Kansas Agricultural Experiment Station Research Reports

Volume 4
Issue 8 *Southwest Research-Extension Center Reports*

Article 7

2018

Effects of Fallow Replacement Crops on Wheat and Grain Sorghum Yields

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Recommended Citation

Holman, J.; Obour, A.; Roberts, T.; and Maxwell, S. (2018) "Effects of Fallow Replacement Crops on Wheat and Grain Sorghum Yields," *Kansas Agricultural Experiment Station Research Reports*: Vol. 4: Iss. 8. https://doi.org/10.4148/2378-5977.7627

Effects of Fallow Replacement Crops on Wheat and Grain Sorghum Yields

Abstract

Interest in replacing fallow with a cash crop or cover crop has necessitated research on soil, water, and wheat yields following 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 during the fallow period of a no-till wheat-fallow rotation is stored. The remaining 75 to 70% of precipitation is lost, primarily due 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 replacing part of the fallow period with a cover, annual forage, or short-season grain crop. Plant available water at wheat and grain sorghum planting and winter wheat and grain sorghum yields were measured.

Keywords

cover crops, fallow, soil water, crop yield, and flex-fallow

Authors

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Summary

Producers are interested in growing cover crops and reducing fallow. Growing a crop during the fallow period would increase profitability if crop benefits exceeded expenses. Benefits of growing a cover crop were shown in high rainfall areas, but limited information is available on growing cover crops in place of fallow in the semiarid Great Plains. A study was conducted from 2007–2018 that evaluated cover crops, annual forages, and short season grain crops grown in place of fallow. In the first experiment (2007–2012), the rotation was no-till wheat-fallow. The second experiment (2012–2018) rotation was no-till wheat-grain sorghum-fallow. This report presents results from the second experiment. Wheat yield was affected by growing a crop in place of fallow, but managing the crop as either cover or hay did not affect wheat yield. Wheat yield following the previous crop was dependent on precipitation during fallow and the growing season. In dry years growing a crop during fallow reduced wheat yields, while growing a crop during fallow had little impact on wheat yield in wet years. Grain sorghum yield was only reduced one year by growing a crop in place of fallow, other years there was no yield difference. The length of the fallow period affected subsequent wheat yield. Growing a cover or hay crop in place of fallow had a less negative impact on wheat yield compared to growing a spring grain crop due to a shorter fallow period. Cover crops did not improve wheat or grain sorghum yields compared to fallow. To be successful, the benefits of growing a cover crop during the fallow period must be greater than the expense of growing it; and must compensate for any negative yield impacts on the subsequent crop. Cover crops always resulted in less profit than fallow, while annual forages often increased profit compared to fallow. The negative effects on wheat yields might be minimized with flex-fallow, which is the concept of only growing a crop in place of fallow in years when soil moisture at planting and precipitation outlook are favorable at the time of making the decision to plant.

Introduction

Interest in replacing fallow with a cash crop or cover crop has necessitated research on soil, water, and wheat yields following 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 during the fallow period of a no-till wheat-fallow rotation is stored. The remaining 75 to 70% of precipitation is lost, primarily due 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 replacing part of the fallow period with a cover, annual forage, or short-season grain crop. Plant available water at wheat and grain sorghum planting and winter wheat and grain sorghum yields were measured.

Experimental Procedures

A study from 2007–2014 evaluated cover crops, annual forages, and spring grain crops (peas, oat, or triticale) grown in place of fallow in a no-till wheat-fallow rotation. This first experiment was modified beginning in 2012 to a wheat-grain sorghum-fallow rotation. Treatments that stayed the same between experiments 1 and 2 were maintained in the same plots so that long-term treatment impacts could be determined. Fallow replacement crops (cover crop, annual forage, or short-season grain crop) were either grown as standing cover, harvested for forage (annual forage crop), or harvested for grain.

In experiment 1 (2007–2012), both winter and spring crop species were evaluated. Winter species included yellow sweet clover (*Melilotus officinalis* (L.) Lam.), hairy vetch (*Vicia villosa* Roth ssp.), lentil (*Lens culinaris* Medik.), Austrian winter forage pea (*Pisum sativum* L. ssp.), Austrian winter grain pea (*Pisum sativum* L. ssp.), and triticale (×*Triticosecale* Wittm.). Spring species included lentil (*Lens culinaris* Medik.), forage pea (*Pisum sativum* L. ssp.), grain pea (*Pisum sativum* L. ssp.), and triticale (×*Triticosecale* Wittm.). Crops were grown in monoculture and in two-species mixtures of each legume plus triticale. Crops grown for grain were grown in monoculture only. Winter lentil was grown in place of yellow sweet clover beginning in 2008. Crops grown in place of fallow were compared with a wheat-fallow and continuous wheat rotation for a total of 16 treatments. The study design was a split-split-plot randomized complete block design with four replications; crop phase (wheat-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 480-ft wide × 120-ft long, the split-plot was 30-ft wide × 120-ft long, and the split-split plot was 15-ft wide × 120-ft long.

In experiment 2 (2012–2018) spring crops were grown the year following grain sorghum. Grain sorghum is harvested late in the year and most years do not allow growing a winter crop during the fallow period. Spring planted treatments included spring grain pea, spring pea plus spring oat (*Avena sativa* L.), spring pea plus spring triticale, 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 only grown in 2012, and that treatment was replaced with spring oat grown for grain beginning in 2013. Additional treatments initiated in 2013 were yellow sweet clover planted with grain sorghum and allowed to grow into the fallow year, daikon radish (*Brassica rapa* L.) planted with winter wheat in a wheat-grain sorghum-fallow rotation, shogoin turnip (*Raphanus sativus* L.) planted with winter wheat in a wheat-grain sorghum-fallow rotation, and spring oats or a cocktail planted in a "flex-fallow" system (Table 1). The flex-fallow treatment was planted when a minimum of 12 inches of PAW (2013 and 2016) 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 growing a crop during the fallow period in wet years and fallowing in dry years. Crops grown for grain were grain peas, spring oat, and triticale. Crops grown in place of fallow were compared with a wheat-grain sorghum-fallow rotation for a total of 16 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 × 120-ft long, the split-plot was 30-ft wide × 120-ft long, and the split-split plot was 15-ft wide × 120-ft long.

Annually, winter wheat was planted on 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 at early heading (Feekes 10.1) (Large, 1954). Biomass yields for both cover crops and forage crops were determined from a 3- × 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- × 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

Fallow and Growing Season Precipitation

Fallow and growing season precipitation varied greatly during the course of this study (Table 2). Historical 30-yr (1984-2014) average precipitation during the fallow period between grain sorghum harvest and wheat planting (November-December plus January-September) was 18.03 in., and precipitation during the fallow period between wheat harvest and grain sorghum planting (July-December plus January-May) was 16.12 in. Long-term average growing-season precipitation for wheat (October-June) averaged 12.51 in., and growing-season precipitation for grain sorghum (June-October) averaged 11.06 in. Precipitation during the fallow period ahead of wheat planting was below normal in 2012 and 2013, average in 2017, and above average in 2014, 2015, and 2016. Growing-season precipitation for wheat was below normal in 2012, 2013, and 2017; near average in 2015; and above average in 2014 and 2016. Precipitation preceding grain sorghum planting was below average in 2012, 2013, and 2014, and above average in 2015, 2016, and 2017. Growing-season precipitation for grain sorghum was below normal in 2012, near normal in 2016 and 2017, and above average in 2013, 2014, and 2015. These differences in precipitation amount and timing affected plant-available soil water at wheat and grain sorghum planting and subsequently affected crop yields.

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 in. with hay at wheat planting. Plant-available soil water in the top 0-3-in. soil depth was not different between cover and hay treatments. 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 is likely due to more surface residue in the cover crop treatments compared with hay treatments, which likely helps reduce water runoff and evaporation near the soil surface.

Winter Wheat Yield in Wheat-Grain Sorghum-Fallow

In 2013, 6.25 inches of precipitation occurred during the winter wheat growing season between planting and harvest. This was 50% of normal (12.5 inches) for this time period, and was the third consecutive year of drought. Below-normal precipitation during fallow and the winter wheat growing season resulted in any treatment other than fallow significantly reducing wheat yield 50% or more. The cover crop cocktail treatment yielded 79% less than fallow. Wheat following fallow yielded 19 bu/a and all other treatments yielded between 3 to 9 bu/a (Figure 1).

In 2014, 14.57 inches of precipitation occurred during the winter wheat growing season between planting and harvest. This was above average, but most of the rain came in June (10.5 inches), which was too late to benefit the wheat crop. Therefore, wheat yields were significantly reduced by 40-80% by any treatment other than fallow, and fallow only yielded 6 bu/a (Figure 2).

In 2015, 12.18 inches of precipitation occurred during the winter wheat growing season between planting and harvest, with most of this occurring in May (6.38 inches). Were it not for the rainfall received in May, yields likely would have been less than 10 bu/a in fallow. Precipitation received in the previous fallow period (between grain sorghum harvest and wheat planting) from November 2014 to October 2015 was 18.87 inches and the 30-yr average for this period was 18.03 in. The early season moisture stress and late season precipitation minimized yield differences between treatments and fallow (Figure 3). Only oats for grain, oat, and pea/triticale yielded less than fallow (15 bu/a).

In 2016, a large infestation of rabbits and feeding damage resulted in a failed crop and no grain production.

In 2017, 11.09 inches of precipitation occurred during the winter wheat growing season between planting and harvest. Most of the precipitation occurred in the spring of 2017 and soil conditions were dry at planting through winter. Precipitation received in the previous fallow period (between grain sorghum harvest and wheat planting) from November 2013 to October 2015 was 18.69. The early season moisture stress reduced yield potential and all treatments yielded less than 16 bu/a (Figure 4). Spring grain treatments yielded (16 bu/a) more than fallow (8 bu/a), which might have been due to more residue from the grain treatments improving water use efficiency.

Grain Sorghum Yield in Wheat-Grain Sorghum-Fallow

The first grain sorghum crop grown in-phase following cover crop treatments was in 2015. The above normal rainfall in 2015, particularly early in the growing season (5.36 inches in July and 3.24 inches in August), resulted in above normal sorghum yields, ranging from 84–109 bu/a (Figure 5). Despite the above-normal rainfall and yields, there was still a correlation with 2015 grain sorghum and 2014 winter wheat yields; thus, the impact of growing a cover crop was evident two years later.

In 2016, sorghum yield was similar among treatments. The difference in sorghum yield response to treatment between years was likely due to greater wheat yields and more residue following the 2015 wheat crop compared to the 2014 wheat crop. The poor wheat crop in 2014 resulted in low soil residue cover, and the effect of this was shown by differences in sorghum water use efficiency (WUE) among treatments in 2015. In 2016, there were no differences in sorghum yield or WUE across treatments. Additionally, sufficient precipitation during the preceding fallow period and growing season resulted in an average sorghum yield of 63 bu/a, which helped negate any antecedent differences in soil water.

Grain sorghum in 2017 was affected by previous cover crop treatments in 2015. Wheat yields were too low to harvest in 2016, so no comparisons could be made between 2017 grain sorghum and 2016 wheat yields. However, grain sorghum WUE in 2017 matched closely with grain yields. The results in 2017 suggest a similar response to grain sorghum in 2015, that those wheat plots that grew more biomass (data not available) improved grain sorghum WUE and yield (Figure 6). Fallow yield was similar to the other treatments, while pea (grain) yielded less than oat/triticale/pea, triticale (grain), cocktail, oat/triticale, and oat (grain). The lower yield following pea (grain) was most likely due to more weeds present in that treatment.

Cover vs. Annual Forage

Similar to the first experiment, there was no difference in wheat or grain sorghum yields whether the previous crop was left as cover or harvested for forage, despite slightly more plant available water following cover than forage harvest. This indicates the previous crop can be harvested for forage rather than left standing as a cover crop without negatively affecting wheat or grain sorghum yields.

Conclusions

Fallow helps stabilize crop yields in dry years. Annual precipitation in this study ranged from 12.1 to 23.3 inches. The 30-year average precipitation was 19.24 inches. In dry years, growing a crop during the fallow period reduced wheat yields, but previous research showed that in wet years, growing a crop during the fallow period had little impact on wheat yield. The length of the fallow period also affected yields of the following wheat crop. Growing a cover or hay crop until June 1 affected wheat less than if spring grain crops were grown in place of fallow until July 1. When wheat yields were very low there was a carryover effect onto grain sorghum, reducing WUE and grain yield.

Forages can be profitable to grow in place of fallow in favorable moisture years. However, cover crops were always an expense to grow. The cropping system can be intensified by replacing part of the fallow period with annual forages to increase profit and improve soil quality; however, in semiarid environments, wheat yields will be reduced in years with below-normal precipitation. Across all years (2007–2018) there was a tendency for wheat yields to not be affected by growing a crop in place of fallow when wheat yield potential was 50 bu/a or greater. The negative effect on yield was greater when wheat yield potential was least and the drought period lasted for more than a year. Some of the reduction in grain yield can be offset by growing a cover crop for forage or grain. Negative impacts on grain yields might also be minimized over time with “flex-fallow.” Flex-fallow is the concept of only planting a crop in place of fallow when soil moisture levels and precipitation outlook are favorable. Under drought conditions such as 2011–2014, using flex-fallow, a crop would not have been grown in place of fallow. Therefore, flex-fallow may help reduce the negative effects of reduced fallow. Conversely, flex-fallow will not prevent reduced yield in years when growing-season precipitation levels are below normal. Additional years of data are required to determine the feasibility of flex-fallow and the effects of replacing fallow in a wheat-summer crop-fallow rotation.

References

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Table 1. Fallow treatments 2007–2018 at the Southwest Research-Extension Center near Garden City, KS, 2012–2017

				Year produced											
Crop	Cover	Hay	Grain	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Fallow				x	x	x	x	x	x	x	x	x	x	x	x
Cocktail mix†	x	x		-	-	-	-	-	x	x	x	x	x	x	x
Cocktail mix† (flex)††		x		-	-	-	-	-	-	-	-	N	Y	N	N
Spring oat (flex)		x		-	-	-	-	-	-	Y	N	N	Y	N	N
Spring oat		x		-	-	-	-	-	x	x	x	x	x	x	x
Spring oat (grain)			x	-	-	-	-	-	-	x	x	x	x	x	x
Spring pea	x	x		x	x	x	x	x	x	-	-	-	-	-	-
Spring pea (grain)			x	-	-	-	x	x	x	x	x	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	-	-	-	-
Spring triticale		x		-	x	x	x	x	x	x	x	x	x	x	x
Spring triticale (grain)			x	-	-	-	-	-	-	-	-	x	x	x	x
Spring oat/triticale/pea	x	x		-	-	-	-	-	-	-	-	x	x	x	x
Spring triticale/oat	x	x		-	-	-	-	-	-	-	-	x	x	x	x
Spring triticale/pea		x		-	x	x	x	x	x	x	x	-	-	-	-
Spring triticale/lentil				-	x	x	x	x	-	-	-	-	-	-	-
Spring lentil				x	x	x	x	x	-	-	-	-	-	-	-

†Oat, triticale, pea, buckwheat, forage brassica, and forage radish.

††Flex: Plant when soil moisture is 14 in. (12 in. in 2013) or > and precipitation outlook is neutral or favorable.

Table 2. Annual and 30-year monthly, growing season, and fallow precipitation at the Southwest Research-Extension Center near Garden City, KS, 2012–2017

Year	Month	Precipitation	30-year precipitation average†
		------------------- in. -------------------	
2012	January	0.00	0.46
	February	0.59	0.55
	March	1.92	1.31
	April	1.77	1.74
	May	0.30	2.98
	June	1.03	3.12
	July	2.41	2.80
	August	1.22	2.51
	September	1.19	1.42
	October	0.98	1.21
	November	0.00	0.55
	December	0.73	0.59
	Total	12.14	19.24
	Wheat growing season (October-June)	8.50	12.51
	Grain sorghum growing season (June-October)	6.83	11.06
	Fallow preceding wheat (November-September)	16.17	18.03
	Fallow preceding grain sorghum (July-May)	10.81	16.12
2013	January	0.48	0.46
	February	1.54	0.55
	March	0.13	1.31
	April	0.28	1.74
	May	1.25	2.98
	June	1.84	3.12
	July	2.23	2.80
	August	6.09	2.51
	September	1.83	1.42
	October	0.88	1.21
	November	0.74	0.55
	December	0.00	0.59
	Total	17.29	19.24
	Wheat growing season (October-June)	7.23	12.51
	Grain sorghum growing season (June-October)	12.87	11.06
	Fallow preceding wheat (November-September)	16.40	18.03
	Fallow preceding grain sorghum (July-May)	10.21	16.12

continued

Table 2. Annual and 30-year monthly, growing season, and fallow precipitation at the Southwest Research-Extension Center near Garden City, KS, 2012–2017

Year	Month	Precipitation	30-year precipitation average†
		------------------- in. -------------------	
2014	January	0.12	0.46
	February	0.38	0.55
	March	0.25	1.31
	April	0.69	1.74
	May	0.63	2.98
	June	10.50	3.12
	July	3.81	2.80
	August	1.99	2.51
	September	2.71	1.42
	October	1.78	1.21
	November	0.03	0.55
	December	0.40	0.59
	Total	23.29	19.24
	Wheat growing season (October-June)	14.19	12.51
	Grain sorghum growing season (June-October)	20.79	11.06
	Fallow preceding wheat (November-September)	21.82	18.03
	Fallow preceding grain sorghum (July-May)	13.84	16.12
2015	January	0.30	0.46
	February	1.21	0.55
	March	0.32	1.31
	April	0.37	1.74
	May	6.38	2.98
	June	1.39	3.12
	July	5.36	2.80
	August	3.24	2.51
	September	0.04	1.42
	October	2.87	1.21
	November	0.98	0.55
	December	0.81	0.59
	Total	23.27	19.24
	Wheat growing season (October-June)	12.18	12.51
	Grain sorghum growing season (June-October)	12.90	11.06
	Fallow preceding wheat (November-September)	19.04	18.03
	Fallow preceding grain sorghum (July-May)	19.30	16.12

continued

Table 2. Annual and 30-year monthly, growing season, and fallow precipitation at the Southwest Research-Extension Center near Garden City, KS, 2012–2017

Year	Month	Precipitation	30-year precipitation average†
		------------------ in. ------------------	
2016	January	0.04	0.46
	February	0.22	0.55
	March	0.06	1.31
	April	4.59	1.74
	May	0.92	2.98
	June	3.61	3.12
	July	5.97	2.80
	August	1.85	2.51
	September	0.17	1.42
	October	0.00	1.21
	November	0.08	0.55
	December	0.22	0.59
	Total	17.73	19.24
	Wheat growing season (October-June)	14.10	12.51
	Grain sorghum growing season (June-October)	11.60	11.06
	Fallow preceding wheat (November-September)	19.22	18.03
	Fallow preceding grain sorghum (July-May)	19.13	16.12
2017	January	1.54	0.46
	February	0	0.55
	March	2.55	1.31
	April	4.03	1.74
	May	1.47	2.98
	June	1.25	3.12
	July	2.02	2.80
	August	2.46	2.51
	September	3.29	1.42
	October	1.75	1.21
	November	0.01	0.55
	December	0	0.59
	Total	20.37	19.24
	Wheat growing season (October-June)	11.09	12.51
	Grain sorghum growing season (June-October)	10.77	11.06
	Fallow preceding wheat (November-September)	18.69	18.65
	Fallow preceding grain sorghum (July-May)	21.27	18.65

†30–year average (1984–2014).

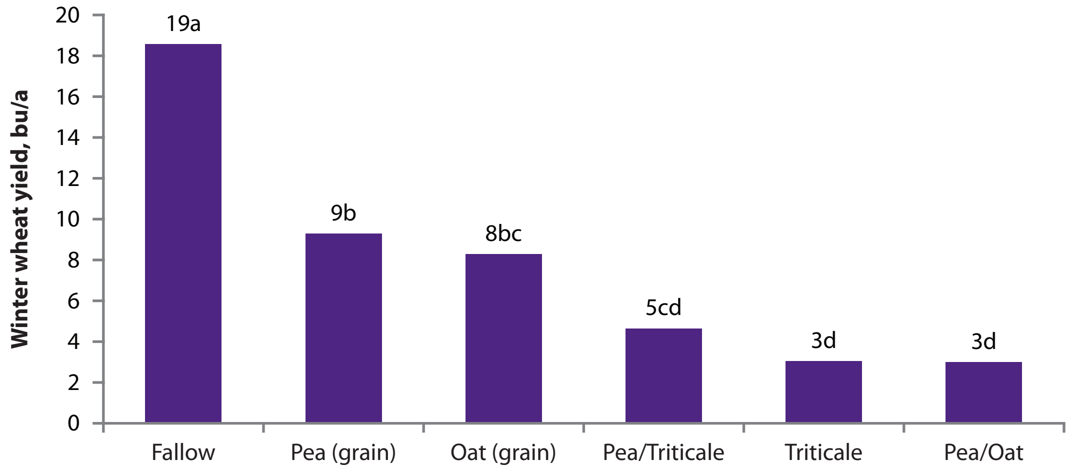

Figure 1. Winter wheat yield (bu/a) in 2013 following various cover crop treatments. Means followed by same letter are statistically similar at *P* ≤ 0.05.

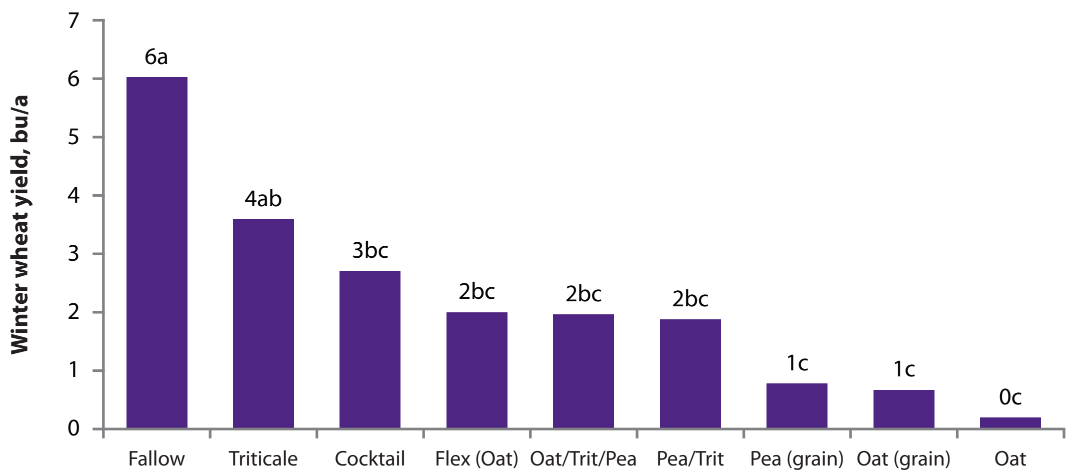

Figure 2. Winter wheat yield (bu/a) in 2014 following various cover crop treatments. Means followed by same letter are statistically similar at *P* ≤ 0.05.

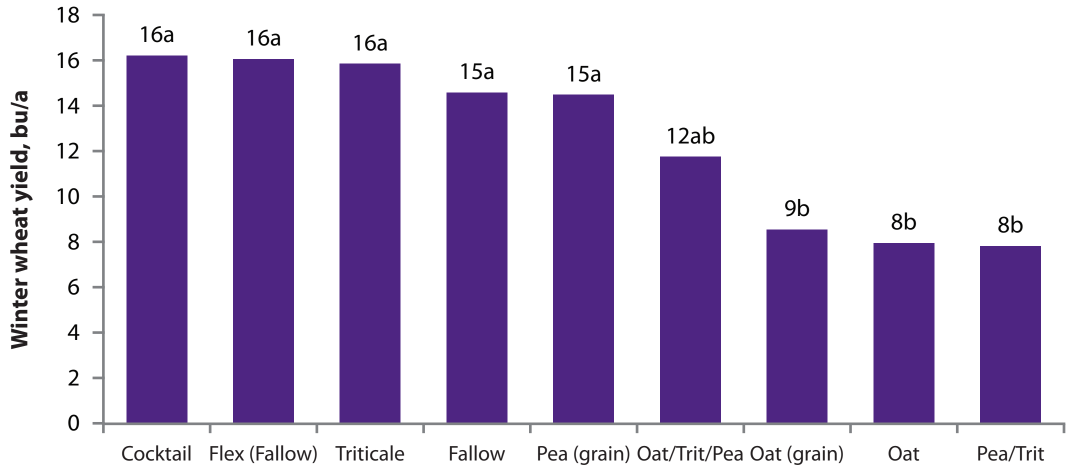

Figure 3. Winter wheat yield (bu/a) in 2015 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$.

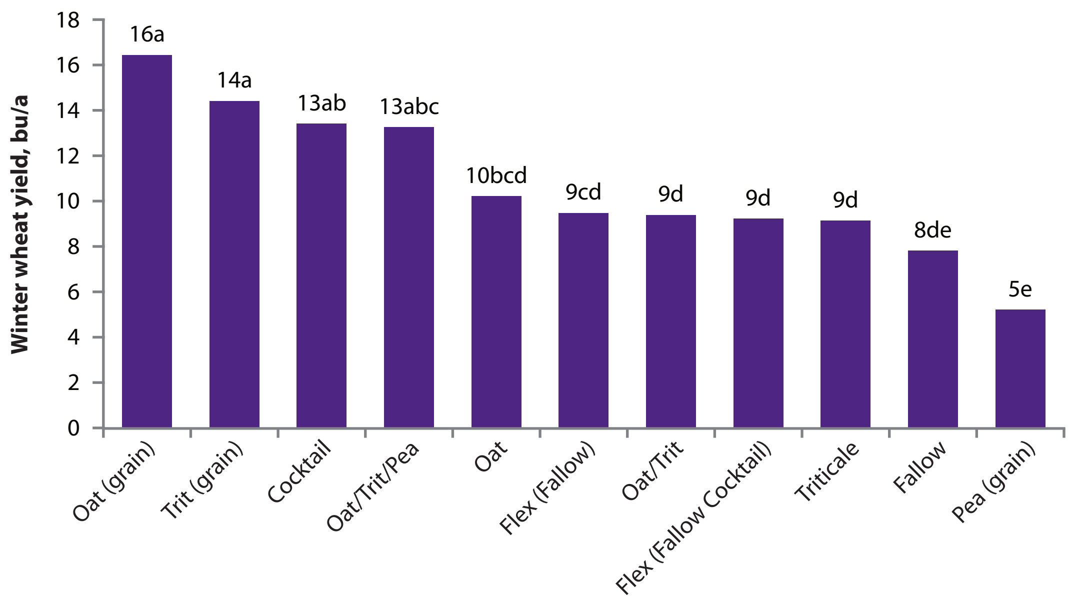

Figure 4. Winter wheat yield (bu/a) in 2017 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$.

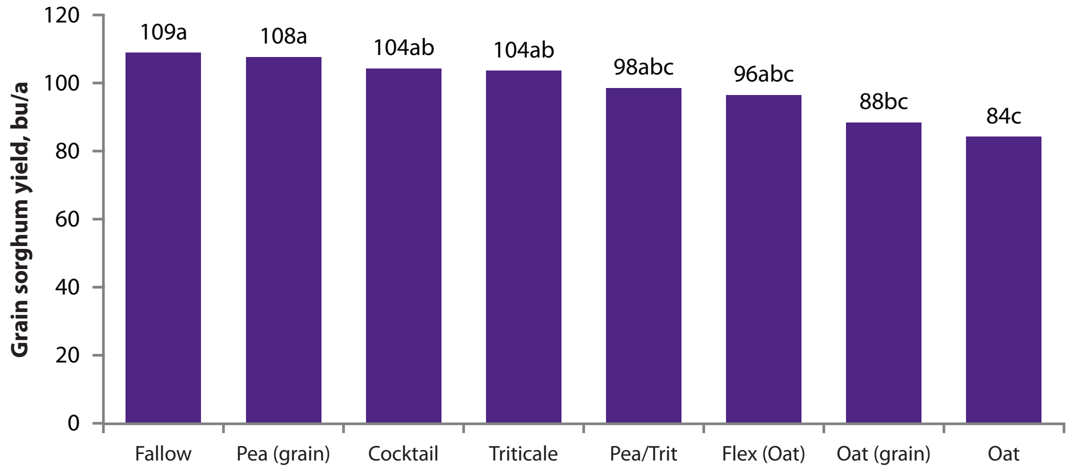

Figure 5. Grain sorghum yield in 2015 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$.

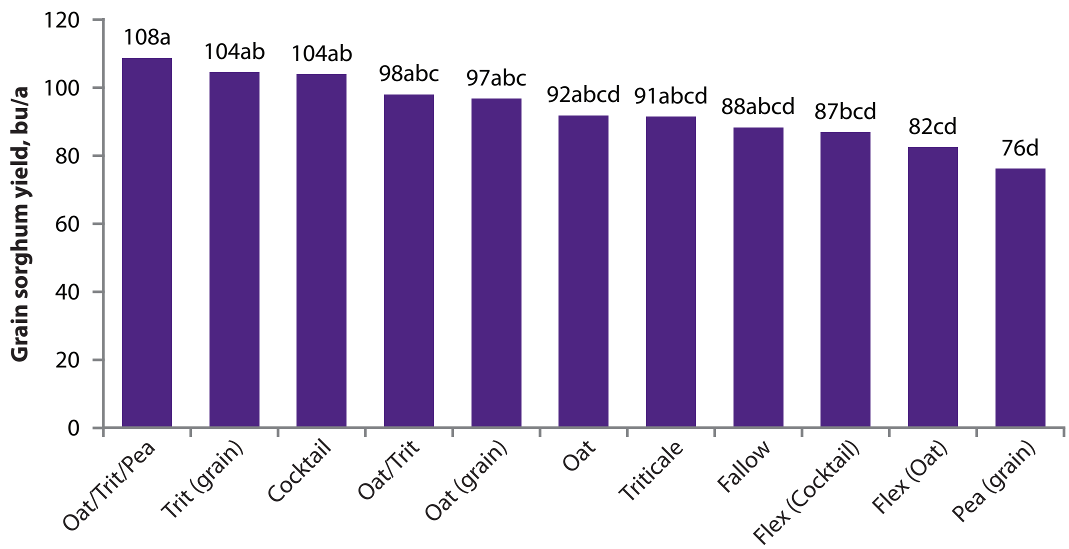

Figure 6. Grain sorghum yield in 2017 following various cover crop treatments. Means followed by same letter are statistically similar at $P \leq 0.05$.