COVER CROP PLANTING TIME EFFECTS ON BIOMASS PRODUCTIVITY, SOIL HEALTH AND WHEAT YIELD IN DRYLAND SYSTEMS

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ABSTRACT

Ecosystem benefits of cover crops (CCs) in semi-arid dryland cropping systems are dependent on CC biomass productivity. This study evaluated how CC planting time (spring vs. fall) and fallow management practices [no-tillage (NT) vs. occasional tillage (OT)] influenced CC biomass, surface residue, selected soil health properties and crop yields within a winter wheat (*Triticum aestivum* L.)-sorghum (Sorghum bicolor Moench)–fallow (WSF) rotation. The experiment was conducted from 2023 to 2025 at the Kansas State University Hearting Beason (HB) Ranch using a split-plot randomized complete block design with four replications. Main plots were cropping phases of the WSF rotation, while sub-plots included fallow management treatments: a fall-planted CC mixture of triticale, pea, and rapeseed; a spring-planted mixture of oat, pea and triticale; NT fallow and OT fallow. Fall-planted cover crops produced slightly more biomass than spring-planting though the difference was not statistically significant, indicating flexibility in planting time. Cover crops retained significantly more residue cover and increased soil organic carbon (SOC) in the top 0-2-in depth compared to fallow treatments. Soil bulk density was lower under fall-planted CCs and OT compared to NT fallow. Soils under CCs had greater water stable aggregates compared to NT or OT fallow indicating improved soil structure and overall soil health. Winter wheat yields were decreased by CCs but utilizing CC biomass as forage resource increased system profitability compared to fallow. Our findings showed either NT with CCs planted in the fall or spring can maintain soil health by increasing residue cover and soil aggregation in semi-arid dryland cropping systems.

INTRODUCTION

In semi-arid environments like the central Great Plains, improving soil health is crucial for water storage and sustainable crop production. Integrating CCs can play a significant role in enhancing soil properties, improving nutrient cycling, and increasing water retention. However, their effectiveness is highly dependent on CC biomass productivity. The timing of CC establishment influences growth duration, biomass accumulation, and soil health benefits, making it a critical factor for farmers and land managers in these water-limited environments. Cover crops contribute to soil health improvements by increasing organic matter, enhancing microbial activity, and reducing soil erosion. Early-planted CCs generally produce greater biomass due to an extended growing period, leading to improved soil cover and associated soil health benefits. Conversely, delayed planting may limit biomass accumulation due to shorter growth periods and reduced soil moisture availability, which are major concerns in semi-arid regions where precipitation is scarce.

In water-limited environments, improper timing of CCs can lead to soil moisture depletion, potentially competing with cash crops for water resources. However, when effectively managed, CCs can enhance soil infiltration, increase water retention, and promote wet aggregate stability, which contributes to improved soil resilience over time. This study investigated the effect of CC planting time (spring or fall) on CC biomass production, fallow management and CC effects on soil properties, wheat yield and profitability in a semi-arid cropping system. Understanding the relationship between CC timing, management strategies, and soil properties is essential for developing best management practices to improve soil sustainability and productivity in semi-arid environments.

Materials and Methods

This study is a component of a large CC field experiment initiated in spring 2015 at the Kansas State University experiment fields at HB Ranch near Brownell, KS. The overall goal of the CC trials was to develop climate-specific CC management options for integrating CCs into dryland crop production in western. The current study was established in fall 2023 to investigate the effects of CC planting timing and fallow management on biomass productivity, crop yields and soil physical properties. The study design was a split-plot randomized complete block with four replications. Crop phase was the main plot and split-plots treatments were oat (Avena sativa L.)−triticale (× Triticosecale Wittm.) CCs grown during the fallow phase of the WSF rotation, planted either in the spring or in fall. Cover crops were managed as standing cover and were compared with NT and OT fallow treatments. The OT treatment was accomplished by tilling once in July or August during the fallow phase of the rotation prior to winter wheat planting to a depth of 3 inches using a sweep plow equipped with 5 feet blades and treaders (Premier Tillage Inc., Quinter, KS, USA). This is a non-inversion, a conservation tillage implement commonly used in the semi-arid CGP.

The CC biomass was determined by hand-clipping close to the ground level (~ 1 inch above the soil surface), two areas of 2 × 3 ft per plot. Samples were dried at 122˚F in a forced-air oven and weighed to determine dry matter. Oven-dried samples were ground to pass through a 1-mm mesh screen in a Wiley Mill (Thomas Scientific, Swedesboro, NJ). The ground samples were then analyzed for forage nutritive value [crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), *in vitro* dry matter digestibility (IVDMD)], tissue potassium (K) and phosphorus (P) concentrations (Ward Laboratories, Inc., Kearney, NE) using Foss 6500 near infrared spectroscopy (NIRS).

Intact soil samples were carefully obtained using a flat shovel to determine water stable aggregate stability. These samples were air-dried and gently passed through a 0.75-inch sieve to separate larger aggregates. Subsamples of <0.31-inch diameter aggregates were then obtained and used to estimate mean weight diameter (MWD) of water-stable aggregates (WSA) using the wet-sieving method. Residue cover was determined using the line transect method. 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 $P < 0.1$.

RESULTS AND DISCUSSION

Crop Yields and Net Returns

Averaged across years, fall-planted CCs produced more biomass (6080 lbs/ac) than spring-planted (4930 lbs/ac), but the difference was not statistically significant (Table 1). Spring-planted CCs had more CP, P, K and IVDMD concentrations compared to fall-planted CCs. However, ADF and NDF concentrations were not different between CC planting times. The CP requirement for growing replacement heifers with body weight (BW) of 1200 lb at maturity ranged from 8.1% (with growing BW of 960 lb) to 10.2% (with growing BW of 660 lb) assuming the forage contains ≥ 60% total digestible nutrients (NRC, 2000). The average CP concentration of the fall or spring-planted CCs in this study were within the minimum CP requirement for growth or maintenance of grazing beef cattle. These results suggests that both planting times are viable options for maximizing CC biomass production and nutritive value (if used as forage), offering flexibility when CCs can be planted after sorghum in the WSF rotation**.**

Winter wheat yields were low in 2024 due to below average precipitation with an average of 25 bu/ac and no significant differences in yields across treatments. In 2025, there was no significant yield difference between NT and OT treatments. However, growing a fall-planted or spring-planted CCs decreased wheat yields but 20 bu/ac and 14 bu/ac, respectively (Figure 1). Net returns across years were least with fall-planted CCs, followed by spring-planted CC, whiles NT and OT had similar net returns. However, utilizing the CC biomass as forage increased net returns two-fold compared to the NT or OT fallow treatments (Figure 2). This agrees with previous studies that showed replacing fallow with CCs can decrease subsequent wheat yields in low-and high yielding years but haying CCs as forage increased profitability of the production system (Holman et al., 2021).

Residue Cover and Soil Properties

Residue cover measured at winter wheat planting were similar under fall-planted and spring-planted CCs, which were significantly greater than NT and OT treatments (Table 2). Although significantly lower than CCs treatments, the NT (70%) maintained adequate residue cover compared to OT (53%). The lower residue cover in OT is likely due to soil disturbance from tillage, which could accelerate residue decomposition. The higher residue cover with CCs and NT will armored the soil against erosion and potentially increase SOC accretion. The CC treatments increased SOC concentration and MWD of water stable aggregates in the 0-2-in depth (Table 2) but no differences were found among treatments in the 2-6-in depth. Similarly, growing CCs and OT decreased bulk density near the soil surface compared to NT. The distribution of water stable aggregates varied across treatments. The soils under fall and spring-planted CCs had the highest percentage of larger water stable aggregates, suggesting better soil stability (Table 3). These findings support other studies in western Kansas that showed growing CCs in place of fallow improved soil properties (Simon et al., 2021). In contrast, OT resulted in the smallest proportion of large aggregates and the highest amount of microaggregates. This finding indicates OT could break down soil structure and could predispose dryland soils to erosion. No-tillage treatment had a higher percentage of small macroaggregates (42%), showing that NT can preserve soil aggregation. Overall, the results highlight that CCs regardless of planting time and NT help maintain healthier soil structure, while OT weakens soil aggregate stability.

Conclusion

This study highlights the impact of cover crop planting time on biomass production and soil properties in a semi-arid cropping system. Fall planting produced slightly more biomass than spring planting, but the difference was not statistically significant, suggesting flexibility in planting times for biomass production. Planting CCs in the fall resulted in in more residue cover but soil improvement as indicated by aggregate stability and SOC was not different from spring-planted CCs. The OT had the lowest residue cover and aggregate stability due to soil disturbance from tillage. Growing CCs decreased wheat yields and net returns but utilizing CC biomass as forage increase profitability compared to fallow. Overall, cover cropping, either planting in the spring or fall and NT practices maintain soil health by increasing residue cover, improve SOC and soil aggregation in a dryland WSF cropping system.

References:

Holman, J., A. Obour, and Y. Assefa. (2021). Productivity and profitability with fallow replacement forage, grain, and cover crops in W-S-F rotation. *Crop Science*. 62:913-927. https://doi.org/10.1002/csc2.20670

Simon, L.M., A. K. Obour, J.D. Holman, S.K. Johnson, and K. L. Roozeboom. 2021. Forage productivity and soil properties in dual-purpose cover crops systems. Agronomy Journal. 113; 5569-5583. http://dx.doi.org/10.1002/agj2.20877

National Research Council. 2000. *Nutrient Requirements of Beef Cattle: Seventh Revised Edition: Update 2000*. Washington, DC: The National Academies Press. https://doi.org/10.17226/9791.

Table 1. Cover crop planting time effects on biomass produced and nutritive content averaged over 3 years at the Kansas State University experiment fields at HB Ranch near Brownell, KS.

Treatment	Biomass	CP†	ADF	NDF	IVDMD	K	P
Fall-planted	6083a‡	10.3a	32.1a	52a	66.5a	0.21b	1.56b
Spring Planted	4929a	12.1a	35.6a	57a	75.1a	0.27a	2.3a
p-value	0.207	0.007	0.27	0.3	0.14	0.001	0.001

†CP = crude protein. ADF = acid detergent fiber (higher values reflect lower digestibility). NDF = neutral detergent fiber (higher values reflect lower animal intake). IVDMD = *in vitro* dry matter digestibility (reflects relative energy differences).

‡Means within a column followed by the same letter (s) are not significantly different ($P < 0.05$).

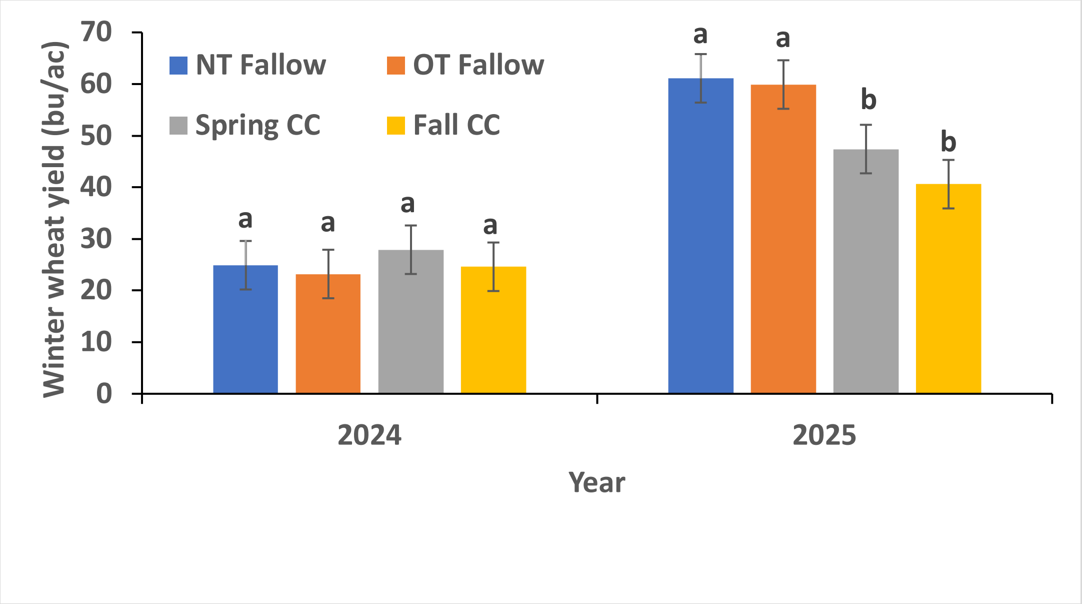

Figure 1. Cover crop planting time and fallow management effect on winter wheat yields at HB Ranch near Brownell, KS. Means followed by the same letter (s) are not significantly different (*P* < 0.1).

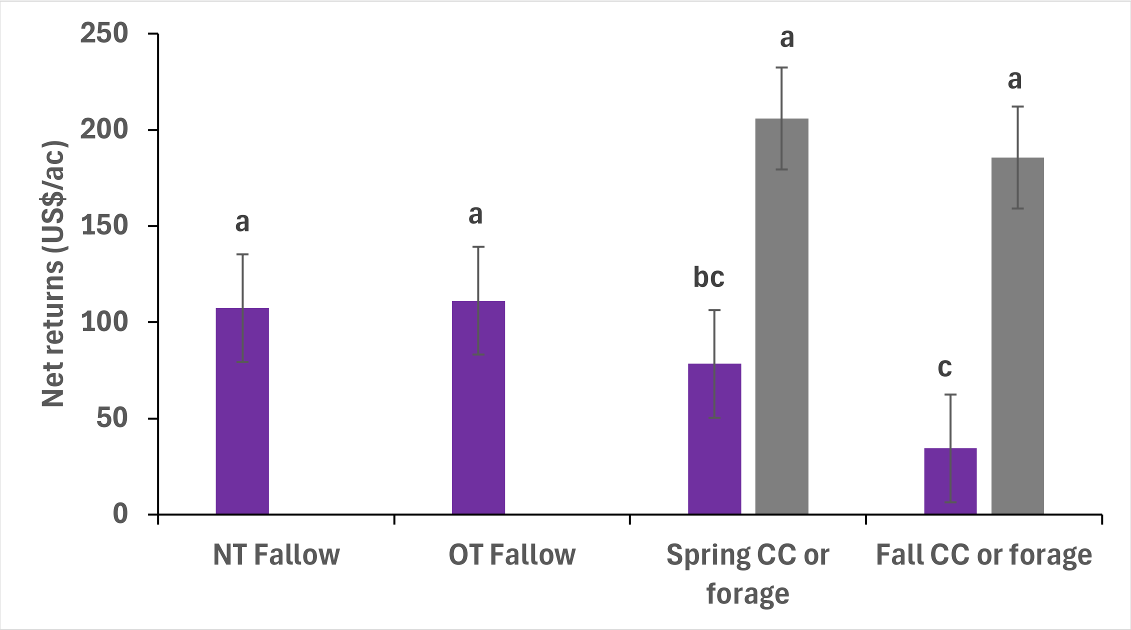

Figure 2. Profitability of wheat-sorghum-fallow rotation as affected by cover crop or forage crop planting time and fallow management. Means followed by the same letter (s) are not significantly different (*P* < 0.1).

Table 2. Cover crop planting time and fallow management effects on residue cover, bulk density, soil organic carbon (SOC) and mean weight diameter (MWD) of water stable aggregates measured in 0-2-in depth in 2023 and 2024 at the Kansas State University experiment fields at HB Ranch near Brownell, KS.

Treatment	Residue cover	Bulk density	SOC	MWD
	%	g/cm^3	%	mm
Fall Planted	84a	1.20a	1.50a	0.92ba
Spring Planted	83a	1.26ab	1.47ab	0.98a
NT Fallow	70b	1.33a	1.41b	0.65c
OT fallow	53c	1.19b	1.39b	0.73bc

Means followed by the same letter within a column are not significantly different (P < 0.10).

Table 3. Cover crop planting time and tillage affected water stable aggregate size distribution measured in the 0-2-in depth in 2023 and 2024 at the Kansas State University experiment fields at HB Ranch near Brownell, KS.

TRT	>2mm (%)	2-0.25(%)	<0.25mm (%)
Fall Planted	11.9a	35.9ba	52.3b
Spring Planted	12.1a	38.9ba	48.9b
Occasional Tillage	6.8b	31.3b	61.8a
No Tillage	7.4b	41.9a	50.6b

Means followed by the same letter within a column are not significantly different (*P* < 0.10).