Long-Term Forage Rotation Yields, Soil Water Use, and Profitability

J.D. Holman[1], A.K. Obour[2], L. Simon[1], and A.J. Schlegel[3]
[1]Kansas State University, Southwest Research Center and Extension Center, Garden City, KS; [2]Kansas State University, Agricultural Research Center, Hays, KS; [3]Kansas State University, Southwest Research Center and Extension Center, Tribune, KS
jholman@ksu.edu (620) 276-8286

ABSTRACT

Forages are important for the region's livestock industry and are becoming increasingly important as irrigation capacity and grain prices decrease. Forages require less water than grain crops and may allow for increasing cropping system intensification and opportunistic cropping. A study was initiated in 2012 at the Southwest Research-Extension Center near Garden City, KS, comparing several 1-, 3-, and 4-year forage rotations with no-tillage and minimum-tillage. Data presented are from 2013 through 2019. Tillage generally increased winter triticale yields by 700 lb/a or 30% compared to no-till yields, due largely to increased plant available water. Plant available water at planting winter triticale averaged 5.9 in./a in min-till and 3.9 in./a in no-till. Double-crop forage sorghum yielded 17% less than full-season forage sorghum and yields were not affected by tillage. Oat yields were lower than forage sorghum or winter triticale, averaging 2,100 lb/a across years.

INTRODUCTION

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

Annual forages are grown for a shorter period and require less water than traditional grain crops. Including annual forages into the crop rotation might enable increasing cropping system intensity and opportunistic cropping. "Opportunistic cropping" or "flex cropping" is the planting of a crop when conditions (soil water and precipitation outlook) are favorable or fallowing when unfavorable. Wheat yields following spring annual forages such as oat (O) were similar to wheat yields following fallow in a wheat-fallow rotation in non-drought years, but wheat yields were reduced in drought years (Holman et al., 2012). This indicates the opportunity to intensify the cropping system in favorable years. Forage producers in the region commonly grow continuous winter triticale (T), winter triticale or summer crop silage, or forage sorghum (S). However, they lack a proven rotation concept for forages such as that developed for grain crops (e.g. winter wheat-summer crop-fallow). Continuous winter triticale often develops winter annual grass problems, while continuous forage sorghum produces lower quality forage than triticale. Producers are interested in identifying forage rotations that increase pest management control options, spread out equipment and labor resources over the year, reduce the impact of variable weather risks, and increase profitability. Growing forages throughout the year greatly reduces the risk of crop failure due to variable precipitation.

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

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

MATERIAL AND METHODS

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

Treatments:

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

Winter triticale was planted at the end of September, spring oat was planted the beginning of March, and forage sorghum was planted the beginning of June. Crops were harvested at early heading to optimize forage yield and quality (Feekes 10.1) (Large 1954). Each year, winter triticale was harvested approximately May 15, spring oat was harvested approximately June 1, and forage sorghum was harvested approximately the end of August. Forage yields were determined from a 3- × 30-ft area cut 3 in. high using a small plot Carter forage harvester from each plot. Forage yield and nutritive value (protein, fiber, and digestibility) were measured at each harvest. Gravimetric soil moisture content was measured at planting and harvest to a depth of 6 ft using 1-ft increments. Precipitation storage efficiency

(% of precipitation stored during the fallow period) was quantified for each fallow period, and crop water use efficiency (forage yield divided by soil water used plus precipitation) was determined for each crop harvest. Crop yield response to plant available water (PAW) at planting was used to develop a yield prediction model based on historical or expected weather conditions. Most producers use a soil probe rather than gravimetric sampling to determine soil moisture status, so soil penetration with a Paul Brown soil probe was used four times per plot at planting to estimate soil water availability. Previous studies found a soil moisture probe provided a practical, easy way to determine soil moisture level and crop yield potential. Profitable forage and tillage systems identified in this study will benefit producers in the High Plains region.

RESULTS AND DISCUSSION

Rotation Yield

Annual rotation yield was determined by measuring total yield for the rotation and dividing by the number of years in the rotation. This method allowed for comparing rotations of different years to each other for annual forage production (Table 1). A very dry year in 2013 resulted in low crop yields and no O 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-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. The T-S-O annual yield was less than all other treatments in 2015. Between 2016 and 2018, precipitation primarily occurred in late spring and summer, which favored S yield. The highest yielding rotations in 2016 through 2018 were S-S, followed by T/S-S-S-O, and T-S-O yielded the least. In 2019 precipitation was favorable for T and O and T/S-S-O (min-till) had the highest mean yield. Tillage generally 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 T 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 O and T yield less than S, they are also higher in crude protein and digestibility and are worth more per unit than S. 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 (data not shown). 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 less than S-S or T/S-S-S-O (no-till), but comparable to the other treatments. Between 2016 and 2019, 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 (O and T), the ability to winter graze when native pastures are dormant, or the ability to reduce weather risk by growing a crop during different times of the year.

Crop Yield

Full-season S either grown after T/S or S yielded similarly across rotations (Figure 1). Double-crop S yielded less than full-season S, but varied greatly from year to year based on precipitation during the growing season. Double crop S yielded 70% less than full-season in 2013, 7% less in 2014, 12% less in 2015, 10% less in 2016, 38% less in 2017, and 15% less in 2018. Across all years, double-crop (6,160 lb/a) averaged 17% less than full-season S (7,460 lb/a). The lower yield of double-crop S was due to less available soil moisture at planting. Sorghum yield was not affected by tillage or length of rotation, although there was a tendency for no-till forage sorghum yields to be greater than min-till yields.

Triticale yield was not affected by length of rotation but was affected by tillage. Averaged across years, triticale in min-till (3,260 lb/a) yielded 28% more than no-till (2,550 lb/a). The only tillage in this study occurred in the fallow period before T and, in this study, benefitted the T crop. The exception was in 2017 when no-till (1,869 lb/a) yielded more than min-till (1,518 lb/a). Other studies and producers have found tillage ahead of a winter wheat crop has minimal impact on yield and can improve weed control, but tillage ahead of grain sorghum often reduced grain yield. For these reasons, tillage was only used ahead of T and, similar to winter wheat, did not reduce yields, but actually increased yields in the first 5 years of this study.

Oats failed to make a crop in 2013 due to drought conditions and varied by year due to differences in growing season conditions. Oat forage yield was 400 lb/a in 2014, 4,900 lb/a in 2015, 2,300 lb/a in 2016, 883 lb/a in 2017, 300 lb/a in 2018, and 3,421 lb/a in 2019. Yields in 2015, 2016 and 2019 were higher than other years due to favorable spring precipitation and cool temperatures. Oat yield was not affected by tillage or crop rotation.

Soil Water

Plant available water at planting was measured to a 6-foot soil depth, and soil water content varied by year and planting period. Soil water was greatest for full-season S planting averaging 7.7 in across treatments, which was more than double crop S that averaged 5.6 in. No-till T (3.9 in) was less than min-till T (5.9 in). At oat planting (March) PAW averaged 3.9 in. (Figure 2).

Water use efficiency (WUE) was greatest in S, with full-season averaging 597 lb/a/in. and double-crop producing 555 lb/a/in. Water use efficiency for T averaged 343 lb/a/in., and oat was 250 lb/a/in. The yield potential and thus water use efficiency was greater with S than T or O. However, when precipitation was favorable during a particular growing season, such as O in 2015, the WUE of oat was comparable to forage sorghum. In years with moisture stress, WUE of double-crop S was less than full-season, but in favorable moisture years WUE of double-crop was greater than full-season (data not shown).

Precipitation storage efficiency (PSE) varied by fallow period and ranged from 9% ahead of T to 40% for full-season S. Precipitation storage ahead of double-crop S was 32% and ahead of O planting was 22% (data not shown).

Table 1. Rotation treatment yields across years between 2013 and 2019.

Crop rotation	2013	2014	2015	2016	2017	2018	2019	2015-19 Average†
	Annualized Treatment Yield (DM lbs/acre)							
S-S	4262	7426	10244	8025	5954	5799	7338	7472
T/S-S-O(no-till)	1150	4441	8577	5356	4462	4097	7968	6092
T/S-S-O(min-till)	1340	6710	9581	6135	3897	4849	8023	6497
T/S-S-S-O(no-till)	1926	6815	9523	6830	4845	4817	7389	6681
T/S-S-S-O(min-till)	2224	7566	9099	5958	4353	5113	7775	6459
T-S-O	*	*	6135	3353	3194	2284	6336	4261
$LSD_{0.05}$¶	1508	3038	1488	801	1391	1306	1320	

† Average of years 2015-2019. § T-S-O treatment started in 2015.

SUMMARY

Forages can be grown throughout the growing season (spring, summer, and fall) to diversify rotations. Although T and O have greater forage quality, S produces more yield. Tillage can help manage weeds, alleviate soil compaction from grazing and improved T yield. Growing a combination of cool and warm season forages produces a large amount of forage and offers several advantages. A diverse rotation would reduce risk of crop failure, spread work load, and ensure an annual forage supply throughout the year. Based on an individual operation's forage needs of timing, quality, and yield, a rotation could me modified to include a higher percentage of O, T, and S by changing the length of the rotation growing more of the highest need crop.

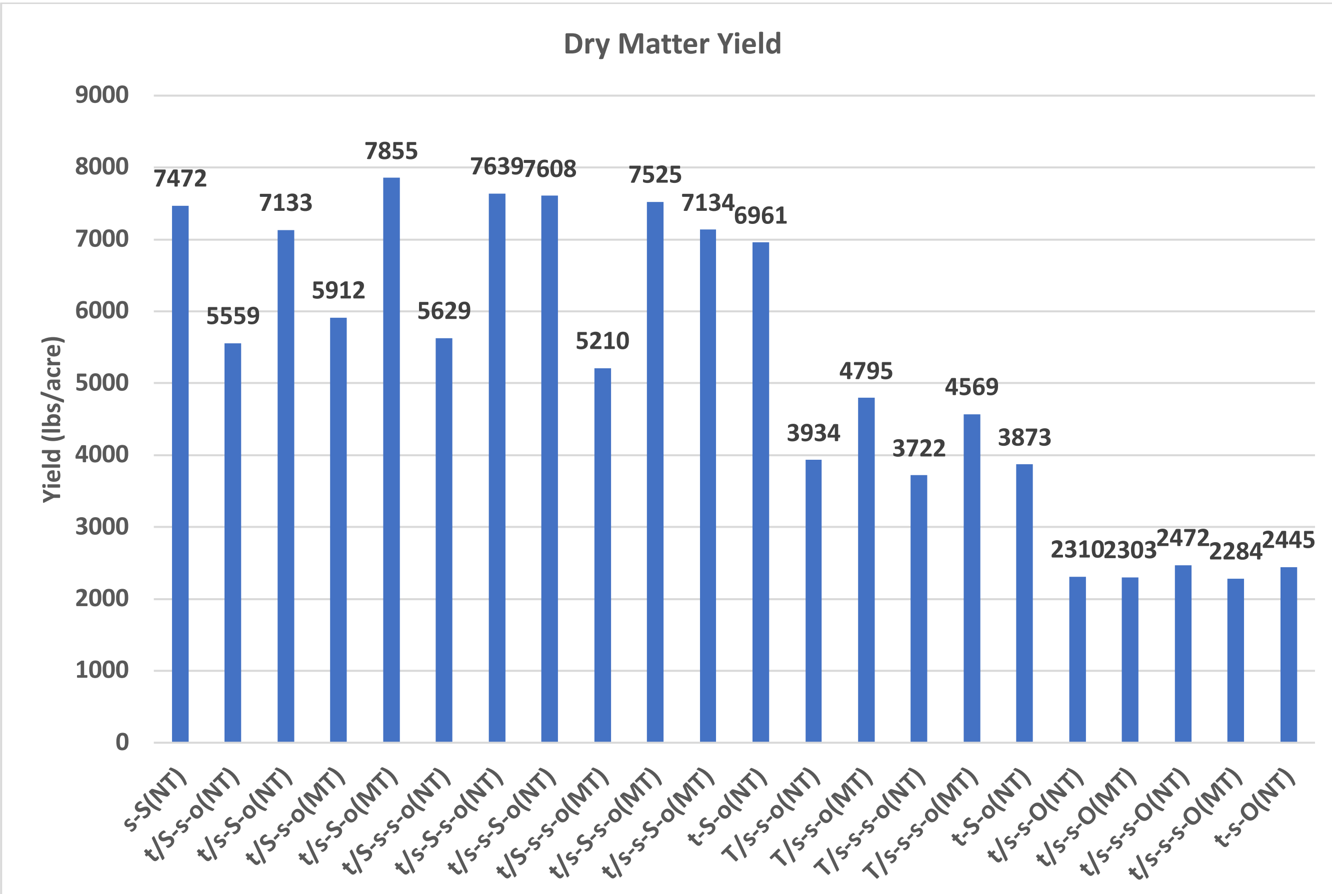

Figure 1. Forage dry matter yield for all crop rotations and phases averaged across years from 2013 to 2018. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.

ACKNOWLEDGEMENT

The USDA-NRCS Ogallala Aquifer Grant program and the Kansas Agricultural Experiment Station supported this work.

REFERENCES

Blanco, H. and J. Holman. 2012. Cover crops reduce wind and water erosion. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Report of Progress. SRP1070:7-11.

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

Holman, J.D., K. Arnet, J. Dille, S. Maxwell, A.K. Obour, T. Roberts, K. Roozeboom, and A. Schlegel. 2018. Can cover (or forage) crops replace fallow in the semiarid central Great Plains? Crop Sci. 58:1-13.

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

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

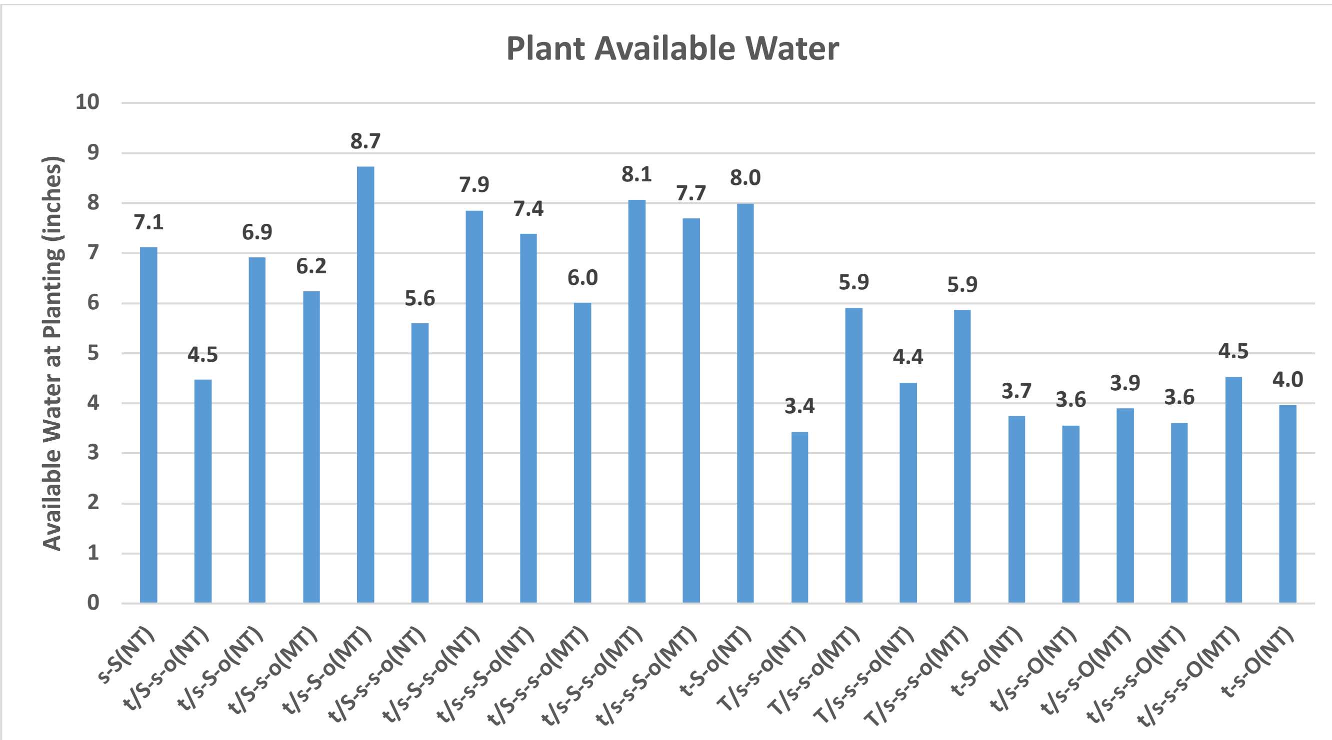

Figure 2. Plant available water in a 6-ft soil profile at planting for all crop rotations and phases averaged across years from 2013 to 2018. Crop is identified by capitalization in X axis. S = Forage sorghum. S-S = Continuous forage sorghum. T/S = Winter triticale/double crop forage sorghum. O = Spring oat.