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Summary

Producers are interested in growing cover crops and reducing fallow. Limited information is available on growing crops in place of fallow in the semiarid Great Plains. Between 2012 and 2015, spring cover, annual forage, and grain crops were grown in place of fallow in a no-till wheat-grain sorghum-fallow (WSF) rotation in southwest Kansas. Growing a cover, hay, or grain crop in place of fallow reduced the amount of stored soil moisture at wheat planting. On average, cover crops stored slightly more moisture than hay crops, but this soil moisture difference did not affect wheat yields. Soil moisture after grain crops was less than after cover or hay crops, and this difference resulted in reduced wheat yields. These results do not support claims that cover crops increase soil moisture compared to fallow. Soil moisture storage from fallow crop termination to wheat planting was greatest among those treatments that were most dry at termination and produced the most aboveground biomass. On average, cover crops had a 28% precipitation storage efficiency (PSE) and hay crops had a 22% PSE between termination and wheat planting. Fallow during the full-fallow period (sorghum harvest to wheat planting) had an 18% PSE. Crops grown in place of fallow must compensate for the expense of growing the crop plus the reduction in soil moisture for the next crop.

Introduction

Interest in replacing fallow with a cash crop or cover crop has necessitated research on soil water storage and crop yields after a shortened fallow period. Fallow stores moisture, which helps stabilize crop yields and reduces the risk of crop failure; however, only 25 to 30% of the precipitation received is stored during the fallow period of a no-till wheat-fallow rotation. The remaining 70 to 75% of precipitation is lost, primarily to evaporation. Moisture storage in fallow is more efficient earlier in the fallow period, when the soil is dry, and during the winter months, when the evaporation rate is lower. It may be possible to increase cropping intensity without reducing winter wheat yield. This study evaluated the effect on plant-available water at wheat and grain sorghum planting of replacing part of the fallow period with a cover crop, annual forage, or short-season grain crop.

Procedures

Wheat-Sorghum-Fallow

Spring crops were grown in place of fallow the year following grain sorghum (Table 1). Grain sorghum is harvested late in the year and, in most years, harvest timing does not allow for growth of a fall-planted cover crop in place of fallow. Spring-planted treatments included spring grain pea (*Pisum sativum* L. ssp.), spring pea plus spring oat (*Avena sativa* L.), spring pea plus spring triticale (×*Triticosecale* Wittm.), spring oat, spring triticale, and a six species "cocktail" mixture of spring oat, spring triticale, spring pea, buckwheat var. Mancan (*Fagopyrum esculentum* Moench), purple top turnip (*Brassica campestris* L.), and forage radish (*Raphanus sativus* L.). In addition, spring grain pea, spring oat, and safflower (*Carthamus tinctorius* L.) were grown for grain. Safflower was grown only in 2012, and that treatment was replaced with spring oat grown for grain beginning in 2013. An additional treatment initiated in 2013 was spring oat planted in a "flex-fallow" system. The flex-fallow treatment was planted using spring oat when a minimum of 1 ft (2013 only) and 1.5 ft (2014 and subsequent years) of plant-available water was determined using a Paul Brown moisture probe at spring planting; otherwise the treatment was left fallow. The flex-fallow treatment was intended to take advantage of extra moisture in wet years by growing a crop during the fallow period and fallowing in dry years. Crops grown for grain were grain pea, spring oat, and safflower. Crops grown in place of fallow were compared with a wheat-grain sorghum-fallow rotation for a total of 11 treatments (Table 1). The study design was a split-split-plot randomized complete block design with four replications; crop phase (wheat-grain sorghum-fallow) was the main plot, fallow replacement was the split-plot, and fallow replacement method (forage, grain, or cover) was the split-split-plot. The main plot was 330 ft wide and 120 ft long, the split-plot was 30 ft wide and 120 ft long, and the split-split plot was 15 ft wide and 120 ft long.

Winter wheat was planted approximately October 1. Spring crops were planted as early as soil conditions allowed, ranging from the end of February through the middle of March. Spring cover and forage crops were chemically terminated or forage-harvested approximately June 1. Biomass yields for both cover crops and forage crops were determined from a 3-ft × 120-ft area cut 3 in. high using a small plot Carter forage harvester from within the split-split-plot managed for forage. Winter and spring grain peas and winter wheat were harvested with a small plot Wintersteiger combine from a 6.5-ft × 120-ft area at grain maturity, which occurred approximately the first week of July. Volumetric soil moisture content was measured at planting and harvest of winter wheat, grain sorghum, and fallow using a Giddings Soil Probe by 1-ft increments to a 6-ft soil depth. In addition, volumetric soil content was measured in the 0–3-in. soil depth at wheat planting to quantify moisture in the seed planting depth. Grain yield was adjusted to 13.5% moisture content, and test weight was measured using a grain analysis computer. Grain samples were analyzed for nitrogen content.

Results and Discussion

Wheat-Grain Sorghum-Fallow (2012–2015)

Year

Fallow and growing-season precipitation varied greatly during the course of this study (Table 2). Long-term (1908–2014) average precipitation during the fallow period between grain sorghum harvest and wheat planting (November–December plus January–September) was 17.54 inches, and precipitation during the fallow period between wheat harvest and grain sorghum planting (July–December plus January–May) was 15.83 inches. Long-term average growing season precipitation for wheat (October–June) averaged 12.28 inches, and growing season precipitation for grain sorghum (June–October) averaged 10.87 inches. Fallow precipitation ahead of wheat was above average preceding the 2014 growing season and about average preceding the 2013 growing season. Fallow precipitation ahead of grain sorghum was below average preceding the 2013 and 2014 growing seasons. Growing-season precipitation for wheat was below average in 2012 and 2013, but above average in 2014, primarily due to 10.5 inches that occurred in June. Growing-season precipitation for grain sorghum was above average in 2013 and 2014. These differences in precipitation amount and timing affected plant-available soil water at wheat and grain sorghum planting (Tables 3–5) and subsequently affected crop yields. Plant-available soil water in the 0–3-in. and 0–6-ft profile for wheat were greater in 2013 than 2014.

Cover vs. Annual Forage

Leaving the cover crop standing as compared to haying did not affect precipitation storage efficiency or stored soil water in the 0–6-ft soil profile ahead of wheat planting in 2013 or 2014. Across years, precipitation storage efficiency averaged 28% with cover and 22% with hay, and stored soil water in the 0–6-ft profile averaged 3.5 inches with cover and 2.8 inches with hay at wheat planting. Plant available soil water in the 0–3-in. soil depth was also not different between cover and hay treatments. In 2013, 0.11 inches of available soil water followed cover crop treatments and 0.09 inch followed hay treatments at the 0–3-in. soil depth at wheat planting. Although more soil water tended to be available in the profile following cover crops compared to hay crops, this effect was not large enough to affect wheat yields. The greater average plant-available soil water and precipitation storage with cover crop may be due to more surface residue in the cover crop treatments compared with hay treatments, which likely helps reduce evaporation near the soil surface as well as water runoff.

Fallow Crop (0- to 3-inch soil depth)

No differences occurred between crop treatments at the 0- to 3-inch soil depth.

Fallow Crop (0- to 6-ft soil depth)

Treatments changed slightly across years. Safflower and spring forage pea were only grown in 2012, and beginning in 2013 spring oat was grown for grain, and yellow sweet clover was planted with grain sorghum and allowed to grow into the fallow year. In 2012, fallow had 5.94 inches of plant-available soil water in the 0- to 6-ft profile at wheat planting, which was greater than all other treatments (Table 3). All other fallow replacement treatments had similar plant-available soil water. The drought and heat in 2012 terminated growth early and resulted in low grain pea yield (12.4 bu/a) and no grain oat yield. The early drought-induced termination resulted in a longer fallow period and more time for moisture storage than normal, helping to improve soil moisture storage relative to the other treatments.

In 2013, drought again resulted in no grain production from spring oat and spring pea, although more moisture kept the crop growing longer into the fallow period. These crops were managed more as a long-season cover crop than as a grain crop since they did not produce any grain. At wheat planting, cocktail and fallow had more soil moisture than spring grain pea. All other treatments were comparable to fallow (Table 4). There was a slight tendency for the cocktail treatment to have more soil water than other treatments, which was very different than 2012 and other studies. In 2013, little precipitation occurred early in the year, and most occurred late in the summer. It is possible that little early season moisture, but more crop residue from growing a cover crop, improved precipitation storage late in the season. However, wheat yields in 2014 were reduced by any treatment other than fallow, and cocktail reduced yields 40% compared to fallow. The yield results confirm earlier results from a wheat-fallow study that growing anything in place of fallow in dry years reduces subsequent wheat yields.

The very dry condition across years creates difficulty in determining differences in available soil water when so little is available. Averaged across years, fallow had the most available soil water (4.89 inches), which was significantly more than peas grown for grain (1.3 inches), which practically had no soil moisture to grow a crop (Table 5). Data for more years with normal rainfall are necessary to determine treatment differences, but it appears that growing anything during a drought year greatly reduces subsequent crop yields.

Precipitation Storage from Termination to Wheat Planting

Precipitation storage efficiency (PSE) was measured between fallow crop termination and wheat planting. Precipitation amounts in 2013 and 2014 were below normal. Precipitation storage efficiency is the percent of precipitation stored in the soil.

$$\text{Precipitation storage efficiency (PSE)} = \frac{\text{Soil water content at wheat planting-Soil water content at fallow crop termination}}{\text{Precipitation between fallow crop termination and wheat planting}}$$

Precipitation storage efficiency ranged from 16% to 36% (Table 6), and was highest following spring oats grown for grain and least following spring oats for forage. Grain crops were allowed to grow longer into the fallow period, though they failed to produce grain due to the drought. The increase in efficiency was an artifact of a shorter fallow period and drier soils, but did not improve moisture conditions ahead of wheat planting.

Conclusions

Fallow is important for storing precipitation and stabilizing crop yields, particularly in semiarid climates, such as the central Great Plains. Growing a cover, hay, or grain crop in place of fallow reduced the amount of stored soil moisture at wheat planting. On average, cover crops stored 0.7 inch more moisture than hay crops, but this soil moisture difference did not affect wheat yield. Soil moisture following grain crops was less than after cover or hay crops, and this difference resulted in reduced wheat yields. Stored soil water was low following a cover crop cocktail (six-species mixture) in 2012, but not in 2013. More years of data are needed to compare cocktail mixtures to fallow. Soil moisture storage from fallow crop termination to wheat planting was greatest among those treatments that were most dry at termination and produced the most aboveground biomass. On average, cover crops had a 28% PSE while hay crops had a 22% PSE between termination and wheat planting. Crops grown in place of fallow must compensate for the expense of growing the crop plus the reduction in soil moisture for the following crop.

Table 1. Fallow Treatments 2012–2014.

					Year produced		
Season	Crop	Cover	Hay	Grain	2012	2013	2014
Spring	Cocktail mix[†]	x	x		x	x	x
""	Fallow				x	x	x
""	Flex-Fallow/Spring oat (1.5' PAW[††] at planting)		x		-	x	No
	Safflower (grain)			x	x	-	-
""	Spring oat		x		x	x	x
""	Spring oat (grain)			x	-	x	x
""	Spring pea	x	x		x	-	-
""	Spring pea (grain)			x	x	x	x
""	Spring pea/Spring oat	x	x		x	x	x
""	Spring pea/Spring triticale	x	x		x	x	x
""	Spring triticale	x	x		x	x	x

[†] Oat, triticale, pea, buckwheat, forage brassica and forage radish.
[††] Plant-available water..

Table 2. Monthly, growing season, and fallow precipitation at Garden City, Kansas, 2012–15. Monthly precipitation (P) at Garden City, Kansas, during the experimental period and long-term averages (Pavg). Growing season amounts are only those amounts accumulated between crop emergence and termination.

Year	Month	P	Pavg† (30yr)	Pavg††
		------- in. -------		
2012	Jan	0.00	0.46	0.43
	Feb	0.59	0.55	0.64
	Mar	1.92	1.31	1.12
	Apr	1.77	1.74	1.69
	May	0.30	2.98	2.80
	Jun	1.03	3.12	3.01
	Jul	2.41	2.80	2.56
	Aug	1.22	2.51	2.47
	Sep	1.19	1.42	1.53
	Oct	0.98	1.21	1.30
	Nov	0.00	0.55	0.72
	Dec	0.73	0.59	0.57
	Total	12.14	19.24	18.84
	Wheat Growing Season (Oct–Jun)	8.50	12.51	12.28
	Grain Sorghum Growing Season (Jun–Oct)	6.83	11.06	10.87
	Fallow Preceding Wheat (Nov–Sep)	16.17	18.03	17.54
	Fallow Preceding Grain Sorghum (Jul–May)	10.81	16.12	15.83

continued

Table 2. Monthly, growing season, and fallow precipitation at Garden City, Kansas, 2012–15. Monthly precipitation (P) at Garden City, Kansas, during the experimental period and long-term averages (Pavg). Growing season amounts are only those amounts accumulated between crop emergence and termination.

Year	Month	P	Pavg† (30yr)	Pavg††
		----------------------------	in.	----------------------------
2013	Jan	0.48	0.46	0.43
	Feb	1.54	0.55	0.64
	Mar	0.13	1.31	1.12
	Apr	0.28	1.74	1.69
	May	1.25	2.98	2.80
	Jun	1.84	3.12	3.01
	Jul	2.23	2.80	2.56
	Aug	6.09	2.51	2.47
	Sep	1.83	1.42	1.53
	Oct	0.88	1.21	1.30
	Nov	0.74	0.55	0.72
	Dec	0.00	0.59	0.57
	Total	17.29	19.24	18.84
	Wheat Growing Season (Oct–Jun)	7.23	12.51	12.28
	Grain Sorghum Growing Season (Jun–Oct)	12.87	11.06	10.87
	Fallow Preceding Wheat (Nov–Sep)	16.40	18.03	17.54
	Fallow Preceding Grain Sorghum (Jul–May)	10.21	16.12	15.83

continued

Table 2. Monthly, growing season, and fallow precipitation at Garden City, Kansas, 2012–15. Monthly precipitation (P) at Garden City, Kansas, during the experimental period and long-term averages (Pavg). Growing season amounts are only those amounts accumulated between crop emergence and termination.

Year	Month	P	Pavg† (30yr)	Pavg††
		---------- in. ----------		
2014	Jan	0.12	0.46	0.43
	Feb	0.38	0.55	0.64
	Mar	0.25	1.31	1.12
	Apr	0.69	1.74	1.69
	May	0.63	2.98	2.80
	Jun	10.50	3.12	3.01
	Jul	3.81	2.80	2.56
	Aug	1.99	2.51	2.47
	Sep	2.71	1.42	1.53
	Oct	1.78	1.21	1.30
	Nov	0.03	0.55	0.72
	Dec	0.40	0.59	0.57
	Total	23.29	19.24	18.84
	Wheat Growing Season (Oct–Jun)	14.19	12.51	12.28
	Grain Sorghum Growing Season (Jun–Oct)	20.79	11.06	10.87
	Fallow Preceding Wheat (Nov–Sep)	21.82	18.03	17.54
	Fallow Preceding Grain Sorghum (Jul–May)	13.84	16.12	15.83

continued

Table 2. Monthly, growing season, and fallow precipitation at Garden City, Kansas, 2012–15. Monthly precipitation (P) at Garden City, Kansas, during the experimental period and long-term averages (Pavg). Growing season amounts are only those amounts accumulated between crop emergence and termination.

Year	Month	P	Pavg† (30yr)	Pavg††
		---------------------------- in. ----------------------------		
2015	Jan	0.30	0.46	0.43
	Feb	1.21	0.55	0.64
	Mar	0.32	1.31	1.12
	Apr	-¶	1.74	1.69
	May	-	2.98	2.80
	Jun	-	3.12	3.01
	Jul	-	2.80	2.56
	Aug	-	2.51	2.47
	Sep	-	1.42	1.53
	Oct	-	1.21	1.30
	Nov	-	0.55	0.72
	Dec	-	0.59	0.57
	Total	-	19.24	18.84
	Wheat Growing Season (Oct–Jun)	-	12.51	12.28
	Grain Sorghum Growing Season (Jun–Oct)	-	11.06	10.87
	Fallow Preceding Wheat (Nov–Sep)	-	18.03	17.54
	Fallow Preceding Grain Sorghum (Jul–May)	-	16.12	15.83

† 30-year average (1984–2014).
†† 1908–2014.
¶ '-' Indicates a time when the crop was not present.

Table 3. Fallow, cover crop, and grain crop effects on plant-available soil water in the 0- to 6-ft soil profile and the difference in soil moisture compared with fallow at wheat planting in a wheat-sorghum-fallow rotation in 2012.

Fallow method	Plant available water (0–6 ft)	Difference from fallow
	---------------------------- in.	----------------------------
Fallow	5.94 a	0.00
Spring Oat	2.63 b	-3.31
Spring Pea/Triticale	2.61 b	-3.33
Spring Pea/Oat	2.41 b	-3.54
Spring Triticale	2.04 b	-3.90
Cocktail[a]	1.95 b	-3.99
Spring Pea (grain)[b]	1.78 b	-4.16
LSD 0.05	2.54	

[a] Cocktail (oat, triticale, pea, buckwheat, forage brassica, and forage radish).
[b] Spring grain crop failed to produce grain due to drought.

Table 4. Fallow, cover crop, and grain crop effects on plant-available soil water in the 0- to 6-ft soil profile and the difference in soil moisture compared with fallow at wheat planting in a wheat-sorghum-fallow rotation in 2013.

Fallow method	Plant available water (0–6 ft)	Difference from fallow
	---------------------------- in.	----------------------------
Cocktail*	4.31 a	0.46
Fallow	3.84 ab	0.00
Radish/Turnip	3.67 abc	-0.18
Spring Pea/Oat	3.62 abc	-0.22
Spring Pea/Triticale	3.44 abc	-0.40
Clover	3.40 abc	-0.44
Flex Spring Oat	2.44 abc	-1.40
Spring Oat (grain)[b]	2.41 abc	-1.43
Spring Triticale	2.40 abc	-1.45
Spring Oat	1.73 bc	-2.11
Spring Pea (grain)[b]	1.31 c	-2.54
LSD 0.05	2.44	

[a]Cocktail (oat, triticale, pea, buckwheat, forage brassica, and forage radish).
[b]Spring grain crop failed to produce grain due to drought.

Table 5. Fallow, cover crop, and grain crop effects on plant-available soil water in the 0- to 6-ft soil profile and the difference in soil moisture compared with fallow at wheat planting in a wheat-sorghum-fallow rotation of similar treatments across years 2012–13.

Fallow method	Plant available water (0–6 ft)	Difference from fallow
	---------------------------- in. ----------------------------	
Fallow	4.89 a	0.00
Cocktail[a]	3.45 ab	-1.44
Spring Pea/Oat	3.21 ab	-1.68
Spring Pea/Triticale	3.04 ab	-1.85
Spring Oat (grain)[b]	2.97 ab	-1.92
Spring Triticale	2.27 ab	-2.62
Spring Oat	2.22 ab	-2.67
Spring Pea (grain)[b]	1.31 b	-3.58
LSD 0.05	2.19	

[a]Cocktail (oat, triticale, pea, buckwheat, forage brassica, and forage radish).
[b]Spring grain crop failed to produce grain due to drought.

Table 6. Fallow, cover crop, and grain crop effects on precipitation storage efficiency in the fallow period ahead of wheat planting based on plant-available soil water in the 0- to 6-ft soil profile of similar treatments across years 2012–13.

Fallow Method	Precipitation Storage Efficiency (PSE) (0-6 ft)
	%
Spring Oat (grain)	35.86 A
Spring Pea/Triticale	27.64 Ab
Spring Triticale	27.25 Ab
Spring Pea/Oat	25.17 Ab
Cocktail*	24.54 Ab
Fallow	18.75 Ab
Spring Pea (grain)	18.67 Ab
Spring Oat	16.00 B
LSD 0.05	19.42

*Cocktail (oat, triticale, pea, buckwheat, forage brassica, & forage radish).