LONG-TERM COVER CROP AND ANNUAL FORAGE EFFECTS ON SOIL ORGANIC CARBON, NITROGEN STOCKS, AND WATER STABLE AGGREGATES IN THE SEMIARID CENTRAL GREAT PLAINS

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ABSTRACT

Growing cover crops (CC) in semiarid dryland cropping systems in the central Great Plains (CGP) may provide several benefits to soil health. This study examined long-term CC management effects on soil health in a no-till winter wheat (*Triticum aestivum* L.)–grain sorghum (*Sorghum bicolor* L.)–fallow (WSF) cropping system in southwestern Kansas. The experimental design was a split-split-plot randomized complete block with four replications. Main plots were crops in each phase of WSF, and sub-plots were CC treatments including fallow, grain pea, triticale in monoculture, a three-species mixture of oat/triticale/pea, and a six-species cocktail mixture of oat/triticale/pea/buckwheat/turnip/radish. Half of each CC treatment was harvested for forage with the remainder left as cover. Soil samples were collected from the 0 – 6 in depth in 2012 and 2018. Haying of CCs as forage had no effect on soil health indicators compared to when CCs were left standing. Soil organic carbon (SOC) in 2018 showed no significant change with CCs compared to fallow, but was greater compared to 2012. This lack of differences compared to fallow was possibly due to recent periods of drought reducing total carbon inputs compared to earlier periods of relatively greater precipitation. Grain peas or CCs did not increase soil N compared to fallow. Mean weight diameter of wet aggregates was not different between CCs hayed (0.042 in.) and CCs left standing (0.044 in.) but both were greater than fallow (0.033 in.) or spring pea (0.030 in.). Growing a CC significantly increased proportion of larger (2 – 8 mm) aggregate (36%) size fractions compared to spring peas (22%) but not compared to fallow (25%). Our findings suggest SOC gains made in semiarid environments could be sustained even during sustained periods of drought that reduce total carbon inputs from lower crop yields when CCs or annual forages are grown under very dry conditions.

INTRODUCTION

Growing cover crops (CC) in semiarid dryland cropping systems in the central Great Plains (CGP) has potential to provide several benefits to soil health in the region. These include reduced susceptibility to wind and water soil erosion as well as improved nutrient cycling (Blanco-Canqui et al., 2013, 2015). However, even with these potential benefits and an increasing interest among CGP crop producers, CC adoption has been slow in the region. This is mostly due to the fact that CCs will deplete vital soil water, which can result in reduced yields of subsequent cash crops compared to chemically-controlled summer-fallow, where herbicides are used to manage weed growth to store soil moisture for the next crop.

Past research efforts in southwest Kansas have shown that replacement of fallow with CCs or forage crops resulted in increased soil organic matter (SOM) content and stability of wet soil aggregates, as well as reduced soil wind-erodible fraction and run-off (Blanco-Canqui et al., 2013). These results indicate that CCs in semiarid regions have the potential to improve soil health similarly to those reported in more humid regions, at least in the short-term (<10 years), despite limited rainfall and high evaporative demand. However, information is lacking regarding the long-term (>10 years) soil health effects of integrated cover crops in dryland crop production.

Increased adoption of CC by dryland producers in the semiarid CGP can enhance residue cover to reduce the susceptibility of the soil to erosion (Blanco-Canqui et al., 2011, 2013, 2014). Reducing erosion is particularly important in semiarid dryland crop production systems where residue levels are often low, and fallow fields are left exposed. Grazing and or haying of CC for forage can provide an economic benefit to offset potential lost revenue associated from decreased crop yields when CC are grown ahead of a cash crop in dry years (Holman et al., 2018). However, there is concern that harvesting CC as forages and the resulting reduction in residue left on the soil surface may negate the beneficial effects of CC for soil conservation.

With all things considered, there is great motivation for researchers and others involved in production agriculture to develop and evaluate new and innovative crop production strategies and technologies to boost profitability and sustainability of dryland, wheat-based crop production systems in the CGP. Our objectives were to assess the long-term impacts of CCs on 1) soil organic carbon and nitrogen stocks, 2) soil susceptibility to erosion, as well as to 3) quantify the effects of haying cover crops as annual forages upon soil health.

MATERIALS AND METHODS

This study was conducted in a long-term experiment of fallow replacement (cover crops, forage crops, and grain crops) at the Kansas State University Southwest Research-Extension Center near Garden City, KS. The soil is a Ulysses silt loam with 1 to 3% slope. Cover crops included spring triticale (×*Triticosecale* Wittm.), a three-species mixture of oats (*Avena sativa* L.)/triticale/pea (*Pisum sativum* L.), and a six-species cocktail mixture of oats/triticale/pea/buckwheat (*Fagopyrum esculentum* Moench)/turnip (*Brassica rapa*)/radish (*Raphanus sativus* L.). Cover crops plots were split with half of each plot harvested for forage. Additionally, spring peas were harvested for grain. Treatments with crops grown in place of fallow were compared with WSF for a total of 8 treatments. All phases of each crop rotation were present every year. The study design was a split-split-plot randomized complete block with four replications. Crop phase was the main plot, crop species or mixture was the split plot, and termination method (cover, forage, or grain) was the split-split plot. Main plot was 250 ft wide by 120 ft long, split plot was 30 ft wide and 120 ft long, and split-split plot was 15 ft wide and 120 ft m long.

All soil sampling occurred shortly before wheat planting in fall 2018. Soil cores were taken from the 0 to 2, 2 to 6, and 6 to 12-inch depths for determination of bulk density as well as SOC and inorganic nitrogen (NO_3 and NH_4) stocks. Briefly, the samples taken at each depth were dried at 220 °F for 48-hr, and bulk density was determined by mass of oven dry soil divided by volume of the core. Subsamples from each depth were air-dried and ground to pass through a 0.08 in. sieve. Soil nitrate-N (NO_3-N) and ammonium-N (NH_4-N) concentrations in samples were determined colorimetrically after the soil samples were extracted with 2 M KCl. A portion of the samples were ground with a mortar and pestle to pass through a 0.01 in. sieve, and SOC concentration was determined by dry combustion using a CN analyzer after pretreating samples with 10% (v/v) HCl to removed carbonates. Additional samples collected from the 0 to 2 in. soil depth with a flat shovel were air-dried and passed through sieves with 0.185 to 0.30 in. mesh to obtained air-dry aggregates of 0.185 to 0.30 in. diameter. These samples were used to estimate water-stable aggregates by the wet-sieving method. Sand correction was done for each aggregate size fraction, and the data was used to compute aggregate size distribution and mean weight diameter (MWD) of water-stable aggregates.

RESULTS AND DISCUSSION

Soil Organic Carbon and Nitrogen Stocks

Treatments of differing CC species diversity were not significantly different for any observed soil health parameter. Soil organic carbon stocks (Fig. 1) in 2018 showed no significant differences compared to fallow, but were greater than SOC values determined in 2012. This suggests SOC gains made in semiarid environments could be may not be increased, but may be maintained, even with sustained periods of drought that reduce total carbon inputs from lower CC biomass and wheat and grain sorghum yields that result under very dry conditions. Grain peas and CCs did not increase soil N (Fig. 1) compared to fallow. However, recommended rates of N applied to both wheat and sorghum crops may have masked any potential differences.

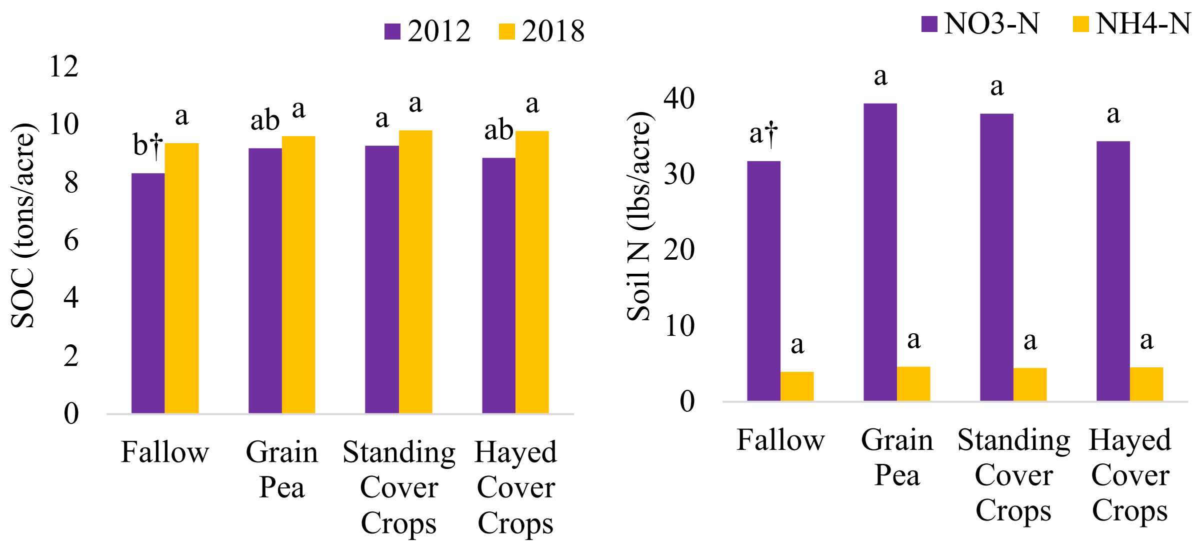

Figure 1. Impact of cover crops on the (a) soil organic carbon (SOC) pool in tons/acre from the 0 – 2 in. soil depth in 2018 and 2012 and (b) soil nitrate (NO_3) and ammonium (NH_4) in lbs/acre from the 0 – 6 in. soil depth.
†Means with the same lowercase letter are not significantly different among treatments within years.

Bulk Density and Water Stables Aggregates

Soil bulk density (BD), a common measurement of soil compaction, was decreased with CCs (1.36 g cm^{-3}) compared to fallow (1.62 g cm^{-3}), but was similar to grain pea (1.47 g cm^{-3}). Water stable aggregates are measured as an indicator of soil erosion. Larger aggregates are less susceptible to erosive forces. In this study, the proportion of larger (0.08 – 0.30 in.) aggregate size fractions (Fig. 2) was increased with CCs (36%) compared to grain pea (22%), but was similar to fallow (25%). The proportion of smaller (0.01 – 0.04 in.) aggregates was decreased with CCs (32%) compared to fallow (45%) but was similar to grain pea (41%). Mean weight diameter of wet aggregates (Fig. 2) was not different when CCs were left standing (0.044 in.) versus when they were hayed as an annual forage (0.042 in.), but both were greater than fallow (0.033 in.) or grain pea (0.030 in.).

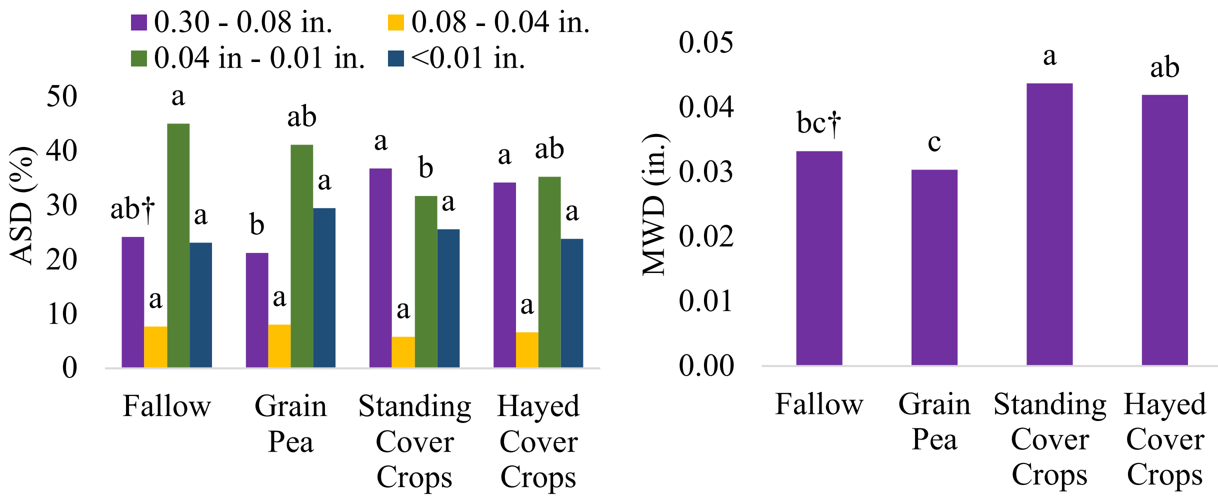

Figure 2. Impacts of cover crops on (a) aggregate size distribution (%) and (b) mean weight diameter (in.) of wet aggregates from the 0 – 2 in. soil depth.
†Means with the same lowercase letter are not significantly different among treatments within each aggregate-size fraction.

SUMMARY

Eleven years of growing a CC or forage crop in place of fallow in the semiarid CGP generally increased aggregation and reduced soil bulk density but had little impact on SOC and N stocks. Treatments of differing CC species diversity did not significantly differ for any observed soil health parameter. Interestingly, haying of CCs as annual forage also had little effect on soil health indicators compared to when CCs were left standing. Similar results were observed by Blanco-Canqui et al (2013) six years earlier in this same experiment. Intensification of cropping systems with CCs, annual forages, or grain crops under no-till management may be a good means of improving soil health in semiarid drylands.

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