POST-WHEAT SUMMER COVER CROP EFFECTS ON CROP YIELDS AND SOIL PROPERTIES IN A NO-TILLAGE DRYLAND CROPPING SYSTEM

L.M. Simon, A.K. Obour, J.D. Holman, M.E. Schipanski, S.K. Johnson, and K.L. Roozeboom
Kansas State University Agricultural Research Center-Hays, Hays, KS
lsimon@ksu.edu (217)617-0290

ABSTRACT

Traditional dryland cropping systems in the semi-arid central Great Plains include long fallow periods of up to 14 months to conserve soil moisture. However, precipitation capture and storage with fallow is inefficient even under continuous no-tillage (NT). As less water is needed to produce forage compared to grain, cover crops (CCs) could be integrated for increased soil cover and potentially greater income when grazed or hayed for forage. An experiment was initiated in 2016 near Brownell, KS to investigate the effect of post-wheat summer CCs on crop yields and soil properties in a NT winter wheat (*Triticum aestivum* L.)-grain sorghum (*Sorghum bicolor* Moench.)-fallow cropping system. Cover crops were grazed, hayed, or left standing (no forage removal) and compared to fallow. A second experiment was initiated in 2019 on producer fields near Hays and Alexander, KS to further quantify the effect of grazing CCs on soil properties in NT fields. At these sites, grazed CCs were compared to un-grazed CCs (no forage removal). Across years, CCs produced 3446 lb/ac dry matter (DM) at Brownell. Haying removed 62% of the available DM while grazing removed only 39%. Grain sorghum yields were 11% less following standing or grazed CCs compared to fallow (74 bu/ac) but yields following hayed CCs were similar to fallow. Soil organic carbon concentration in the 0- to 2- inch soil depth was about 8% greater with CCs (hayed, grazed, and standing) compared to fallow (1.24%) through there were no treatment differences in the 2- to 6-inch soil depth. Soil bulk density was marginally greater (4%) with hayed and grazed CCs compared to standing CCs (1.16 g/cm^3) though all were similar to fallow. Soil properties at Hays and Alexander were unaffected by grazing CCs compared to un-grazed CCs at either soil depth. Results showed post-wheat summer CCs can produce considerable DM with more residue retained following grazing compared to haying. However, grain sorghum yield following CCs can be reduced compared to fallow when all or most of the CC DM is retained, possibly due to nitrogen immobilization. Using CCs for forage can compensate for reduced grain yields and potentially increase cropping system profitability without negative impacts on soil properties.

INTRODUCTION

Integrating cover crops (CCs) to replace portions of the fallow periods in semi-arid dryland cropping systems has the potential to improve soil health by increasing soil organic carbon (SOC), reducing compaction, and enhancing soil structure. Previous research has emphasized the fallow period following summer crop [corn (*Zea mays* L.), grain sorghum (*Sorghum bicolor* Moench.), or proso millet (*Panicum milliaceum* L.)] harvest before winter wheat planting in the three-year winter wheat (*Triticum aestivum* L.)-summer crop-fallow cropping system of the semi-arid central Great Plains (Nielsen et al., 2015; 2017). However, less attention has been paid to the fallow period following wheat harvest. As this region has a summer-dominant precipitation pattern, the months following wheat harvest has a high likelihood for rainfall and could provide an opportunity for warm-season CCs to be incorporated (Mahama et al., 2016). Although the benefits that CCs provide for soil health have been widely recognized, their adoption in semi-arid dryland crop production remains limited due to subsequent grain yield penalties when soil moisture is reduced following CCs (Holman et al., 2018). However, utilizing CCs as an annual forage for livestock could offset losses in subsequent crop yield to balance goals of environmental and economic sustainability in dryland crop production. Still, concerns with grazing CCs include reduced SOC accrual, increased soil compaction, and degraded soil structure compared to ungrazed CCs especially in NT production systems. The objectives of this study were to determine the dry matter (DM) accumulation of post-wheat summer CCs as well as effects on subsequent grain sorghum yields and soil properties in a NT dryland cropping system.

MATERIALS AND METHODS

The first experiment was conducted from 2016 to 2021 near Brownell, KS to investigate the effect of post-wheat summer CCs on crop yields and soil properties in a NT wheat wheat-grain sorghum-fallow cropping system. Cover crops were either grazed, hayed, or left standing (no forage removal) and were compared to traditional fallow. A second experiment was conducted from 2019 to 2021 on two cooperative producer fields near Hays and Alexander, KS to further test the influence of grazing CCs on soil properties in NT dryland cropping systems. Annual precipitation in the study region is summer-dominant and averages 22 inches annually at these three sites.

The experiment at Brownell was arranged in a split-plot randomized complete block design. Main plots were the three crop phases of the wheat-sorghum-fallow crop rotation and split-plots (600 ft^2) included three CC treatments as well as fallow. Cover crops were a mixture of forage sorghum, pearl millet (*Pennisetum glaucum* L.), sunn hemp (*Crotalaria juncea* L.), and cowpea (*Vigna unguiculata* L.) at seeding rates of 7.5, 2.5, 5, and 20 lb/a, respectively. Cover crops were planted into wheat stubble each year shortly after harvest (approximately July 1) using a Great Plains no-till drill (Great Plains Manufacturing Inc., Salina, KS) and were either harvested as hay, grazed, or left standing (no forage removal). No fertilizer was applied to CCs in this study.

Prior to grazing, aboveground DM was determined from samples that were hand-clipped to ground level in two areas of 3 ft × 2 ft from each plot. Fresh weights were recorded and samples were oven-dried at 122°F until a constant weight was reached. Grazed CCs were stocked with yearling heifers (1500 lb/ac live weight) which were moved daily for four days. Following grazing, the retained CC residue was measured as previously described. Hayed CCs were harvested at a 6-inch cutting height from a 3 ft × 100 ft strip in the middle of each plot using a small-plot forage harvester (Carter Manufacturing Company, Brookston, IN). Whole plot weights were recorded with sub-samples collected and weighed. Sub-samples were oven-dried at 122°F until a constant weight was reached to determine DM yield. Termination with herbicides was not needed as CC species were selected to be terminated by frost (approximately October 15).

Grain sorghum was planted the following June at a rate of 35,000 seeds/ac with 15-inch row spacings using the same planting equipment as used for CCs and harvested in October using a Massey-Ferguson 8XP plot combine (Kincaid Equipment Manufacturing, Haven, KS). Following a 12-month fallow period, winter wheat was planted in the fall (approximately October 1) at a seeding rate of 60 lb/ac with 7.5-inch row spacing and harvested in June using the same planting and harvesting equipment as used for grain sorghum. For both grain crops, 18 lb/ac P_2O_5 and 5 lb/ac N was applied as monoammonium phosphate (11-52-0) with the seed. Additionally, 75 lb/ac N was applied as broadcasted urea (46-0-0) for a total of 80 lb/ac N for both grain crops.

Whole fields at Hays and Alexander were 50 and 80 acres, respectively. Four areas within each field were assigned as fenced zones to exclude grazing (un-grazed treatment) and cattle were allowed full access to the adjacent unfenced areas (grazed treatment). Cover crops were a mixture of forage sorghum, German millet (*Setaria italica* L.), sunflower (*Helianthus annuus* L.), sunn hemp, and radish (*Raphanus stivus* L.) at seeding rates of 7.5, 5, 1, 1, and 1 lb/ac, respectively. At Hays, CCs were grazed with cow-calf pairs (278 lb/ac live weight), and at Alexander, CCs were grazed with yearlings (459 lb/ac live weight) for a target duration of 35 days.

Soil samples were collected in the spring around sorghum planting in 2020 at Hays and in 2021 at Alexander and Brownell. At each site, two intact soil cores of 6 inches in depth and 2 inches in diameter were randomly taken from each plot to determine soil bulk density. Samples were dried at 221°F for a minimum of 48 hours and bulk density was computed as the mass of oven-dried soil divided by the volume of the core. Ten additional 6-inch cores were collected randomly from each plot to determine SOC and nutrient (NO_3-N and P) concentrations. Additional soil samples were collected from the 0- to 2-inch soil depth with a flat shovel for the determination of water stable aggregates. Samples were gently passed through sieves with 0.32- to 0.19-inch mesh and allowed to fully air-dry. Two sub-samples from each replicate were used to estimate mean weight diameter (MWD) of water stable aggregates by the wet-sieving method. Statistical analyses were completed using PROC GLIMMIX of SAS ver. 9.4 (SAS Institute, 2012, Cary, NC) with year and treatment considered fixed and replication considered random. Differences were considered significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

On average, post-wheat summer CCs produced 3446 lb/ac DM at Brownell. However, CC productivity varied substantially from a high in 2018 (4593 lb/ac) to a low in 2019 (1714 lb/ac; Figure 1a). Cover crops failed in 2017 due to extended summer drought conditions. On average, haying removed 62% of the available DM while grazing removed only 39%. Grain sorghum yields following CCs were 11% less with standing or grazed CCs compared to fallow (74 bu/ac) but yields following hayed CCs were similar to fallow (Figure 1b). Reductions in grain yield following CCs were observed three out of

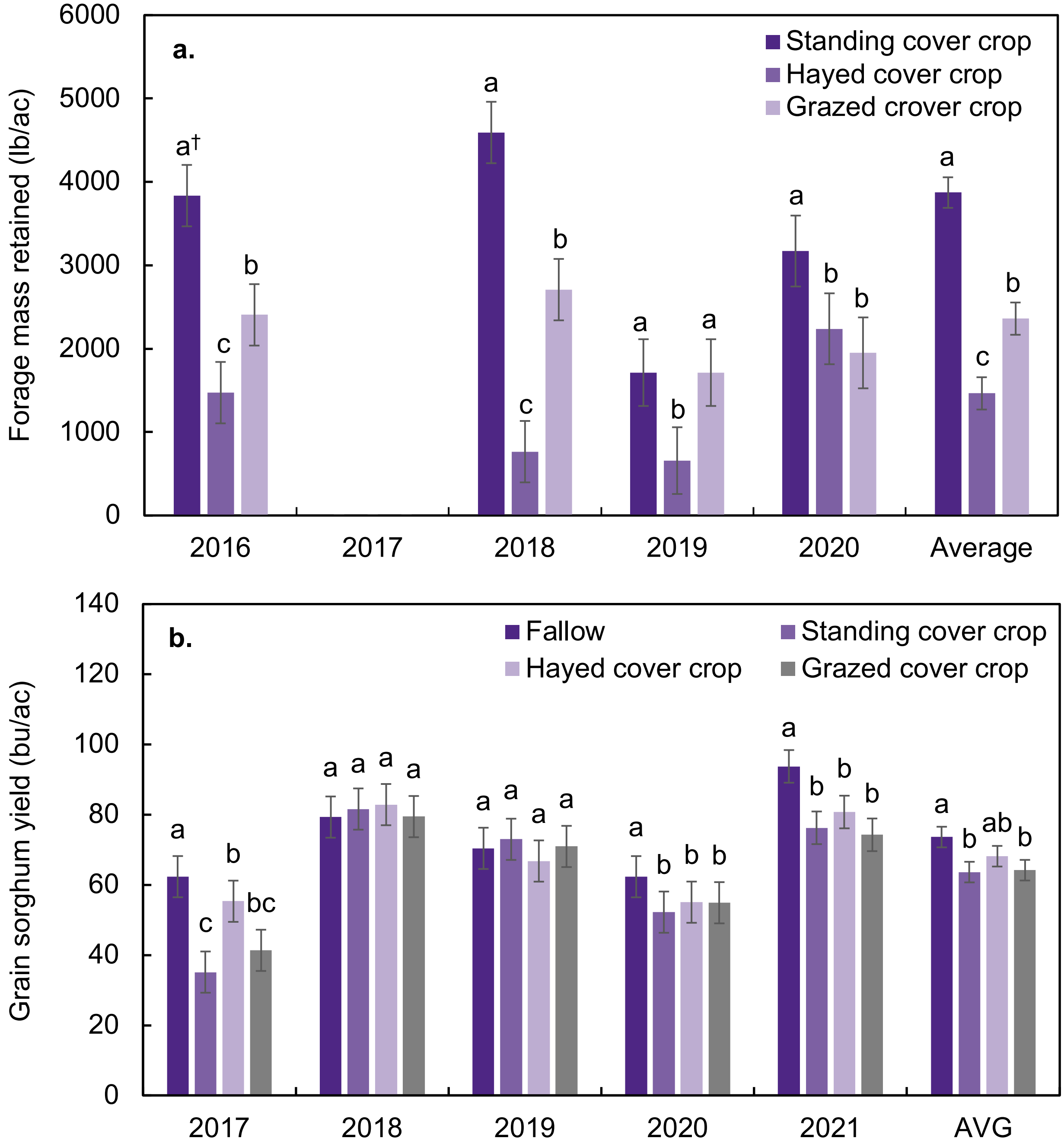

Figure 1. Cover crop residue retained following forage harvest (a.) and effect on subsequent grain sorghum yields (b.) near Brownell, KS.
[†]Error bars indicate standard error (α =0.05) and bars with the same letter are not significantly different (α =0.05) among treatments within the same year.

five (2017, 2020, and 2021) when sorghum experienced summer drought conditions, but not in 2018, when sorghum followed the failed CC of 2017, or in 2019, when precipitation was 36% above average. The yield of wheat following grain sorghum and a 12-month fallow period was generally unaffected by CCs and averaged 46 bu/ac.

At Brownell, SOC concentration in the 0- to 2-inch soil depth was about 8% greater with CCs (hayed, grazed, and standing) compared to fallow (1.24%) (Table 1). Also, in the 0- to 2-inch soil depth, bulk density was marginally greater (4%) with hayed and grazed CCs compared to standing CCs (1.16 g/cm^3) though all were similar to fallow. No treatment differences in SOC or bulk density were observed in the 2- to 6-inch soil depth. Soil NO_3-N concentration were not different across treatments for either soil depth. However, soil P concentration in the 2- to 6-inch soil depth was about 49% greater with grazed CCs compared to all other treatments (7.7 ppm) though no differences were observed across treatments in the 0- to 2-inch depth. At both cooperative producer locations, Hays and Alexander, soil bulk density, SOC, NO_3, P, and MWD were unaffected by grazing CCs compared to ungrazed CCs (Table 1).

Table 1. Effects of post-wheat summer cover crop management on soil physical and chemical properties in the 0- to 2- and 2- to 6-inch soil depths across three sites in western Kansas.

			BD†	SOC	NO_3-N	P	MWD
Location	Depth	Treatment	g/cm^3	%	ppm	ppm	inch
Brownell	0- to 2-inch	Fallow	1.17ab††	1.24b	18.0	29.7	-
		Standing	1.16b	1.31a	20.6	29.8	-
		Hayed	1.21a	1.35a	18.8	30.9	-
		Grazed	1.21a	1.37a	19.2	31.5	-
	2- to 6-inch	Fallow	1.43	1.24	8.9	7.9b	-
		Standing	1.40	1.22	9.4	7.6b	-
		Hayed	1.39	1.22	8.8	7.6b	-
		Grazed	1.42	1.28	10.6	11.5a	-
Hays	0- to 2-inch	Ungrazed	1.25	2.05	14.4	48.3	0.077
		Grazed	1.32	1.89	16.4	45.2	0.057
	2- to 6-inch	Ungrazed	1.38	1.89	5.2	24.6	-
		Grazed	1.41	1.53	8.7	23.8	-
Alexander	0- to 2-inch	Ungrazed	1.36	1.24	7.0	33.7	0.063
		Grazed	1.24	1.40	9.7	42.0	0.056
	2- to 6-inch	Ungrazed	1.46	0.90	3.5	15.2	-
		Grazed	1.41	0.93	3.6	8.27	-

†BD, bulk density; SOC, soil organic carbon; NO_3-N, nitrate-nitrogen; P, phosphorus; MWD, mean weight diameter of water stable aggregates.
††Means with the same letter are not significantly different (α =0.05) among treatments within the same location and depth.

In conclusion, post-wheat summer CCs can produce considerable DM with more residue retained with grazing compared to haying. However, subsequent grain sorghum yields can be reduced compared to fallow when all or most of the CC DM is retained (standing or grazed) but not when CCs are removed as hay. Soil organic carbon can be increased with CCs compared to fallow in shallow soil depths (0- to 2-inch). Soil chemical and physical properties when CCs are grazed on NT fields are similar to when CCs are left standing. These findings indicate that such CCs can be integrated after wheat in the NT cropping systems of the semi-arid central Great Plains to supply forage for livestock to compensate for reduced subsequent grain yields and potentially increase cropping system profitability without negatively impacting soil properties compared to standing CCs.

REFERENCES

Holman, J.D., K. Arnet, J. Dille, S. Maxwell, A. Obour, T. Roberts, K. Roozeboom, and A. Schlegel. 2018. Can cover or forage crops replace fallow in the semiarid central Great Plains? Crop Sci. 58:932-944.

Mahama, G.Y., P.V.V. Prasad, K.L. Roozeboom, J.B. Nippert, and C. W. Rice. 2016. Cover crops, fertilizer nitrogen rates, and economic returns of grain sorghum. Agron. J. 108:1-16.

Nielsen, D.C., D.J. Lyon, G.W. Hergert, R.K. Higgins, and J.D. Holman. 2015. Cover crop biomass production and water use in the central Great Plains. Agron. J. 107:2047-2058.

Nielsen, D.C., D.J. Lyon, and J.J. Miceli-Garcia. 2017. Replacing fallow with forage triticale in a dryland wheat-corn-fallow rotation may increase profitability. Field Crops Res. 203:227-237.