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Integrated Grain and Forage Rotations

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Integrated Grain and Forage Rotations

Abstract

Forage production is important for the western Kansas region's livestock and dairy industries and has become increasingly important as irrigation-well capacity declines. Forages require less water than grain crops and may allow for increased cropping intensity and opportunistic cropping. Being able to estimate forage production is important for determining forage availability versus forage needs. Data from several studies were used to quantify annual forage yield response to plant available water (PAW) at planting and growing season precipitation (GSP). In addition, water use efficiency was quantified. Forages evaluated included winter triticale, spring triticale, and forage sorghum. Preliminary results showed PAW and GSP explained 26% of the variability in forage sorghum yield. Winter triticale yield increased by 640 lb/a for every inch of water use (PAW plus GSP). However, spring triticale produced only 193 lb/a for every inch of water use. The low correlation with water use and spring triticale yield suggests other factors, such as temperature, affect spring forage production more than soil moisture.

Keywords

Crop rotation, Forage, grain, integration

Authors

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Summary

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

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

Introduction

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

Experimental Procedures

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

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

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

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

Results and Discussion

Winter Wheat

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

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

Grain Sorghum

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

Forage Sorghum

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

Forage sorghum yields were not different across treatments in 2014, except double-crop FS in winter wheat/forage sorghum-forage sorghum-spring oat (ww/FS-fs-o) yielded 2,200 lb/a less than full-season forage sorghum in the same rotation of winter wheat/forage sorghum-forage sorghum-spring oat (ww/fs-FS-o) (Table 4). This lower yield was most likely due to less plant available water at planting, 1.3 versus 2.1 inches. In 2014, plant available water averaged 1.0 inch ahead of double-crop forage sorghum and 4.1 inches ahead of full season forage sorghum. Most of the annual precipitation in 2014 occurred later in the year (June-September), which likely helped improve the yield of double-crop forage sorghum relative to full-season forage sorghum. In 2014, double-crop forage sorghum yielded, on average, 17% less than full-season forage sorghum (3,300 versus 3,900 lb/a). In 2015, most of the precipitation occurred earlier in the year (May-August) than 2014, which helped increase wheat yields but also resulted in comparatively less moisture at planting time of double-crop forage sorghum, 1.6 versus 7.2 inches. As a result, 2015 double-crop forage sorghum yields were reduced 70% compared to full-season forage sorghum (2,400 versus 8,000 lb/a). In 2016, moisture conditions were favorable during the growing season (June-August), resulting in good forage yields across all treatments. There were 0.8 inches more PAW at planting of the full-season compared to double-crop forage sorghum. Double crop yields were reduced on average 43% compared to full-season forage sorghum (3,900 vs. 6,900 lb/a). In 2017, most of the precipitation occurred during the spring of the year, which increased moisture storage during the fallow period but little moisture during the growing season, resulting in low yields in the double-crop forage sorghum crop. Full season forage sorghum averaged 6,700 lb/a and double-crop averaged 1,000 lb/a. In 2018, most of the precipitation fell during the second half of the growing season, resulting in good forage yields for both double and full-crop. Full season forage sorghum averaged 10,600 and double-crop averaged 8,200 lb/a. Between 2014 and 2018 full-season sorghum averaged 7,200 and double-crop averaged 4,000 lb/a.

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

Spring Oat

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

Conclusions

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

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

Table 1. Grain and forage crop rotation treatments

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

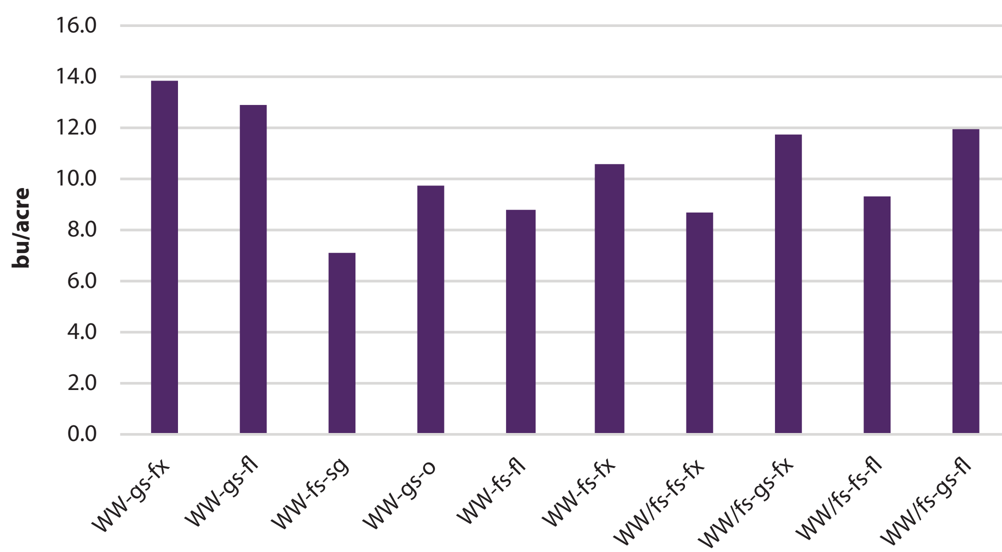

Figure 1. Wheat yield near Garden City, KS, between 2015 and 2018. See Table 1 for treatments.

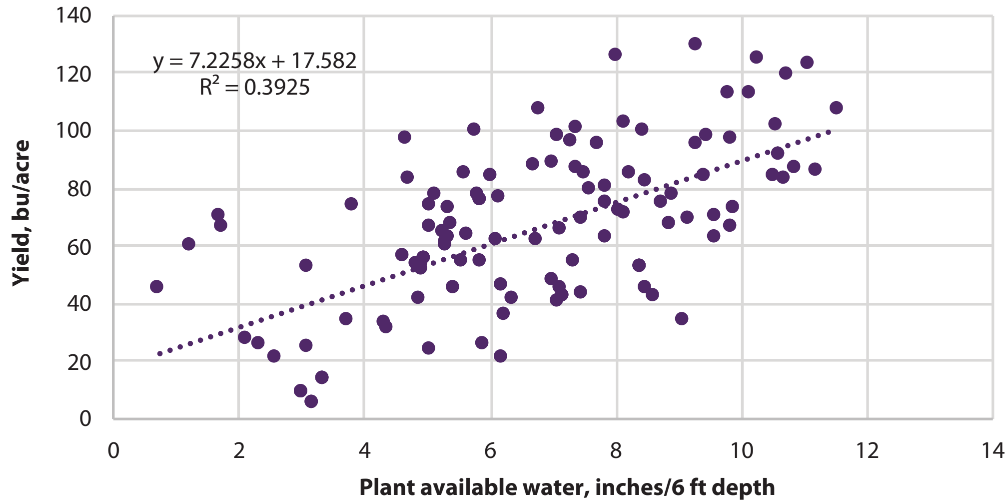

Figure 2. Grain sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2018.

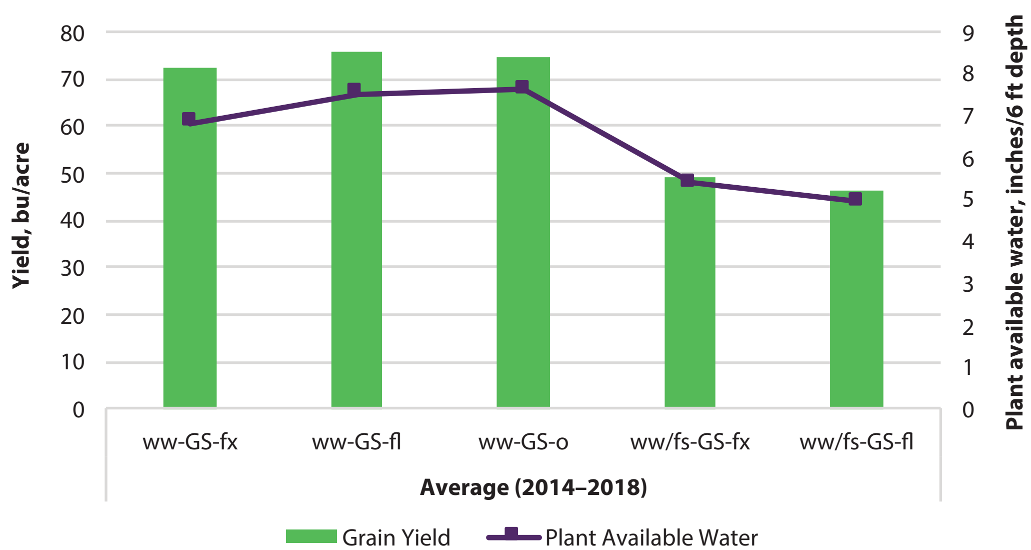

Figure 3. Grain sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2018. See Table 1 for treatments.

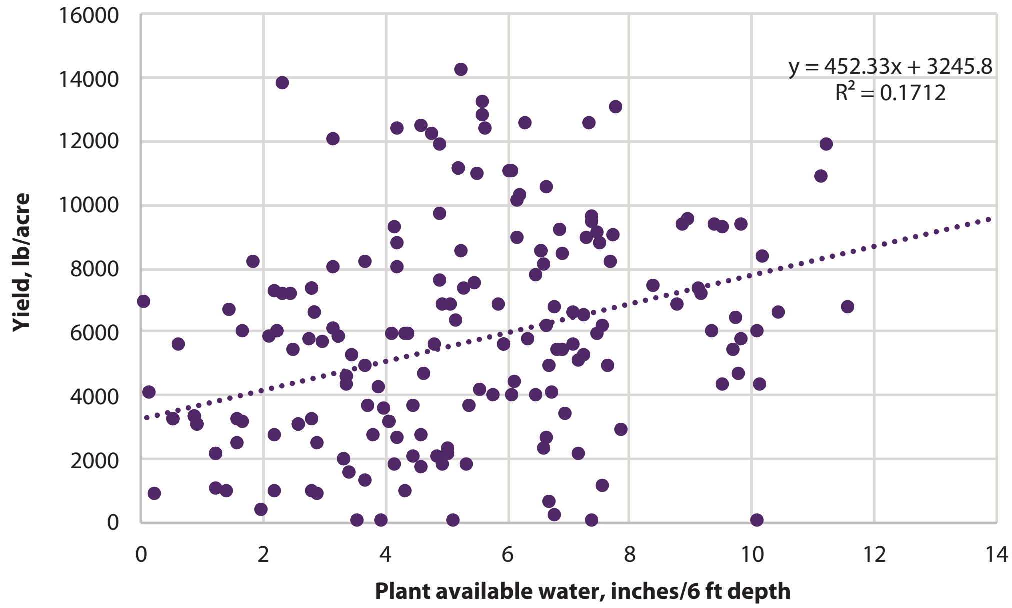

Figure 4. Forage sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2018.

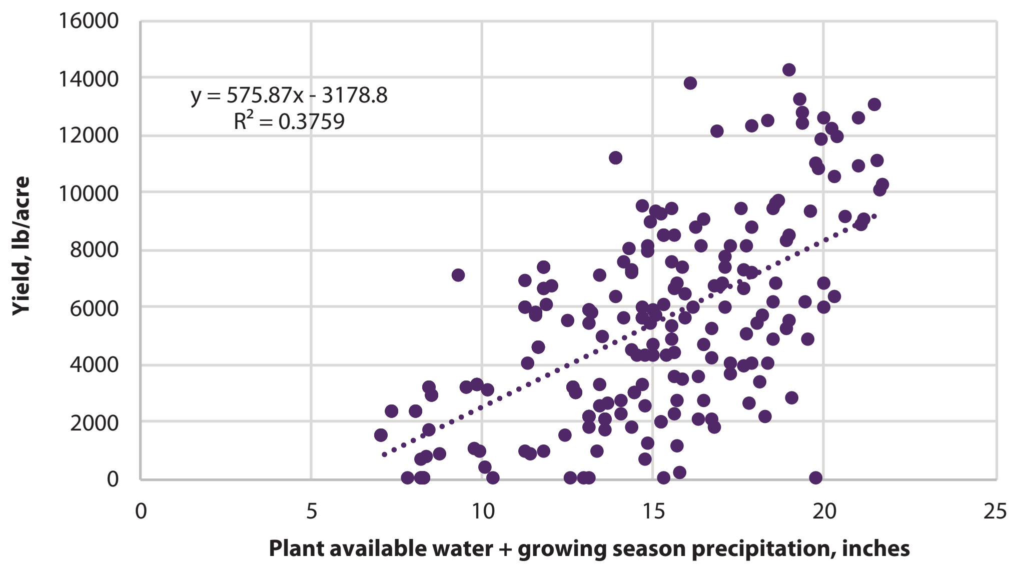

Figure 5. Forage sorghum yield response to plant available water at planting plus growing season precipitation near Garden City, KS, between 2014 and 2018.

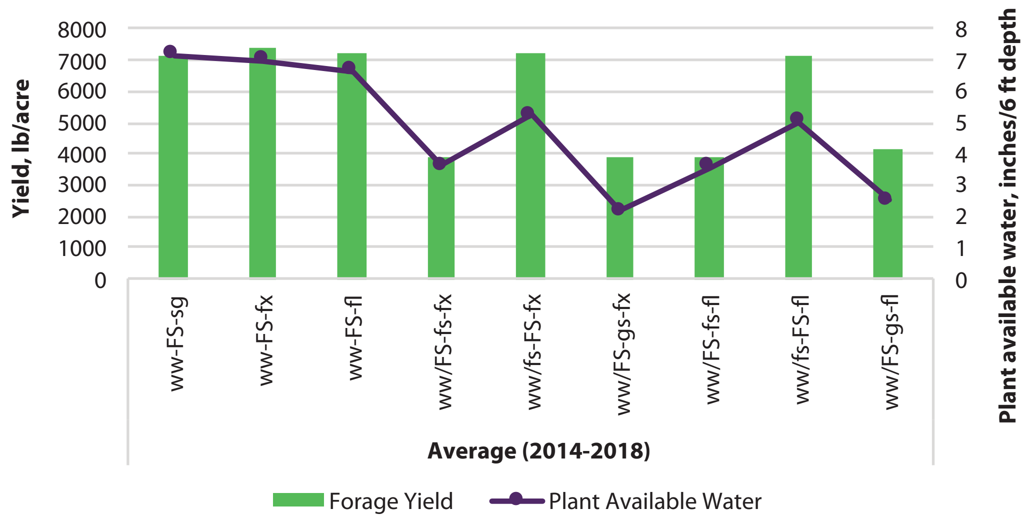

Figure 6. Forage sorghum yield response to plant available water at planting near Garden City, KS, between 2014 and 2018. See Table 1 for treatments.