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Cropping Sequence Influenced Crop Yield, Soil Water Content, Residue Return, and CO2 Efflux in Wheat-Camelina Cropping System

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Abstract

Camelina (*Camelina sativa* L. Crantz) is a short-seasoned oilseed crop with potential as a fallow replacement crop in dryland wheat (*Triticum aestivum*) - based cropping systems. Crop rotation management can affect the quality and quantity of crop residue return to the system. In addition, residue has the ability to sequester carbon and can affect plant available water. This study was conducted to investigate the effect of replacing fallow with camelina on crop yield, soil water at wheat planting, soil carbon dioxide (CO_2) efflux from treatments, and residue return. Treatments were four rotation schemes, and included wheat-fallow (W-F), wheat-sorghum-fallow (W-S-F), wheat-spring camelina (W-SC), and wheat-sorghum-spring camelina (W-S-SC). Our findings showed an increase in crop residue with increasing cropping intensity. Ground cover in W-S-SC, W-S-F, and W-SC were similar, but greater than that with W-F. Soil CO_2 efflux in W-SC was greatest among the crop rotations regardless of sampling time. Average CO_2 efflux in W-SC was 11.3, 26.5, and 7.6 pounds of CO_2 per acre per hour in the spring, summer, and fall, respectively. Soil water content at 0-24 in. was greater in W-S-F (7.2 in.) compared to W-SC (6.0 in.), and W-S-SC (6.0 in.). However, W-S-F and W-F (6.6 in.) were not different. Wheat and sorghum yields were not affected by crop rotation. However, camelina yields were greater in W-SC (754 lb/a) compared to W-S-SC (339 lb/a) rotation.

Keywords

Camelina, wheat, soil carbon dioxide efflux, soil moisture

Authors

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Summary

Camelina (*Camelina sativa* L. Crantz) is a short-seasoned oilseed crop with potential as a fallow replacement crop in dryland wheat *(Triticum aestivum)* - based cropping systems. Crop rotation management can affect the quality and quantity of crop residue return to the system. In addition, residue has the ability to sequester carbon and can affect plant available water. This study was conducted to investigate the effect of replacing fallow with camelina on crop yield, soil water at wheat planting, soil carbon dioxide (CO_2) efflux from treatments, and residue return. Treatments were four rotation schemes, and included wheat-fallow (W-F), wheat-sorghum-fallow (W-S-F), wheat-spring camelina (W-SC), and wheat-sorghum-spring camelina (W-S-SC). Our findings showed an increase in crop residue with increasing cropping intensity. Ground cover in W-S-SC, W-S-F, and W-SC were similar, but greater than that with W-F. Soil CO_2 efflux in W-SC was greatest among the crop rotations regardless of sampling time. Average CO_2 efflux in W-SC was 11.3, 26.5, and 7.6 pounds of CO_2 per acre per hour in the spring, summer, and fall, respectively. Soil water content at 0-24 in. was greater in W-S-F (7.2 in.) compared to W-SC (6.0 in.), and W-S-SC (6.0 in.). However, W-S-F and W-F (6.6 in.) were not different. Wheat and sorghum yields were not affected by crop rotation. However, camelina yields were greater in W-SC (754 lb/a) compared to W-S-SC (339 lb/a) rotation.

Introduction

In decades past, wheat-fallow (W-F) was the predominant wheat production system in the Central Great Plains. The wheat-fallow system is characterized by wheat planting in September and wheat harvesting in June of the following year, followed by a 14-month fallow period. Studies have shown inefficiencies in moisture storage during the fallow period. For example, precipitation storage efficiency has been reported to be less than 30% of total precipitation received during the fallow phase of the rotation system. In addition to this, the use of conventional tillage operations for weed control leads to less residue return, soil organic matter depletion, soil erosion, and inefficiency in moisture storage. In recent years, there has been a shift from W-F to wheat-summer crop-fallow, due to the introduction and adoption of conservation tillage practices during the fallow period. Typical 3-yr rotations in the semi-arid Great Plains are wheat-corn-fallow and wheat-sorghum-fallow cropping systems. Cropping intensification can make use of the soil moisture that is lost during the fallow period, reduce soil erosion by providing ground cover, potentially improve soil quality through residue return and nutrient cycling, and increase farmer revenue. Under the 3-yr rotation systems, there is a 10- to 12-month fallow period, which makes the introduction of a third crop to replace portions of the fallow period a possibility.

Camelina *(Camelina sativa L.* Crantz*)* is an oilseed crop that has the potential to fit in the wheat-summer crop-fallow cropping system. Camelina is cold tolerant, and is well adapted to water-limited environments. In addition, it uses less resources like fertilizer and matures early, i.e., requires 85 to 90 days to mature. The short life cycle can allow enough time for soil moisture recharge for wheat planting in fall, since camelina is harvested in June. Some of the uses of camelina include biodiesel, adhesives, varnishes, animal feed, and an ingredient in food processing. The objective of this study was to investigate the impact of replacing fallow with camelina on crop yield, soil water content at wheat planting, soil carbon dioxide (CO_2) efflux, and residue return.

Procedures

This study was established in the fall of 2013 at the Kansas State University Western Kansas Agriculture Research Center, near Hays, KS. The study comprised of four rotation schemes: wheat-fallow (W-F), wheat-sorghum-fallow (W-S-F), wheat-spring camelina (W-SC), and wheat-sorghum-spring camelina (W-S-SC). The treatments were arranged in a randomized complete block design with four replicates. All phases of the crop rotations were present in each block during each year of the study. Plot size was 35 × 20 ft. Winter wheat was planted in October of each year. Spring camelina was planted in mid-April and sorghum was planted in early June. Before initiating the study, 60 lb P_2O_5/a was applied to the entire study area. During each growing season, nitrogen (N) fertilizer in the form of urea was applied at 60 lb/a to winter wheat and sorghum, and 40 lb/a to camelina.

Yields were determined by harvesting 5 × 36 ft from the middle section of each plot using a plot combine. After harvesting camelina, oil and protein content were determined using the Antaris II FT-NIR Spectrophotometer Analyzer. Soil CO_2 efflux was measured at regular intervals using LI-8100 automated CO_2 efflux system (LI-COR Biosciences, Lincoln, NE, US). Around the same time, soil moisture at 0-10 in. was collected using a neutron moisture probe. Profile soil moisture at wheat planting was measured at 0-24 in. using a soil auger. During summer, i.e. at the end of camelina harvesting, two quadrats of crop residue were collected from each plot in the rotation scheme, and oven-dried at 149°F. In addition, three ground cover assessments were done on each plot using the stick method.

All data were analyzed using Proc GLM procedure in the SAS 9.3 software package (SAS Institute Inc., Cary, NC). Means were separated using least significant difference (LSD). Data from the two years were analyzed together, with rotation scheme as fixed effects in the model.

Results

Crop Residue and Soil Moisture

Increase in ground cover was documented with increasing cropping intensity (Table 1). The 3-yr rotations (W-S-F and W-S-SC) had more crop residue than the 2-yr rotations (W-F and W-SC) (Table 1). Soil moisture at wheat planting was greater in W-S-F relative to the W-SC and W-S-SC rotations. Soil moisture measurements taken in November show that volumetric water content was greater in W-F than W-SC (Figure 2). Volumetric water content in W-S-F and W-F was similar and was not different from W-F and W-SC. In March, soil volumetric water content reduced with increasing cropping intensity, i.e., water content in W-F and W-S-F was greater than W-SC and W-S-SC (Figure 2).

Soil CO_2 Efflux

During wheat harvest in July, more CO_2 efflux was recorded in W-SC than W-F, but CO_2 efflux in W-F was not different from W-S-F and W-S-SC (Figure 1). High CO_2 efflux recorded at this time of the year could be ascribed to high summer temperatures (Figure 3), which accelerates microbial activity. After wheat planting in November, very low CO_2 efflux was recorded across all rotation schemes. This could be as a result of low temperatures (Figure 3). Notwithstanding, more CO_2 efflux was recorded in W-SC compared to the other crop rotations (Figure 1). This could be due to greater decomposition of camelina residue compared to wheat and sorghum. Soil CO_2 efflux at camelina planting in March was greater in W-F compared to W-S-F and W-S-SC, but CO_2 efflux in W-F and W-SC were not different (Figure 1). Residue decomposition and CO_2 efflux may have accelerated in the 2-yr rotation systems due to the presence of moisture in W-F (Figure 2) and the quality of residue produced in W-SC rotation.

Camelina, Sorghum, and Wheat Yields

Spring camelina grain yield was 754 lb/a when planted after wheat (W-SC), but camelina yield was reduced to 339 lb/a when it was planted after sorghum in a 3-yr rotation (W-S-SC) (Table 2). The yield decline could be attributed to more residue in W-S-SC rotation, and lack of moisture to support camelina establishment. Wheat yields reduced with increasing cropping intensity, but statistically there were no differences in yield among the rotation schemes. This could be attributed to less moisture availability for wheat growth. Average wheat yield across the rotation systems was 1884 lb/a (Table 2). Sorghum yields were unaffected by rotation scheme. Average sorghum yield was 3316 lb/a.

Table 1. Effect of crop rotation on residue return and soil water content

Crop rotation	Residue biomass	Ground cover	Soil moisture at 0-24-in. depth at wheat planting
	lb/a	%	in.
Wheat fallow	1342 c	67.1 b	6.6 ab
Wheat-sorghum-fallow	3379 a	82.5 ab	7.2 a
Wheat-spring camelina	1959 b	82.5 ab	6.0 b
Wheat-sorghum-spring camelina	2961 a	92.3 a	6.0 b
LSD	527.7	15.5	0.96

Means within column followed by same letter(s) are significantly different ($P < 0.05$).
Residue and ground cover data were collected after camelina harvest in July 2015.
LSD = least significant difference.

Table 2. Camelina, winter wheat, and grain sorghum yields averaged across two growing seasons (2015 and 2016) at Hays, KS

Crop rotation	Winter wheat	Grain sorghum	Camelina yield	Camelina protein content	Camelina oil content
	------------------ lb/a		------------------	------------ %	------------
Wheat-fallow	2016 a	-	-	-	-
Wheat-sorghum-fallow	2066 a	3334 a	-	-	-
Wheat-spring camelina	1744 a	-	754 a	29.6 a	28.0 a
Wheat-sorghum-spring camelina	1710 a	3298 a	339 b	29.5 a	28.3 a
Mean	1884	3316	546	29.55	28.15
LSD	361	1630	201	1.5	1.3

Means within column followed by same letter(s) are significantly different ($P < 0.05$).
LSD = least significant difference.

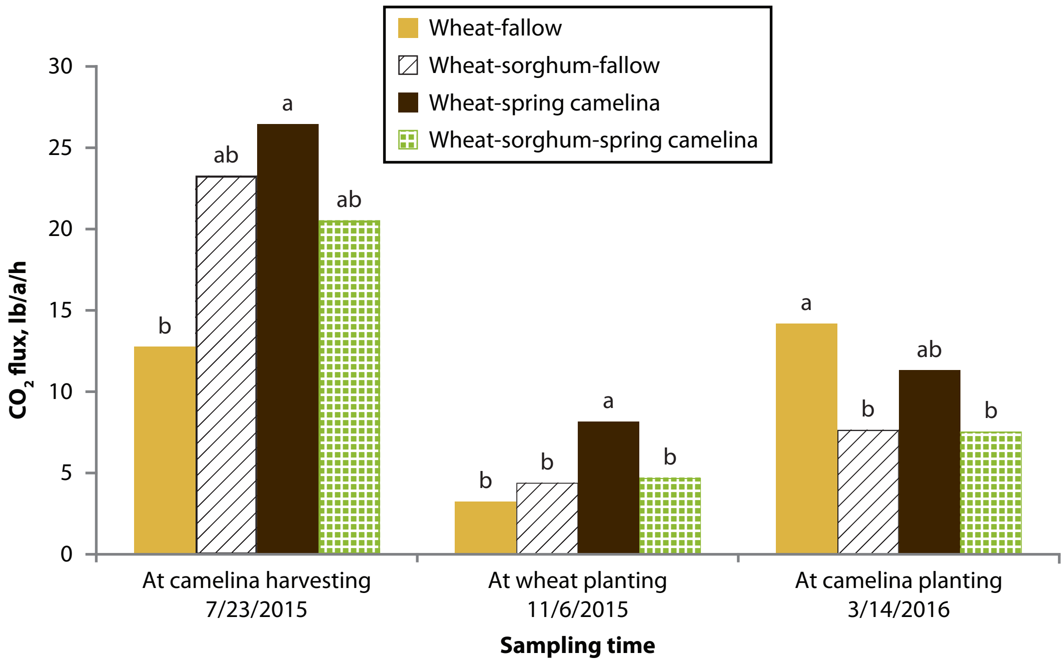

Figure 1. Effect of crop rotation on soil CO_2 efflux from July 2015 to March 2016. (Means within sampling time followed by the same letter(s) are not significantly different at P > 0.05).

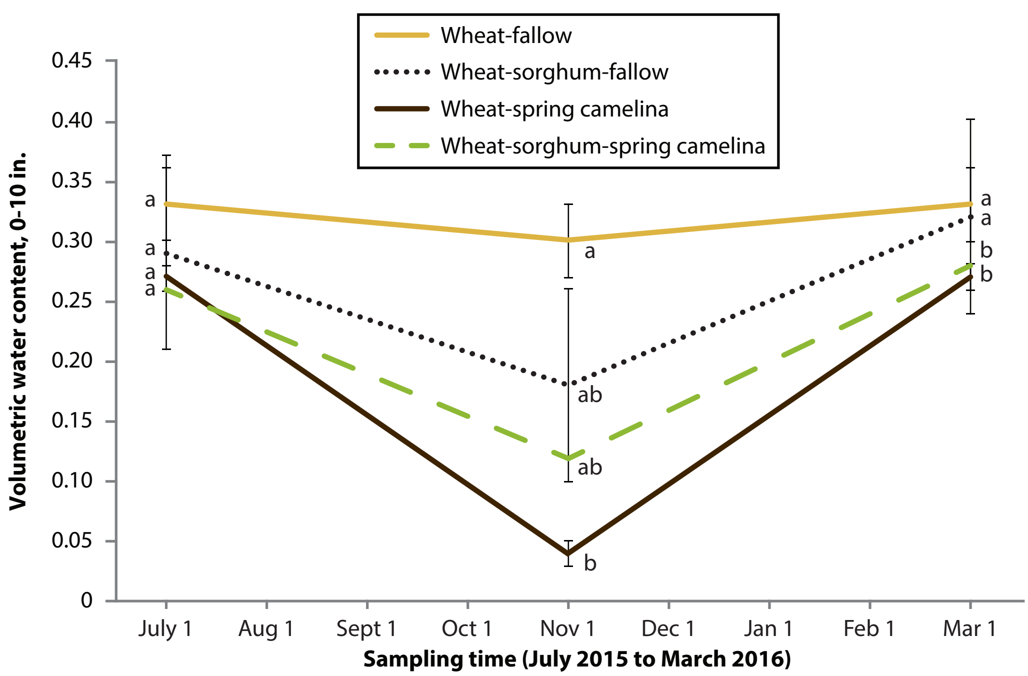

Figure 2. Soil volumetric water content from July 2015 to March 2016. (Means within sampling time followed by the same letter(s) are not significantly different at P > 0.05).

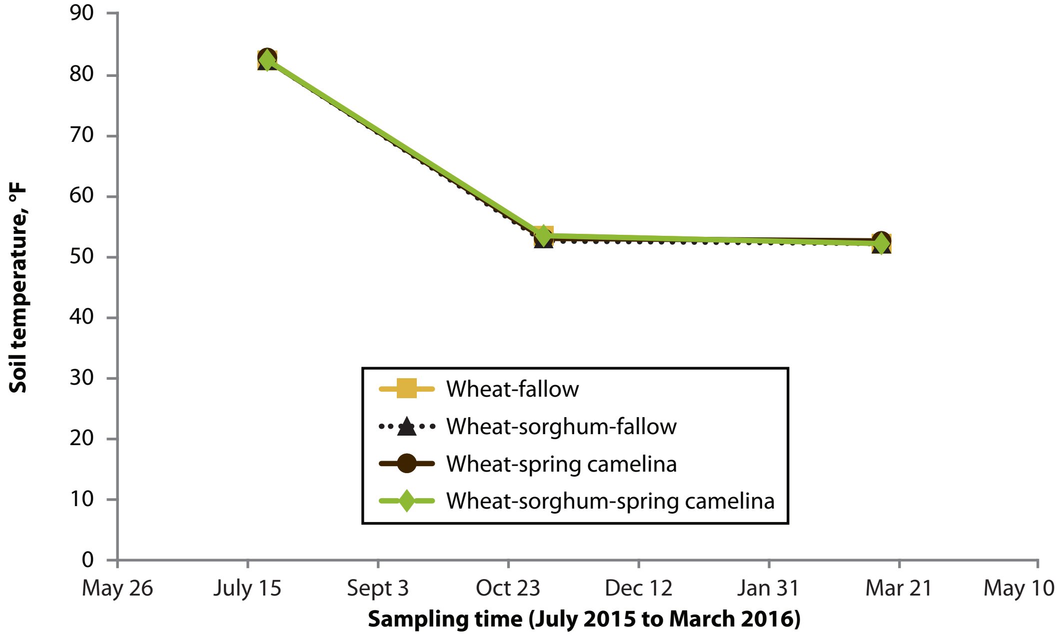

Figure 3. Soil temperature from July 2015 to March 2016. There were no differences in soil temperature within sampling time.