total treatment yield (DM lb/a)			
S-S	4,262	7,426	10,244	7,311
T/S-S-O (no-till)	3,451	13,322	25,732	14,169
T/S-S-O (min-till)	4,020	20,130	28,742	17,631
T/S-S-S-O (no-till)	7,702	27,260	38,091	24,351
T/S-S-S-O (min-till)	8,896	30,266	36,394	25,185
T-S-O‡	*	*	18,404	18,404
	Annualized Treatment Yield (DM lb/a)			
S-S	4,262	7,426	10,244	7,311
T/S-S-O (no-till)	1,150	4,441	8,577	4,723
T/S-S-O (min-till)	1,340	6,710	9,581	5,877
T/S-S-S-O (no-till)	1,926	6,815	9,523	6,088
T/S-S-S-O (min-till)	2,224	7566	9,099	6,296
T-S-O	*	*	6,135	6,135
$LSD_{0.05}$§	1,508	3,038	1,488	
	Yield per Harvest (DM lb/a)			
S-S	4,262	7,426	10,244	7,311
T/S-S-O (no-till)	863	3,331	6,433	3,542
T/S-S-O (min-till)	1,005	5,032	7,185	4,408
T/S-S-S-O (no-till)	1,540	5,452	7,618	4,870
T/S-S-S-O (min-till)	1,779	6,053	12,131	6,655
T-S-O	*	*	3,681	3,681
$LSD_{0.05}$§	1,323	2,566	1,331	

† Average of years 2013-2015.
‡ T-S-O treatment started in 2015.
§ Means in columns followed by different letters are statistically different at P ≤ 0.05.

Table 2. Forage crop (sorghum, triticale, or oat) dry matter yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City from 2013 to 2015.

Rotation	Treat-ment	Crop	Dry matter yield lb/acre	Dry matter yield P < 0.05	Plant available water inches in 6' depth	Plant available water P < 0.05	WUE lb/acre inch-1	WUE P < 0.05	PSE %	PSE P < 0.05
			2013							
s-S†‡	1	Sorghum	4262	A¶	3.55	A-B	440.49	A	0.3233	A-C
t/S-s-o(no-till)	2	Sorghum	1385.4	C-D	1.14	D-G	121.84	D	0.0325	D-E
t/s-S-o(no-till)	2	Sorghum	2612.7	B-C	1.7	C-G	266.76	C	0.0767	C-E
t/S-s-o(min-till)	3	Sorghum	972	D-E	0.93	F-G	80.86	D-E	0.0175	D-E
t/s-S-o(min-till)	3	Sorghum	3875.9	A-B	3.08	A-C	392.72	A-B	0.1433	C-E
t/S-s-s-o(no-till)	4	Sorghum	1199.3	D-E	0.385	G	104.68	D-E	0.0125	D-E
t/s-S-s-o(no-till)	4	Sorghum	3086.5	A-B	2.86	A-D	302.82	B-C	0.2233	B-D
t/s-s-S-o(no-till)	4	Sorghum	3955	A	2.55	B-F	372.03	A-C	0.1225	C-E
t/S-s-s-o(min-till)	5	Sorghum	961.3	D-E	1.11	E-G	80.91	D-E	-0.0075	D-E
t/s-S-s-o(min-till)	5	Sorghum	4220.6	A	3.2525	A-C	445.68	A	0.1375	C-E
t/s-s-S-o(min-till)	5	Sorghum	3989.5	A	2.8867	A-C	324.73	B-C	0.2167	B-D
t-S-o	6	Sorghum	*§	*	*	*	*	*	*	*
T/s-s-o(no-till)	2	Triticale	142.1	D-E	1.56	C-G	9.76	D-E	-0.0867	E
T/s-s-o(min-till)	3	Triticale	188.4	D-E	1.1033	E-G	12.83	D-E	0.0067	D-E
T/s-s-s-o(no-till)	4	Triticale	310.7	D-E	0.8067	G	20.54	D-E	-0.0133	D-E
T/s-s-s-o(min-till)	5	Triticale	722.2	D-E	1.5525	C-G	49.88	D-E	-0.0025	D-E
T-s-o	6	Triticale	*	*	*	*	*	*	*	*
t/s-s-O(no-till)	2	Oat	0	E	2.6833	B-E	0	E	-0.0533	E
t/s-s-O(min-till)	3	Oat	0	E	3.1575	A-C	0	E	0.1	C-E
t/s-s-s-O(no-till)	4	Oat	0	E	3.455	A-B	0	E	0.445	A-B
t/s-s-s-O(min-till)	5	Oat	0	E	4.49	A	0	E	0.56	A
t-s-O	6	Oat	*	*	*	*	*	*	*	*
LSD0.05§			1321.7		1.7319		112.15		0.2664	

continued

Table 2. Forage crop (sorghum, triticale, or oat) dry matter yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City from 2013 to 2015.

			Dry matter yield		Plant available water		WUE		PSE	
Rotation	Treat-ment	Crop	lb/acre	P < 0.05	inches in 6' depth	P < 0.05	lb/acre inch-1	P < 0.05	%	P < 0.05
			2014							
s-S†‡	1	Sorghum	7426	A-C	4.2	C-F	516.8	A-C	0.08	D-G
t/S-s-o(no-till)	2	Sorghum	5341	C-D	2.2	F	399.4	B-D	0.38	A-G
t/s-S-o(no-till)	2	Sorghum	6629	A-C	3.7	D-F	457.4	A-D	0.06	E-G
t/S-s-o(min-till)	3	Sorghum	7016	A-C	3.6	D-F	502.6	A-C	0.39	A-G
t/s-S-o(min-till)	3	Sorghum	7577	A-C	3.7	D-F	582.3	A-C	0.17	C-G
t/S-s-s-o(no-till)	4	Sorghum	6505	A-C	3.6	D-F	469.4	A-D	0.54	A-C
t/s-S-s-o(no-till)	4	Sorghum	8415	A-B	2.9	E-F	633.9	A	-0.01	G
t/s-s-S-o(no-till)	4	Sorghum	9107	A	4.4	C-E	615.3	A-B	0.19	C-G
t/S-s-s-o(min-till)	5	Sorghum	9122	A	3.9	C-F	650.5	A	0.47	A-D
t/s-S-s-o(min-till)	5	Sorghum	7458	A-C	4.3	C-E	511.2	A-C	0.12	D-G
t/s-s-S-o(min-till)	5	Sorghum	5894	B-C	5.5	B-D	382.5	C-D	0.23	C-G
t-S-o	6	Sorghum	*	*	*	*	*	*	*	*
T/s-s-o(no-till)	2	Triticale	695	E	3.2	E-F	98.4	E	0.16	C-G
T/s-s-o(min-till)	3	Triticale	4650	C-D	6.6	B	523.2	A-C	0.46	A-E
T/s-s-s-o(no-till)	4	Triticale	2449	D-E	5.9	B-C	260.8	D-E	0.42	A-F
T/s-s-s-o(min-till)	5	Triticale	7013	A-C	8.9	A	640.8	A	0.64	A-B
T-s-o	6	Triticale	*	*	*	*	*	*	*	*
t/s-s-O(no-till)	2	Oat	657	E	3.0	E-F	52.9	E	0.03	F-G
t/s-s-O(min-till)	3	Oat	887	E	3.8	D-F	78.5	E	0.29	B-G
t/s-s-s-O(no-till)	4	Oat	784	E	3.1	E-F	65.3	E	0.38	A-G
t/s-s-s-O(min-till)	5	Oat	779	E	4.1	C-F	60.8	E	0.70	A
t-s-O	6	Oat	*	*	*	*	*	*	*	*
LSD0.05§			3067		2.0		225.3		0.40	

Table 2. Forage crop (sorghum, triticale, or oat) dry matter yield, plant available water at planting, water use efficiency (WUE), and precipitation storage efficiency (PSE) near Garden City from 2013 to 2015.

			Dry matter yield		Plant available water		WUE		PSE	
Rotation	Treat-ment	Crop	lb/acre	P < 0.05	inches in 6' depth	P < 0.05	lb/acre inch-1	P < 0.05	%	P < 0.05
									continued	
			2015							
s-S†‡	1	Sorghum	10244	A-B	5.8	B-E	861.5	A	0.28	C-G
t/S-s-o(no-till)	2	Sorghum	8665	B-C	4.6	D-H	724.3	A-D	0.41	B-E
t/s-S-o(no-till)	2	Sorghum	9125	B-C	4.7	D-G	774.7	A-C	0.25	C-G
t/S-s-o(min-till)	3	Sorghum	9910	A-C	6.3	B-D	687.2	A-E	0.70	A-B
t/s-S-o(min-till)	3	Sorghum	10380	A-B	7.1	A-B	706.2	A-D	0.36	C-F
t/S-s-s-o(no-till)	4	Sorghum	8988	B-C	5.3	B-F	710.9	A-D	0.55	B-C
t/s-S-s-o(no-till)	4	Sorghum	11216	A	6.5	A-C	801.2	A-B	0.32	C-F
t/s-s-S-o(no-till)	4	Sorghum	9976	A-C	5.8	B-E	725.5	A-D	0.30	C-G
t/S-s-s-o(min-till)	5	Sorghum	8091	C	5.2	C-F	603.8	A-E	0.54	B-C
t/s-S-s-o(min-till)	5	Sorghum	11229	A	8.2	A	818.8	A	0.43	B-D
t/s-s-S-o(min-till)	5	Sorghum	9300	A-C	6.2	B-E	646.5	A-E	0.32	C-F
t-S-o	6	Sorghum	9105	B-C	6.3	B-D	671.2	A-E	0.88	A
T/s-s-o(no-till)	2	Triticale	2870	E	2.3	J	508.0	C-E	-0.37	J-K
T/s-s-o(min-till)	3	Triticale	4072	D-E	4.4	E-I	517.3	C-E	-0.01	G-I
T/s-s-s-o(no-till)	4	Triticale	2738	E	2.8	H-J	422.9	E	-0.41	K
T/s-s-s-o(min-till)	5	Triticale	3356	D-E	3.4	G-J	473.6	D-E	-0.10	H-J
T-s-o	6	Triticale	4008	D-E	3.1	G-J	601.5	A-E	-0.13	J-L
t/s-s-O(no-till)	2	Oat	5072	D	2.2	J	674.2	A-E	0.12	E-I
t/s-s-O(min-till)	3	Oat	4380	D-E	2.7	I-J	592.9	A-E	0.05	F-I
t/s-s-s-O(no-till)	4	Oat	5174	D	2.5	J	748.8	A-C	0.11	E-I
t/s-s-s-O(min-till)	5	Oat	4418	D-E	3.5	F-J	532.8	B-E	0.19	D-H
t-s-O	6	Oat	5291	D	3.0	G-J	637.2	A-E	0.10	E-I
LSD0.05§			2050		1.9		270.4		0.31	

† 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 ≤ 0.05.

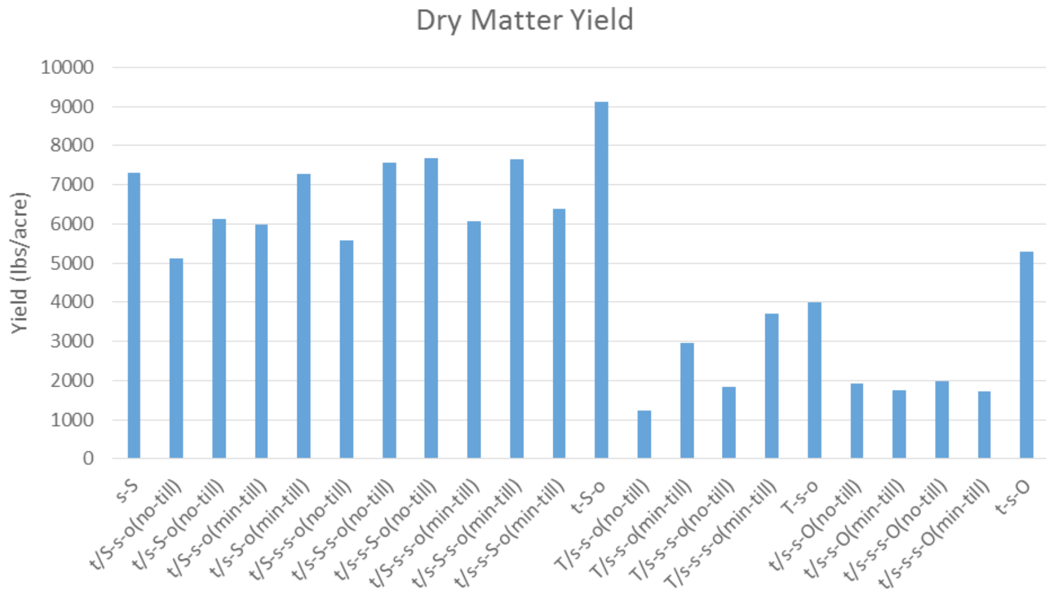

Figure 1. Forage dry matter yield for all crop rotations and phases averaged across years from 2013 to 2015. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization in X axis.

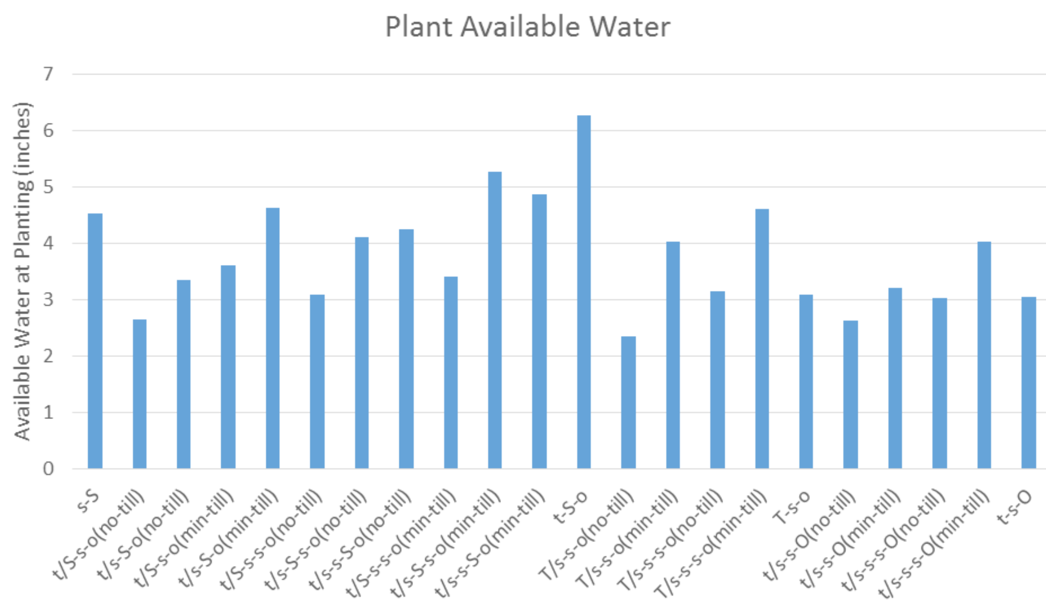

Figure 2. Plant available water in a six foot soil profile at planting for all crop rotations and phases averaged across years from 2013 to 2015. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization in X axis.

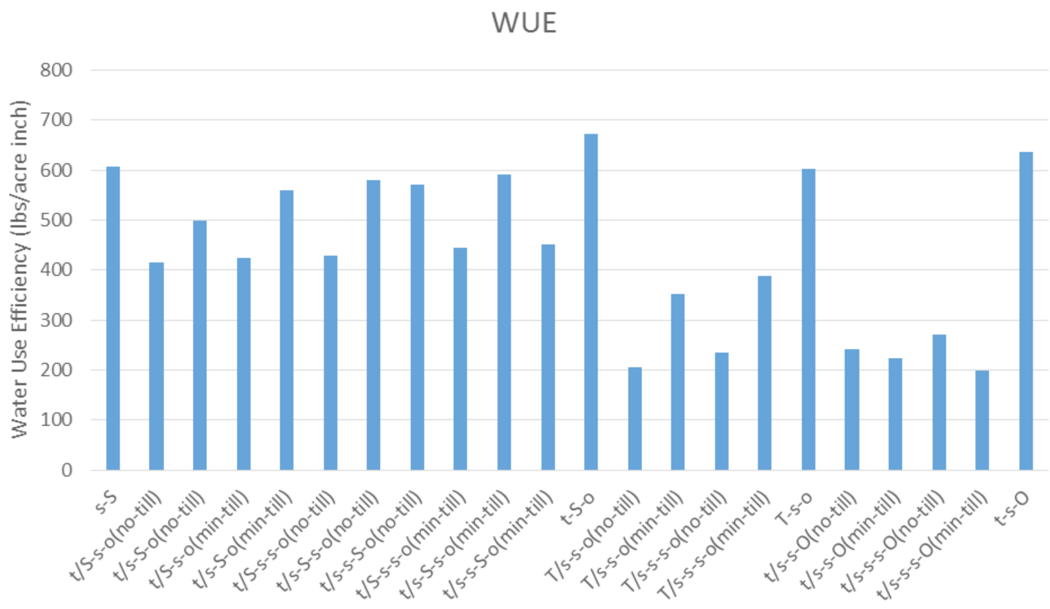

Figure 3. Water use efficiency (WUE) [forage dry matter yield/((ending-beginning soil water content) + growing season precipitation)] for all crop rotations and phases averaged across years from 2013 to 2015. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization in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

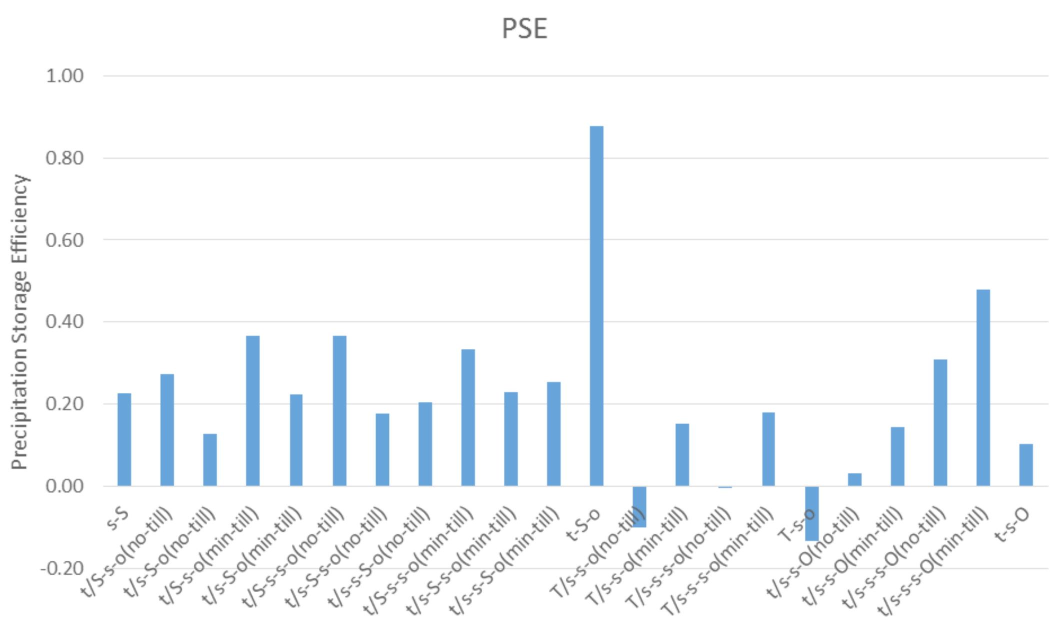

Figure 4. Precipitation storage efficiency (PSE) [precipitation/(ending-beginning soil water content)] for the fallow period preceding the crop for all crop rotations and phases averaged across years from 2013 to 2015. Triticale-forage sorghum-oat was implemented in 2015. Crop is identified by capitalization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