CROP PRODUCTION AND SOIL PROPERTIES IMPACTS OF INTEGRATING ANNUAL FORAGES AND RUMINANT LIVESTOCK INTO WHEAT-BASED CROPPING SYSTEMS

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ABSTRACT

Integrating annual forages and ruminant livestock to intensify dryland cropping systems have the potential to increase profitability, increase water use efficiency, and improve soil health. The objective of this study was to determine the crop yield and soil property impacts of intensifying traditional no-till winter wheat *(Triticum aestivum L.)*-grain sorghum *(Sorghum bicolor Moench)*-fallow (WW-GS-F) with annual forages as well as integrating livestock to graze forages and crop residues. This study was initiated in 2021 at the Kansas State University Agricultural Research Center-Hays in Hays, KS. Treatments were WW-GS-F (control), WW-GS-F with grain sorghum residues grazed, winter wheat/forage sorghum-forage sorghum-fallow (WW/FS-FS-F) with forage sorghum grazed, and WW/FS-FS-F with forage sorghum hayed. The treatments were replicated four times with all phases of the rotation present each year. Grain and forage yields were determined every year with sampling to characterize soil properties in fall 2023. Results showed that full-season forage sorghum harvested for hay produced 5,994 lb/ac on average, while post-wheat forage sorghum harvested for hay produced 1,682 lb/ac. Before grazing, full-season forage sorghum produced 9,735 lb/ac with about 51% biomass remaining as residue after livestock were removed. On average, post-wheat forage sorghum produced 2,988 lb/ac before grazing. Because of smaller yields, post-wheat forage sorghum plots were grazed only in one year when 82% biomass remained as residue on the plots after livestock were removed. In 2023, WW yields were low due to dry weather, but there was no difference among treatments and average was 15 bu/ac. The WW/FS-FS-F (grazed) treatment had greater crop residue cover (77%) at winter wheat planting than all other treatments (53%) in fall 2023. No differences in bulk density or penetration resistance in the 0-2-in and 2-6-in soil depths were observed across treatments. Despite no differences in bulk soil organic carbon (SOC) in the 0-2-in and 2-6-in soil depths, dry aggregate associated SOC was greater with WW-GS-F (grazed) and WW/FS-FS-F (grazed) treatments than WW-GS-F and WW/FS-FS-F (hayed). No differences in mean weight diameter of (MWD) water stable aggregates or the wind-erodible fraction were observed across treatments. These preliminary results suggest that intensifying the WW-GS-F rotation with annual forages and integrating livestock increased available forage, soil residue cover, and dry aggregate associated organic carbon with no effect on winter wheat yields.

INTRODUCTION

Intensifying dryland cropping systems with annual forages and integrating ruminant livestock have the potential to increase profitability, enhance fallow water use efficiency, and improve soil health by increasing residue cover and reducing wind and water erodibility. Currently, the most common crop rotation in this region is winter wheat (WW)-summer crop-F. The most common crops utilized within that rotation are grain sorghum (GS) *(Sorghum bicolor (L.) Moench)* and corn *(Zea mays L.)* (Schlegel et al., 2002). Typically, after the summer crop is harvested, a 12-14-month fallow period ensues to build soil water content for the next WW crop. Due to high evaporation in this climate only 17-30% of precipitation is retained as stored soil moisture during the fallow period (Peterson & Westfall et al., 2004). Even with no-till (NT), less than half of precipitation is retained, and soil cover is lost. Intensifying the rotation with annual forages may reduce soil water and have a negative impact on subsequent grain yield, but the forage that is produced for grazing and haying may offset negative impacts to profitability. Adding annual forages in wheat-based systems may even boost profitability (Holman et al., 2018, 2021, 2023a, 2023b; Carr et al., 2020). Concerns also may arise with the negative impacts haying and grazing could potentially have on soil organic carbon (SOC) reserves, water stable aggregates, and wind erodible fraction due to grazing or haying crop residue. Grazing is often seen negatively as it may increase soil compaction as indicated by greater bulk density (BD) and penetration resistance (PR). The objective of this study was to analyze crop yield and soil health impacts of intensifying traditional NT WW-GS-F system with annual forages, as well as integrating ruminant livestock to graze forages and crop residues.

MATERIALS AND METHODS

This study was initiated at the Kansas State University Agricultural Research Center-Hays in Hays, KS with all phases of the experiment in place by 2021. The study design was a randomized complete block with four replications in a WW-GS-F rotation system. The study compared WW-GS-F rotation with grazing of the GS stalks and with grazing or haying of annual forages grown in place of GS. Each crop phase and hayed or grazed treatments were present each year. Plots were 60-ft wide x 127-ft long for the grazed treatments, and 30-ft wide x 127-ft long for the hayed treatments. Each treatment was grown under NT conditions.

Treatments:

1. Year 1: winter wheat; Year 2: grain sorghum; Year 3: fallow: (WW-GS-F)
2. Year 1: winter wheat; Year 2: grain sorghum (grazed stalks); Year 3: fallow: (WW-GSG-F)
3. Year 1: winter wheat/double-crop forage sorghum (grazed); Year 2: forage sorghum (grazed); Year 3: fallow: (WW/FSG-FSG-F)
4. Year 1: winter wheat/double-crop forage sorghum (hayed); Year 2: forage sorghum (hayed); Year 3: fallow: (WW/FSH-FSH-F)

Winter wheat was planted the end of September, GS and FS were planted at the beginning of June, and post-wheat FS was planted as soon as WW was harvested.

Winter wheat was harvested mid-late June, and GS was harvested mid-October. All grain crops were harvested using a Massey Fergusson 8XP plot combine with a 5-ft wide header attached. Grain yields were determined by a single 5-ft x 127-ft pass with the combine. Hayed FS was harvested at the end of August. Forage sorghum yields were determined by a single harvest of a 3-ft x 127-ft pass with a Carter forage harvester at heading. Grazing of GS stocks occurred post GS harvest and at heading in FS. To determine FS amount before grazing, a 2-ft x 3-ft quadrant was used to sample two different locations within the plot. After grazing, the methods were repeated to determine amount of residue remaining.

In August 2023, soil samples were taken from each plot pre-wheat planting. The soil properties examined were residue cover (RC), wet and dry aggregate stability, BD, PR, SOC, and particulate organic matter (POM). Residue cover was analyzed using the line transect method. Two samples were collected per plot for aggregate stability and BD, while ten samples per plot were collected for all other soil property analyses. Wet aggregate stability MWD was conducted by the wet sieving method using intact soil samples collected at the 0-2-in depth (Nimmo and Perkins, 2002). Dry aggregate stability was determined using a set of rotary sieves and wind erodible fraction was estimated as proportion of aggregates <0.84 at the 0-2-in depth (Chepil, 1962). Wet and dry aggregates were then analyzed for SOC for the >2mm, 2-0.25mm, and <0.25mm size distributions using the dry combustion method (Helmke et al., 2013). The same method was repeated for bulk SOC at 0-2-in and 2-6-in depths. The POM was conducted using the procedure outlined by Cambardella and Elliot (1992) at 0-2-in and 2-6-in depths. Bulk density was determined by the core method with samples taken from 0-2-in and 2-6-in depths (Grossman and Reinsch, 2002). Penetration resistance was determined using an Eijkelkamp Hand Penetrometer (Eijkelkamp Soil & Water, Morrisville, NC). Statistical analyses were completed in the SAS version 9.4 (SAS Institute, 2012, Cary, NC) using PROC GLIMMIX with year and treatment considered fixed and replication considered random. Treatment differences were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Forage Sorghum

Average hayed full season FS produced 5,994 lb/ac, while post-wheat hayed FS produced 1,682 lb/ac. The maximum full season FS production was in 2021 (8812 lb/ac), while the maximum post-wheat FS production was in 2023 (1899 lb/ac) for hayed treatments. Full season grazed FS produced 9,735 lb/ac on average before grazing and left approximately 51% of the forage as residue. Post-wheat FS was grazed only one year during the study due to extreme droughts in 2022 and 2023. In 2021, post-wheat FS produced 5,348 lb/ac and approximately 82% of total biomass was left after grazing.

Winter Wheat Yield

Due to a hail event in 2021 and an extreme drought in 2022, the only WW yields recorded were in 2023. In 2023 yields were low due to dry weather, but there were no significant differences in yield across treatments and the average was 15 bu/ac.

Residue Cover

In August 2023, treatments, WW/FSG-FSG-F had the greatest RC (78%) (Figure 1). The next highest treatments were WW-GS-F (61%) and WW/FSH-FSH-F (56%). With WW-GSG-F (41%) leaving the least soil cover.

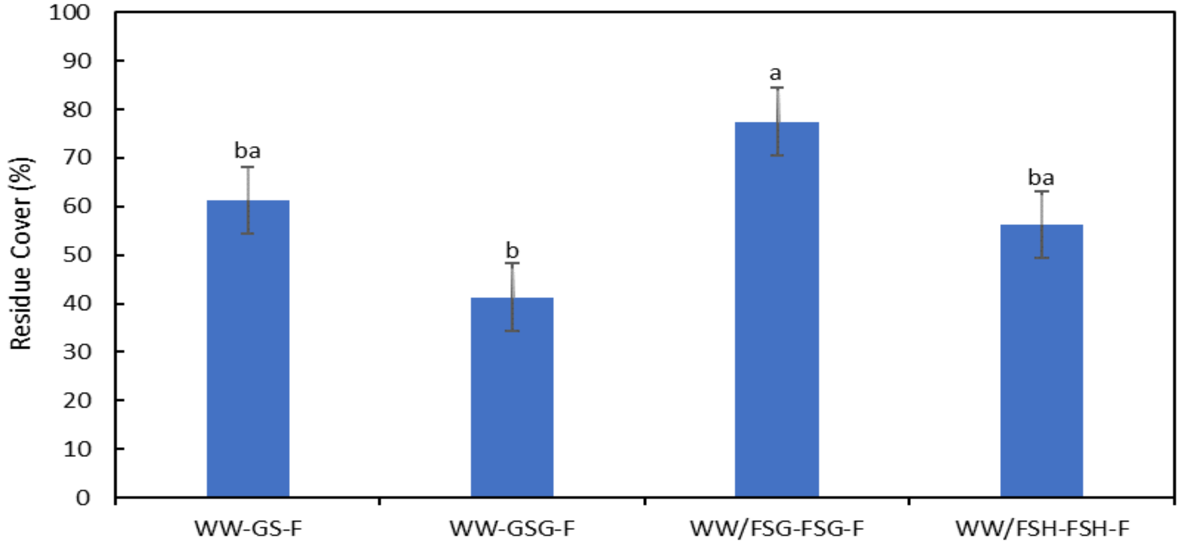

Figure 1. Intensification of WW-GS-F with grazing and forage sorghum effects on residue cover. Means with the same letter are not significantly different (*P*<0.05).

Soil Organic Carbon and Aggregate Associated Carbon

Despite the differences in RC, bulk SOC was not significantly different among treatments. Likewise, water stable aggregate-associated carbon at the 0-2-in depth showed no significant differences among treatments. However, treatments differed significantly in dry aggregate-associated carbon in all three size classes (Figure 2). Grazed treatments (WW-GSG-F and WW/FSG-FSG) ranked first or second in SOC in all aggregate size classes compared to WW-GS-F and WW/FSH-FSH-F.

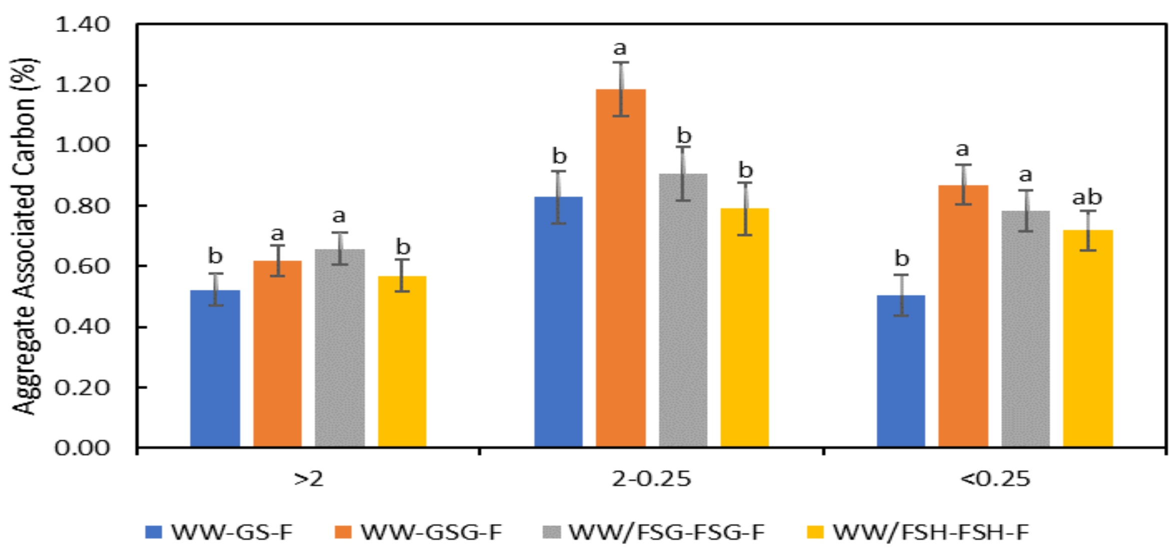

Figure 2. Intensification of WW-GS-F with grazing and forage sorghum effects on dry aggregate-associated carbon. Means with the same letter are not significantly different (P<0.05).

Particulate Organic Matter

Treatment differences in POM differed with depth (Figure 3). At the 0-2-in depth POM was greater for WW-GS-F and WW/FSG-FSG-F than for WW-GSG-F and WW/FSH-FSH-F. At the 2-6-in depth, there were no differences in POM among treatments.

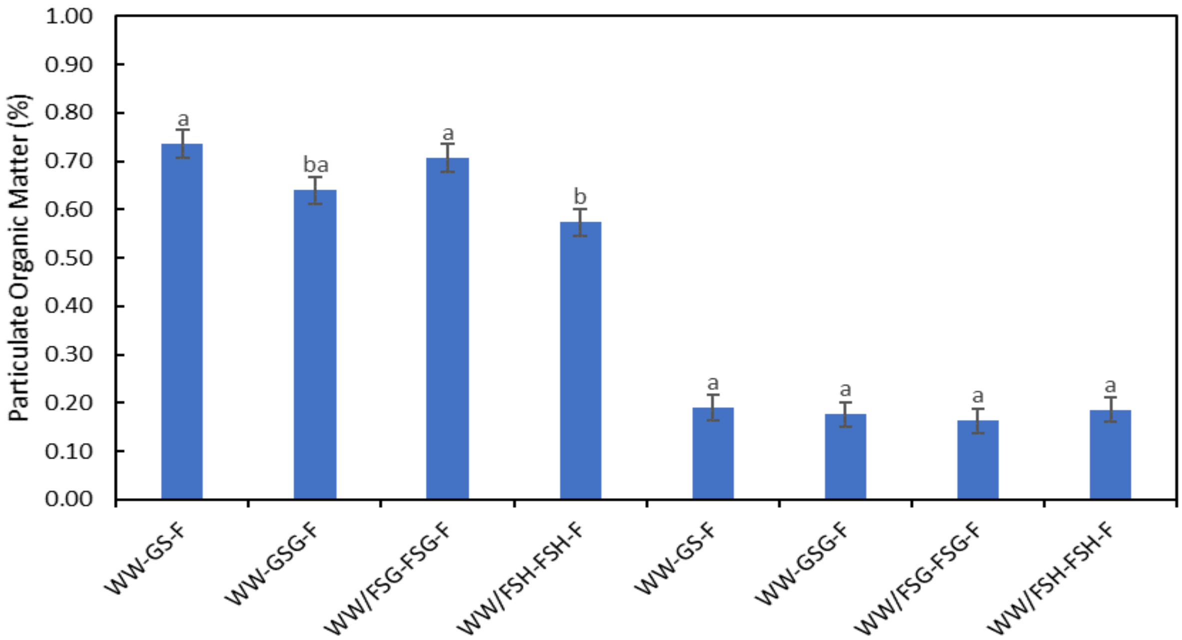

Figure 3. Intensification of WW-GS-F with grazing and forage sorghum effects on particulate organic matter. Means within a depth with the same letter are not significantly different (P<0.05).

Aggregate Analysis

Wet aggregate stability and dry aggregate stability (MWD) and wind erodible fraction were not different across treatments at the 0-2-in depth.

Measures of Soil Compaction

Penetration resistance and BD at 0-2-in and 2-6-in depths were not different across treatments.

CONCLUSION

Intensifying the WW-GS-F rotation with annual forages and integrating ruminant livestock increased aggregate associated organic carbon and residue cover. The addition of annual forages and livestock had no effect on MWD, WEF, PR, BD, bulk SOC, and WW yields. These results occurred while an additional forage available for haying and grazing, potentially increasing profits.

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