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Logan M. Simon
Kansas State University, lsimon@ksu.edu

Augustine K. Obour
Kansas State University, aobour@ksu.edu

Zachariah C. Carson
Kansas State University, zccarson@ksu.edu

See next page for additional authors

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Authors

Logan M. Simon, Augustine K. Obour, Zachariah C. Carson, Frank Weber, Stacie Minson, and Craig Dinkel

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L. Simon, A. Obour, Z. Carson, F. Weber, S. Minson, and C. Dinkel

Summary

Grazing cover crops (CCs) could provide an economic benefit to offset potential lost revenue when grain crop yields are decreased after CCs in dry years. However, there is limited guidance on the optimum biomass removal rate that balances soil health and grazing goals. An on-farm study was established in fall 2022 on a 50-a producer field in Russell Co., KS, to investigate the effects of CC biomass removal rates with cattle grazing on soil health parameters and grain crop yields, and profitability in no-till (NT) dryland cropping systems. The study design was a randomized complete block with three treatments and four replications. The treatments included ungrazed CCs, "take-half-leave-half" (T-H-L-H, 50% biomass removal), and "graze-out" (G-O, 90% biomass removal). Results showed that T-H-L-H and G-O significantly reduced CC residue amount and height compared to ungrazed CCs but maintained residue cover on the soil surface similar to ungrazed CCs. Cover crop management had no significant effect on soil organic carbon, particulate organic matter, nitrate-N, or P concentrations. However, T-H-L-H somewhat increased soil bulk density compared to ungrazed CCs, though both were similar to G-O. Soil penetration resistance, wind-erodible fraction, mean weight diameter of water stable aggregates, time-to-runoff, and subsequent grain sorghum yield were unaffected by CC management. These results suggest that farmers and ranchers may be able to graze CCs at greater intensities than T-H-L-H to maximize livestock gains while maintaining soil health. This approach could increase adoption of CCs and benefit water quality protection and improvement efforts in reaching the goals of the approved 9 Element Watershed Plan through the Kansas Department of Health and Environment and Environmental Protection Agency. However, these observations were made in a 1-year study and under exceptional drought conditions, so further investigation will be necessary under conditions of average or above average precipitation when wet soils may be more susceptible to degradation by cattle hoof traffic.

Introduction

No-tillage (NT) and cover crops (CCs) have been widely recommended to regenerate soils degraded after many years of conventionally tilled, low-intensity crop production. Soil health benefits of CCs in NT cropping systems include increased soil organic carbon (SOC), enhanced nutrient cycling, reduced compaction, increased water infiltration, and reduced wind and water erosion. However, several barriers to adoption of CCs exist in water-limited regions including the costs of establishing CCs (seed, machinery, labor, and fuel) and the risk of CCs reducing subsequent grain yields due to reduced soil water at the next crop planting. Some producers have sought to overcome these barriers by integrating livestock to graze CCs, which have been widely promoted for diversifying agricultural production systems.

Previous research has shown most CC species can provide high-quality forage for livestock, which can extend the grazing season and reduce the need for feeding costly stored forages in concentrated feeding sites for extended periods. Grazing CCs can delay grazing of native rangelands and allow for longer periods of rest and improved rangeland health. Previous research has demonstrated increased system profitability with integrated crop-livestock systems. However, subsequent grain yields have been variable, with incidences of reduced yield often having been attributed to soil compaction, soil aggregate destruction, and reduced water infiltration due to excessive animal hoof traffic. For long-term practitioners of NT, this is a major concern as yield-limiting soil compaction could require tillage for remediation.

There is limited guidance on the optimum biomass removal rate that balances soil health and grazing goals. Previously, USDA-NRCS has made no provisions for grazing CCs and current Kansas NRCS recommended stocking rates are based on those developed for native rangelands (T-H-L-H, 50% biomass removal). Previous research suggests that conservative stocking densities that remove 40 to 50% of biomass do not negatively affect soil properties compared to ungrazed CCs, which suggests that greater levels of biomass removal with grazing could be practical, especially when regrowth occurs after grazing and would generate greater profit for farmers and ranchers. However, higher stocking rates (70 to 90% removal) have occasionally resulted in compaction and reduced water infiltration in some studies. The objective of this research is to determine the optimum amount of CC biomass removal with livestock grazing to optimize farm profits and enhancements in soil health on no-tillage dryland cropping systems in Kansas.

Procedures

An on-farm study was established in fall 2022 on a 50-a producer field in Russell Co., KS (38° 42' 2.2" N, 98° 37' 58.3" W), located in the KSU Kanopolis Reservoir Big Creek Middle Smoky Hill River Watershed Restoration and Protection Strategies (WRAPS) area to investigate the effects of CC biomass removal rates with cattle grazing on soil health parameters, grain crop yields, and system profitability in NT dryland cropping systems. Soil types at the study site are the Crete silt loam (72%) and Harney silt loam (28%), and long-term average (30-yr) annual precipitation is 26 inches. However, the study period coincided with a period of exceptional drought. The study design was a randomized complete block with three treatments and four replications. Treatments included ungrazed CCs, "take-half-leave-half" (T-H-L-H, 50% biomass removal), and "graze-out" (G-O, 90% biomass removal).

In fall 2022, a three-species CC mixture of triticale, pea, and rapeseed was planted into wheat stubble about October 1 at 60, 15, and 2 lb/a, respectively, using an NT drill. No fertilizers were applied. In spring 2023, treatments were established with ungrazed plots of about 1.5 a and grazed plots of about 5 a each replicated and randomized across the field. Plots were grazed with yearling cattle beginning in the last week of April and moved plot-to-plot every 1 to 2 days across the eight grazed plots to achieve desired CC biomass removal rates based on visual assessment. Plots were only grazed once because of declining apparent forage quality (increasing plant maturity) and limited regrowth because of dry conditions. In May 2023, following the end of grazing but before chemical termination, CC biomass was measured in all plots by hand-clipping, to the ground level, two areas of 2 × 3 ft per plot. Samples were dried at 122˚F for a minimum of 48 hours in a forced-air oven and weighed to determine dry matter. Cover crops were chemically terminated in the third week of May, and the whole field was planted to grain sorghum with an NT planter approximately two weeks after termination or about the first week of June. Fertilizer applied to sorghum was based on the standard producer practice and kept consistent across treatments. Grain sorghum was harvested with a field scale combine equipped with a calibrated yield monitor about the last week of October. Plot level yield and moisture content data were extracted using QGIS 3.34 Prizren software, and yields were adjusted to 13.5% moisture content.

At the initiation of the study in fall 2022 before planting CCs, soil samples and water infiltration measurements were collected from the 0 to 2 and 2 to 6 inch soil depths for initial characterization of soil chemical and physical properties. Again, in spring 2023, soil samples and water infiltration measurements from ungrazed, T-H-L-H, and G-O plots were collected to determine the effects of biomass removal on soil chemical and physical properties. Soil bulk density (BD) was determined as mass of oven-dried soil divided by volume of the core following oven-drying at 221°F for 48 hours. Penetration resistance (PR) was measured at 10 random points within each plot using a hand cone penetrometer (Eijkelkamp Co., Giesbeek, The Netherlands) and readings were divided by the area of the cone (0.31 $inch^2$). Values of penetration resistance were adjusted to a field capacity gravimetric water content of 0.35 (g/g).

Additionally, 10 soil cores were randomly collected within each plot, divided into the 0- to 2- and 2- to 6-inch depths, and composited by depth. Samples were air-dried, crushed, and sieved to pass through a 0.08 inch stainless steel screen. The SOC and particulate organic matter (POM, <0.0021 inch) concentrations were determined by loss-on-ignition. Soil pH was determined potentiometrically by an electrode. Soil NO_3-N concentrations in samples were determined with a segmented flow analyzer after extracting the soil with 2 M KCl. Available P was determined by the Mehlich-3 extraction method, and P concentration in the extract was measured using inductively coupled plasma-optical emission spectrometry (ICP-OES). Lastly, intact soil samples were carefully collected with a flat shovel and were allowed to air-dry and then gently passed through a 0.75 inch sieve. Subsamples of <0.31 inch diameter aggregates were obtained and used to estimate mean weight diameter (MWD) of water stable aggregates by the wet-sieving method. The remaining sample was used to estimate wind-erodible fraction (WEF) (<0.03 inch) by the dry-sieving method. Analyses of CC biomass, grain yields, as well as soil chemical and physical properties were performed using the PROC GLIMMIX procedure in SAS ver. 9.4.

Results

Results from this study showed that T-H-L-H and G-O significantly reduced CC residue amount and height compared to ungrazed CCs (Fig. 1) though T-H-L-H maintained greater CC residue amount and height compared to G-O. However, percentage residue cover with G-O was not significantly different from the ungrazed treatment, and T-H-L-H was only somewhat less than G-O and ungrazed CCs (Fig. 1). This suggests that increasing the grazing intensity maintained the residue cover on the soil surface comparably to ungrazed CCs despite reducing the residue amount primarily by reducing residue height. Cover crop management had no significant effect on SOC, POM, NO_3-N, or P concentrations at subsequent grain sorghum planting in spring 2023 (Table 1). These results suggest that increasing the grazing intensity maintained the soil chemical properties comparably to ungrazed CCs. However, SOC, POM, NO_3-N, and P concentrations were greater in the 0 to 2 in soil depth compared to 2 to 6 inches.

Soil BD was somewhat increased with T-H-L-H and G-O grazing management strategies at subsequent grain sorghum planting compared to study initiation (Table 1). Soil BD was slightly increased with T-H-L-H compared to ungrazed CCs though both were comparable to G-O. The WEF at subsequent grain sorghum planting was greater in all CC treatments compared to study initiation but was not affected by CC management (Table 1). Cover crop management had no significant effect on PR, MWD, or time-to-runoff (TTR). This suggests that increasing grazing intensity may slightly increase some indicators of soil compaction (i.e., BD) in the months following CCs termination before subsequent cash crop planting. However, increasing the grazing intensity maintained the indicators of soil erodibility (i.e., MWD and WEF) and water infiltration (i.e., TTR) comparably to ungrazed CCs. This was potentially because of exceptional drought conditions during the CC growing season and grazing period that resulted in very dry soils that were less susceptible to degradation by cattle hoof traffic. Results showed no significant effect of CC management on subsequent grain sorghum yields which were 79, 84, and 82 bu/a for ungrazed, T-H-LH, and G-O, respectively. This suggests that increasing grazing intensity maintained similar subsequent cash crop yields to ungrazed CCs.

Conclusion

Results showed that T-H-L-H and G-O CC grazing strategies significantly reduced CC residue amount and height compared to ungrazed CCs but maintained residue cover on the soil surface comparably to ungrazed CCs. Cover crop management had no significant effect on SOC, POM, NO_3-N, or P concentrations, but T-H-L-H somewhat increased soil BD compared to ungrazed CCs though both were comparable to G-O. Soil PR, WEF, MWD, TTR, and subsequent grain sorghum yield were unaffected by CC management. These results suggest that increasing the grazing intensity maintained the soil health indicators and subsequent grain crop yields similar to ungrazed CCs. Farmers and ranchers may be able to graze CCs at greater intensities than T-H-L-H to maximize livestock gains while maintaining soil health. This approach could increase adoption of CCs and benefit water quality protection and improvement efforts in reaching the goals of the approved 9-Element Watershed Plan through the Kansas Department of Health and Environment and Environmental Protection Agency. Nevertheless, these observations were made in a one-year study and under exceptional drought conditions, so further investigation will be necessary under conditions of average or above average precipitation when wet soils may be more susceptible to degradation by cattle hoof traffic.

Table 1. Cover crop management and sampling depth effects on soil organic carbon (SOC), particulate organic matter (POM), nitrate-nitrogen (NO_3-N), phosphorus (P), soil bulk density (BD), penetration resistance (PR), mean weight diameter (MWD) of water stable aggregates, wind-erodible fraction (WEF), and time-to-runoff (TTR) at subsequent grain sorghum planting in spring 2023 near Dubuque, KS

Treatment	SOC	POM	NO_3-N	P	BD	PR	MWD	WEF	TTR
	%	%	ppm	ppm	g/cm^3	MPa	mm	%	min
Management									
Initial	1.94[†]	1.00	18.9	14.7	1.25c	-	1.23	23.7b	16.4
Ungrazed CCs	2.11	1.17	13.7	23.5	1.26bc	1.04	1.78	33.2a	10.1
Take-half-leave-half (50% removal)	1.86	0.91	9.9	20.1	1.33a	1.10	1.75	32.8a	12.1
Grazed-out (90% removal)	1.92	1.01	10.7	17.9	1.32ab	0.99	1.90	29.7a	9.0
Depth									
0-2 in	2.38a	1.56a	21.0a	25.1a	1.16b	-	-	-	-
2-6 in	1.54b	0.49b	5.6b	13.0b	1.42a	-	-	-	-
Type III test of fixed effects									
Parameter	***P*-values**								
Management (M)	0.3360	0.3956	0.3956	0.3360	0.0377	0.3309	0.2027	0.0038	0.1654
Depth (D)	0.0011	0.0006	0.0006	0.0011	0.0009	<0.0001	---	---	---
M × D	0.7043	0.8675	0.8675	0.7043	0.1019	0.7822	---	---	---

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

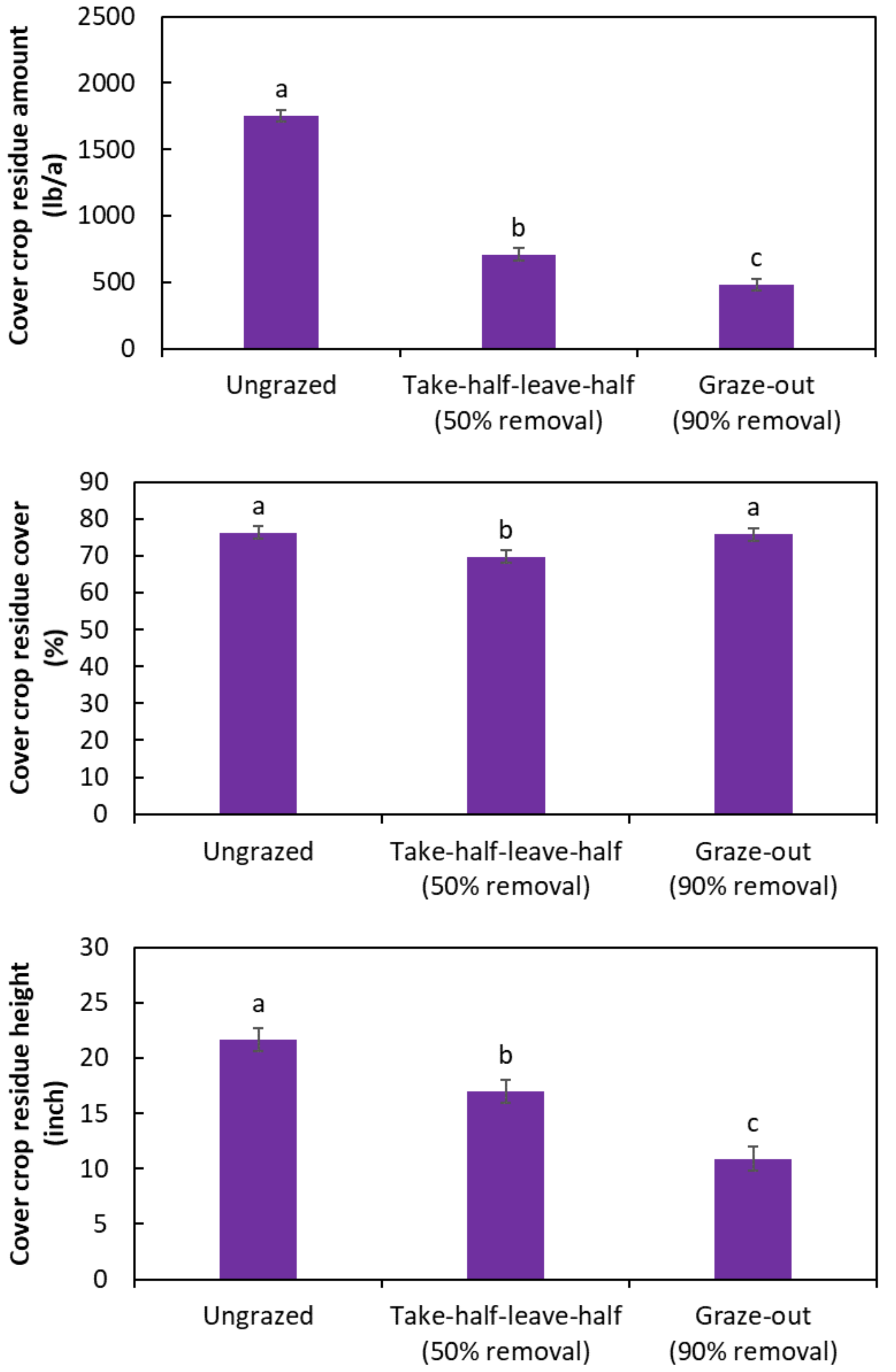

Figure 1. Cover crop residue amount, cover, and height at cover crop termination in spring 2023 near Dubuque, KS. Bars with the same letter are not significantly different across treatments ($\alpha \leq 0.05$). Error bars indicate standard error of the mean.