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Assessing the Influence of Strategic Tillage on Crop Yields and Soil Properties in Dryland No-Tillage Systems

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Assessing the Influence of Strategic Tillage on Crop Yields and Soil Properties in Dryland No-Tillage Systems

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Summary

Implementing strategic tillage (ST) in otherwise long-term no-till (NT) systems could control herbicide resistant weeds and increase profitability of crop production in semi-arid dryland cropping systems. For the purpose of this study, ST is defined as a single tillage event (once every 6-10 years) in an otherwise NT system to reduce density of herbicide tolerant grass weeds. However, there is little information on the long-term (>5 years) effects of ST on soil health parameters and crop yields. This study used long-term tillage and crop rotation plots established in 1976 at the Kansas State University Agriculture Research Center in Hays, KS. Treatments include three rotations: continuous wheat (WW), wheat-sorghum-fallow (WSF), and wheat-fallow (WF); and two tillage regimes: no-till (NT) and reduced tillage (RT). In 2016, a new tillage treatment, ST, was added to control herbicide resistant (HR) grass weeds and to mix soil to reduce nutrient and pH stratification. Soil samples were collected following wheat harvest in 2022 to investigate soil properties after 5 years of ST. Results of the 2022 sampling showed rotation and tillage had no significant effect ($P > 0.05$) on bulk density. However, bulk density was least in the 0- to-2-inch soil depth compared to the 2- to 6-inch and 6- to 12-inch depths, with values of 1.16, 1.44, and 1.39 g/cm^3, respectively. Soil organic carbon (SOC) was greatest in the 0- to 2-inch soil depth. The SOC concentration in soils under NT was not different compared to ST, whereas soils under RT had 8% less SOC than NT. Wind-erodible fraction (WEF) was not different among tillage treatments. Tillage treatments had a significant effect on mean weight diameter (MWD), with NT having the highest MWD followed by ST. Winter wheat yield was greatest in RT across the crop rotations. Strategic tillage increased wheat yields in WW compared to NT. Crop rotation, tillage intensity, and depth were all important with pH because pH was highest in WW rotation, RT tillage, and the 6- to 12-inch soil depth. Phosphorus concentrations were highest in WW and the 0- to 2-inch soil depth. Potassium had the greatest concentrations in RT and the 0- to 2-inch soil depth. Grain sorghum yield was not different between NT and ST, but yields for both were greater than RT. Overall, ST had no negative effect on soil properties or crop yield and can be a mitigation option to control herbicide resistant weeds and increase profitability of dryland crop production.

Introduction

The adoption of NT throughout the Central Great Plains has aided in the conservation of soil moisture as well as minimized soil erosion. These benefits of NT also come with some drawbacks, such as herbicide resistant (HR) weeds and nutrient and pH stratification. No-till producers in the region are fearful that implementing tillage to control HR weeds and stratification will ruin the progress they made with improving soil health and soil structure. The use of ST has been implemented to help reduce the density of HR weeds as well as reduce compaction and nutrient stratification. There are concerns about how ST will affect soil health parameters as well as crop yield, especially in long-term NT systems. Strategic tillage in this research is defined as a tillage pass done with a sweep plow, which is performed when the risk of soil erosion is the lowest, in an otherwise NT cropping system to control HR weeds. After the tillage operation, the field is returned to NT. The tillage pass also reduces soil nutrient and pH stratification. In this study, ST was implemented once and tracked for six years. The objective of this study was to assess the effect of one-time ST on soil properties and crop yields in dryland crop rotations.

Experimental Procedures

This experiment was conducted at the Kansas State University Agricultural Research Center near Hays, KS. The study used long-term plots that have been in place since 1976. The experimental design was a randomized complete block with three replications in a split-plot treatment structure. Main plots were three crop rotations [continuous winter wheat (WW), wheat-fallow (WF), wheat-sorghum-fallow (WSF)] and two tillage treatments (RT and NT) as sub-plots. Every phase of each crop rotation and tillage system combination was present in each replication every year of the study. Individual plot sizes were 40 feet wide by 80 feet long. In July of 2016, the ST treatment was added by splitting the long-term NT treatment into two equal plots, to manage HR weeds (kochia [*Kochia scoparia*] and perennial grass weeds such as purple three-awn [*Aristida purpurea*] and tumble windmill [*Chloris verticillata*]) and nutrient stratification.

The first pass of tillage in the ST plots was done using a sweep plow (Premier Tillage, Minimizer, Quinter, KS) with 5-ft wide blades at a depth of approximately 3 inches, and a second pass was done with the same implement 3 days later but at roughly 6 inches deep. The first pass was to control HR weeds, such as kochia and tumble windmill grass, and the second pass was to control escaped weeds and to mix soil to reduce stratification of nutrients and pH. For RT, tillage was done with the same implement 6 inches deep, for two to three tillage passes during the fallow period. All tillage operations were performed in July prior to winter wheat planting in the wheat-based rotation, and tillage operations were done in May for sorghum planting in the WSF rotation.

Soil samples at the depths of 0–2, 2–6, and 6–12 inches were collected to assess soil chemical and physical properties, including aggregate stability, pH, and nutrient concentrations. To determine bulk density, two soil cores 2 inches in diameter were taken from each plot and were segmented into depths of 0 to 2, 2 to 6, and 6 to 12 inches. The cores were dried at 220°F for a minimum of 48 hours and then weighed to determine mass of dry soil. Bulk density was computed using the mass of oven-dried soil divided by the volume of the core. Data were subjected to ANOVA as a split-plot design using the PROC GLIMMIX procedure of SAS ver. 9.4. Treatment differences were considered significant at $P \leq 0.05$.

Mean weight diameter (MWD) of water stable aggregates was measured by the wet-sieving method using sieves of 2, 1, and 0.25 mm diameter openings raised and lowered in a basin of water for 5 minutes. Soil held on each sieve was collected, dried, and weighed to calculate MWD. Sand corrections were completed for each aggregate size fraction by passing the sample back over the same diameter sieve after dispersion in a solution of sodium hexametaphosphate and 4-hr shaking on a reciprocal shaker. The wind-erodible fraction (WEF), which is the proportion of soil aggregates <0.84-mm, was measured by placing dry soil aggregates on top of a stack of sieves with 19-, 6.3-, 2-, 0.84-, and 0.42-mm openings. Samples were shaken for 5 minutes, collected from each sieve, weighed, and used to calculate WEF.

Winter wheat and grain sorghum yields were determined by harvesting an area 5 feet wide by 80 feet long from the center of each plot using a Massey Ferguson 8XP small plot combine harvester (Massey Ferguson, Duluth, GA). Winter wheat was harvested in July, and grain sorghum harvest was done in October each year of the study. Grain moisture content was determined using a DICKEY-john grain moisture tester (DICKEY-john Inc., Auburn, IL), and yield of both wheat and grain sorghum was adjusted to 13.5% moisture content.

Results and Discussion

Soil Properties

Soil bulk density (BD) was 19% lower in the 0- to 2-inch depth compared to the 2- to 6-inch sampling depth and was 17% lower compared to the 6- to 12-inch sampling depth. However, bulk density was not significantly different among crop rotations or tillage treatments (Table 1). Soil organic carbon (SOC) was 35% higher in the 0- to 2-inch soil surface compared to the 2- to 6-inch depth and 46% higher than the 6- to 12-inch depth. The SOC concentration was 7% greater in the WW rotation compared to WSF and 8% greater compared to WF. The SOC concentration with ST was not different from NT or RT. However, SOC concentration with NT was significantly greater compared to RT (Table 1). Crop rotation had a significant effect on wind-erodible fraction (WEF), and WF had 17% more WEF compared to WW and 18% greater than WSF. The WEF was not different among tillage practices. The mean weight diameter (MWD) of soil aggregates in the upper 2 inches of the soil profile was 20% less in WF compared to WSF and 23% lower when compared to WW. The MWD with NT was greater than RT but not different compared with ST. The pH in WW was 5% higher in the 0- to 2-inch soil depth when compared to the 6- to 12-inch depth (Table 2). Tillage was also significant with pH, with RT having a 3% higher pH compared to NT. The pH in the 6- to 12-inch depth was 22% higher in contrast to the 0- to 2-inch depth. Soil pH had significant interactions with rotation by depth, tillage by depth, and rotation by tillage by depth. The phosphorus concentrations in the WW rotation were 18% higher than the WSF rotation, and the phosphorus concentrations were 77% greater in the 0- to 2-inch soil depth in comparison to the 6- to 12-inch depth. Similarly to pH, phosphorus also had significant rotation by depth, tillage by depth, and rotation by tillage by depth interactions. These interactions could explain the stratification across rotation, tillage, and depth for pH and phosphorus. Potassium concentrations were 4% greater in RT than NT, and the concentrations were 6% greater at the soil surface compared to the 6- to 12-inch depth.

Crop Yields

Across the four growing seasons, WSF had the highest average winter yield (45 bu/a) compared to WF (44 bu/a) and WW (31 bu/a) (Figure 2). Wheat yields for NT, ST, and RT in the WSF and WF rotations were not different. However, in WW, wheat yield with ST were greater than NT, but ST and RT were not different. When averaged across the five growing seasons (2018–2022), sorghum grain yields with NT and ST were greater (68 bu/a) compared to RT (58 bu/a) in the WSF rotation (Figure 3).

Overall Conclusions

Soil physical properties including soil bulk density, SOC, and MWD were not different with ST compared to NT. However, SOC and MWD were lower with RT compared to NT. The WW rotation had higher SOC concentrations compared to WSF and WF, which were rotations that included 11-month fallow periods compared to 3 to 4 months of fallow in WW. Soil organic carbon concentrations were greater in the 0- to 2-inch soil depth compared to the 2- to 6-inch and 6- to 12-inch soil depths. Similar trends were observed for pH, as well as soil P and K, which indicated significant stratification of these soil chemical properties. Soil pH and potassium concentrations were not different for NT and ST, but both NT and ST were lower than RT. Soil P was not different across tillage treatments. Soil pH was significantly lower under WW compared to WSF and WF, and WF was significantly lower than WSF. A similar trend was observed for soil P, though K concentrations were not different across rotations. Across tillage treatments for soil chemical results, it can be noted that ST and RT helped alleviate stratification in comparison to NT. The mean weight diameter of water stable aggregates was greatest for WW followed by WSF followed by WF. Strategic tillage plots have a similar MWD compared to NT, which was significantly greater compared to RT. Wind-erodible fraction was greater in WF plots compared to WSF or WW but was not affected by tillage treatments. The most profitable winter wheat crop rotation across 4 growing seasons was WSF followed by WF then WW, and among the tillage treatments, RT had the highest average, followed by ST then NT. Grain sorghum yield was greatest in the NT and ST tillage treatments compared to RT in the WSF rotation. Results show that soil chemical and physical properties were not different with ST compared to long-term NT. Winter wheat and grain sorghum yields were also increased by the incorporation of ST compared to long-term NT.

Acknowledgments

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Table 1. Effects of rotation, tillage, and depth on selected soil physical properties at the Kansas State University Research Center near Hays, KS

Factor[‡]	BD	SOC	MWD	WEF
Rotation	g cm^{-3}	g g^{-1}	mm	%
WW	1.34	1.29 a	0.69 a	28.70 b
WSF	1.34	1.20 b	0.51 b	28.30 b
WF	1.32	1.19 b	0.41 c	34.50 a
Tillage				
NT	1.32	1.27 a	0.62 a	29.3
ST	1.33	1.23 ab	0.55 ab	31.4
RT	1.35	1.17 b	0.43 b	30.9
Depth, in.				
0–2	1.16 b[†]	1.67 a		
2–6	1.44 a	1.09 b		
6–12	1.39 a	0.91 c		

[†] Means with the same letter within columns are not different ($\alpha = 0.05$) across treatments.

[‡] Soil parameters were bulk density (BD), soil organic carbon (SOC), mean weight diameter (MWD), and wind-erodible fraction (WEF). Rotations were continuous wheat (WW), wheat-sorghum-fallow (WSF), and wheat-fallow (WF). Tillage treatments were no-tillage (NT), strategic tillage (ST), and reduced tillage (RT).

Table 2. Rotation, tillage, and depth effects on selected soil chemical properties at the Kansas State University Research Center near Hays, KS

Factor	pH	P	K
Rotation[‡]		mg kg^{-1}	mg kg^{-1}
WW	5.93 c[†]	28.38 a	544.7
WSF	6.24 a	23.22 b	535.0
WF	6.10 b	26.44 ab	541.3
Tillage			
NT	6.01 b	28.18	532.0 b
ST	6.05 b	25.54	533.6 b
RT	6.21 a	24.32	555.4 a
Depth, in.			
0–2	5.31 c	60.02 a	562.9 a
2–6	6.26 b	13.74 b	530.5 b
6–12	6.81 a	4.29 c	527.6 b

[†] Means with the same letter within a main effect within each column are not different ($\alpha = 0.05$).

[‡] Rotations were continuous wheat (WW), wheat-sorghum-fallow (WSF), and wheat-fallow (WF). Tillage treatments were no-tillage (NT), strategic tillage (ST), and reduced tillage (RT).

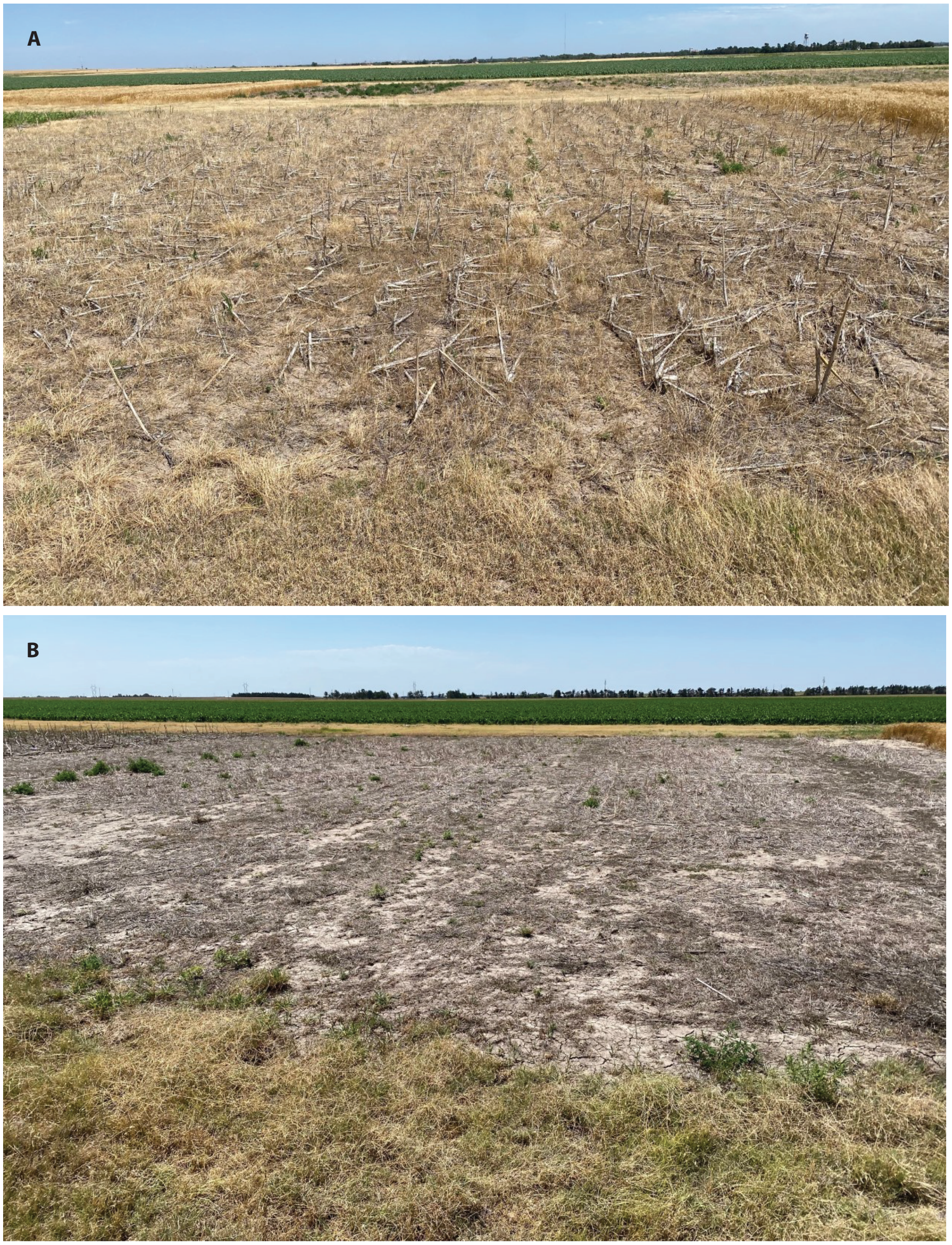

Figure 1. Various weed species and densities within the plots prior to tillage. Photo A is a wheat-sorghum-fallow (WSF) rotation, and photo B is a wheat-fallow (WF) rotation. Photos by Mikaela Lawrence, K-State Research and Extension.

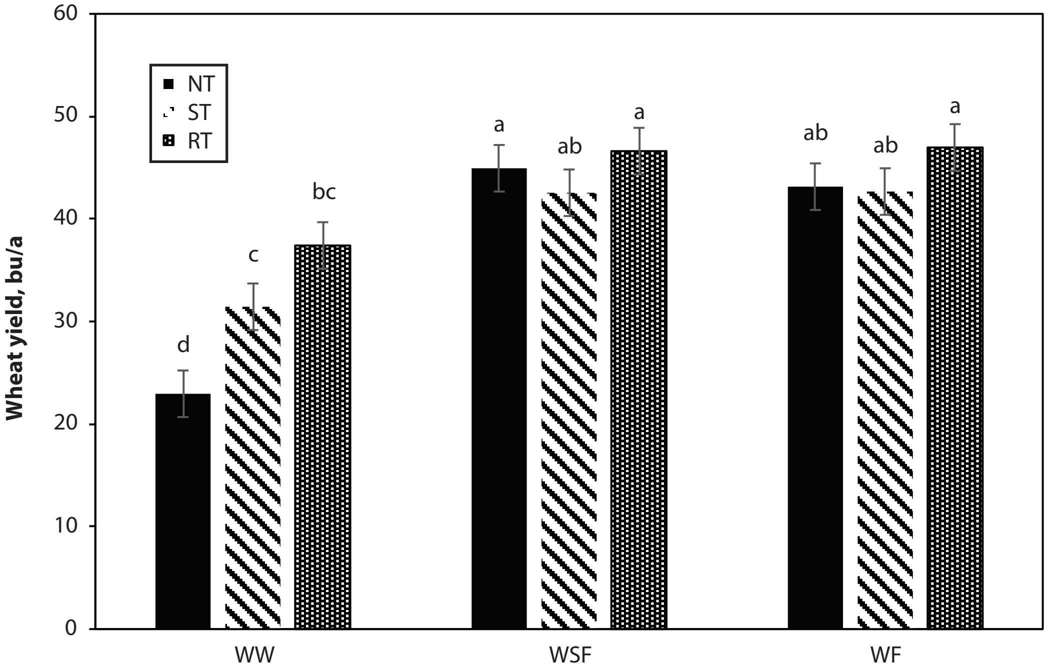

Figure 2. Comparison of winter wheat grain yield in continuous wheat (WW), wheat-sorghum-fallow (WSF), and wheat-fallow (WF) rotations averaged across 4 growing seasons (2018, 2019, 2020, and 2022) as influenced by crop rotation and tillage (no-tillage (NT), strategic tillage (ST), and reduced tillage (RT)). Bars with the same letter within each rotation are not different ($\alpha = 0.05$).

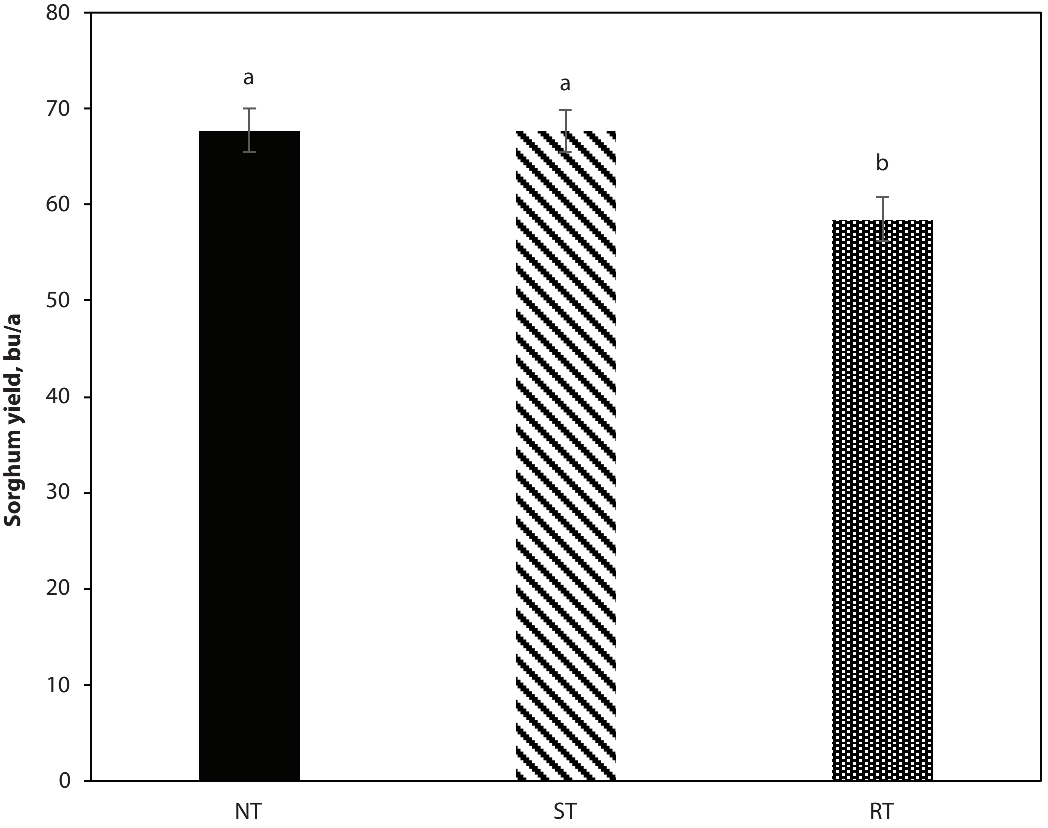

Figure 3. Grain sorghum yield in a wheat-sorghum-fallow (WSF) rotation averaged across 5 growing seasons (2018, 2019, 2020, 2021, and 2022) affected by tillage (no-tillage (NT), strategic tillage (ST), and reduced tillage (RT)). Bars with the same letter are not different ($\alpha = 0.05$).