Summer cover crops fix nitrogen, increase yields,

and improve soil–crop relationships

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Cover crops provide additional biomass input, reduce soil erosion, and promote nutrient cycling, but their impacts on subsequent crop yields and quantitative relationships with soil properties such as physical properties deserve further scrutiny. Because performance of cover crops may vary with crop type, soil type, tillage management, and climate, a site-specific assessment of soil–crop relationships under different cover crops is warranted.

Cover crops may or may not increase yields of subsequent crops. Their impact on subsequent crop yields and soil properties most likely depend on precipitation input, species, growing season (summer vs. winter crops), amount of biomass return, tillage management, and length of cover crop management. Under favorable climatic conditions, high-biomass-producing and high-N-fixing summer or tropical legume cover crops such as sunn hemp may have more rapid and greater effects on increasing crop yields and improving soil properties than crops with low biomass input.

Because of high biomass input, summer legumes can provide an effective protective cover to soil and supply significant amounts of N to subsequent crops. Reports of high biomass production, and subsequent increased corn yields, by sunn hemp have been published, and more studies along these lines are needed to better understand summer cover crop effects.

Research has shown that summer legume crops such as sunn hemp and late-maturing soybean, when used as summer cover crops, reduced soil's susceptibility to compaction and increased wet aggregate stability, water infiltration, earthworm population, and soil organic carbon concentration. These cover crop-induced changes in soil properties may also benefit yields of subsequent crops. While cover crops may not always increase crop yields and improve properties in all soils, some have hypothesized that this practice will increase crop yields if soil physical properties improve and soil organic carbon and soil N concentration increase with cover cropping.

Many have studied the effect of soil properties on crop yields, but little data are available on the changes in soil physical parameters and soil organic carbon concentration affecting crops yields in intensively managed no-till cropping systems. Soil physical properties may affect crop growth and yield by influencing aeration, water transmission and retention, heat flux, organic matter decomposition, N mineralization, nutrient release, and microbial activity. Some physical properties such as compaction may directly affect plant growth, while others such as aggregate stability may have indirect effects. In a recent article in *Agronomy Journal*, researchers assessed the effects of no-till summer cover crops on subsequent wheat and sorghum yields as well as their relationships with soil physical properties, soil organic carbon, and soil total N concentration on an Udic Argiustoll in south-central Kansas.

Materials and methods

Crop yield data and soil properties for this study were collected from a long-term (15 year) experiment of cover crops under a no-till winter wheat and grain sorghum

Table 1. Precipitation input on a monthly and annual basis from 2002 to 2009 for the cover crop experiment at Hesston, KS.

	Precipitation								
Month	2002	2003	2004	2005	2006	2007	2008	2009	20-year average
	cm								
January	3.6	0.2	3.3	7.8	0.3	2.7	0.6	0.1	2.1
February	1.0	3.6	2.5	4.4	0	1.2	4.8	0.8	3.0
March	1.1	7.6	13.3	7.8	7.2	9.9	5.9	5.6	6.5
April	10.6	11.4	4.1	3.8	8.0	10.0	9.1	14.7	8.3
May	7.5	12.1	5.9	15.2	5.6	22.9	12.9	7.9	12.8
June	18.9	7.2	13.5	25.0	10.3	10.6	11.0	13.4	12.6
July	5.4	1.4	14.8	8.9	7.7	8.9	9.0	13.3	11.3
August	6.4	12.1	6.2	17.8	13.0	7.0	13.1	5.2	9.1
September	4.4	11.6	3.3	3.0	3.0	2.3	12.5	10.9	7.6
October	16.8	11.5	7.6	2.9	5.3	6.6	10.9	10.0	7.5
November	1.0	0.2	4.8	0.6	0.3	0.5	4.9	1.6	4.1
December	1.3	3.5	0.5	0.6	4.3	7.4	0.9	1.8	2.6
Annual	78.0	82.4	79.8	98.0	64.9	89.8	95.5	85.2	87.3

rotation at Hesston, KS. The experiment was initiated in 1995 and terminated in 2009 and consisted of a factorial combination of three cover crop treatments and four N rates. The main rotation was winter wheat–grain sorghum in which wheat was no-till planted into sorghum stubble in the fall and harvested in June of the next year. The cover crops were planted after wheat; and sorghum was planted in June of the following year.

Between 1995 and 2000, hairy vetch was used as a winter cover crop. The three treatments during this period were hairy vetch early termination, hairy vetch late termination, and control. Beginning in 2002, sunn hemp and late-maturing soybean were grown as summer cover crops in the plots where hairy vetch treatments had been in place, and the remaining plots retained the no-cover crop treatment. Wheat under no-till was grown without fertilizer across all plots in the transition year between 2000 and 2002. The summer cover crops were planted in early July after wheat harvest in the corresponding years except in 2006 when they were planted in early August due to late seed arrival. The summer cover crops were last grown in the summer of 2008 followed by sorghum in 2009.

Results and discussion

Cover crop height and residue yield

Monthly and annual mean precipitation during the summer cover crops study is given in Table 1. Year to year and monthly fluctuations in precipitation are reflected in the yield performance of cover crops as well as the main crops (Tables 1 and 2; Fig. 1 and 2). Despite some really dry years, summer cover crops afforded enough time between fall termination and succeeding grain crop for soil moisture replenishment. In this experiment, summer cover crops were never terminated early. Wheat depended more on timely fall precipitation than sorghum since wheat followed as a double crop after sorghum. Wheat yield was somewhat low but not uncommon for this region.

Results indicate that summer cover crops, particularly sunn hemp, can produce significant amounts of residues in as little as 12 weeks, despite fluctuating rain. The high aboveground residue input can have beneficial effects on crop yields and soil properties as discussed later. The increased height of sunn hemp may also be beneficial for shading and smothering weeds.

Cover crop effects on grain sorghum and winter wheat yield

Cover crops and N application rates increased sorghum (Fig. 1) and wheat (Fig. 2) yield. The cover crop × N rate interaction was significant in some years. Sunn hemp increased sorghum and wheat yield following the first year of the cover crop's establishment, particularly in nonfertilized plots, suggesting that summer cover crops may have rapid effects on increasing yields of subsequent crops. Late-maturing soybean did not increase sorghum yield in 2003, but it increased sorghum yield at 0 lb N/ac in 2005 and at all levels of N application except at 90 lb N/ac in 2009.

Wheat appeared to be more responsive to N application than sorghum. For example, from 0 to 90 lb N/ac, wheat yield in non-cover crop plots increased by 4.3 times in 2004, 6.9 times in 2006, and 4.2 times in 2008, while sorghum yield in the same plots increased only by 2.1 times in 2005 and 1.5 times in 2007 and 2009. A similar greater wheat response to N application was observed in plots under sunn hemp and late-maturing soybean. The greater wheat yield increase with N fertilization suggests: (i) less cover crop-derived N may have been available for wheat than for sorghum, which succeeded cover crops before wheat; (ii) sorghum may scavenge more N from the soil than wheat; and (iii) differences in soil water content between sorghum (spring) and wheat (fall) planting may have affected crop response to N application.

The significant and rapid increase in no-till wheat and sorghum yields with the inclusion of cover crops shows the potential benefit of these crops for increasing subsequent crop yields in no-till systems. These results suggest that cover crops may sufficiently supplement applied N to maintain crop yields in a profitable range all while suppressing weeds, lowering input costs for herbicides and fertilizers, and preserving soil moisture.

Cover crops and soil nitrogen fixation

Crop yield data in Fig. 1 and 2 suggest that summer cover crops supplement N at both low and optimum levels of N application. Fixation of N through legume cover crops may reduce the excessive dependence on inorganic N fertilizers in this region. It is important to note that this study only reports soil total N.

Studies in other regions have also found high N contribution from tropical legume cover crops. Summer cover crops return a high amount of N-enriched biomass. Because of their rapid growth and high biomass production and N fixation, legume summer crops such as sunn hemp may supplement N for subsequent crops and reduce inorganic N fertilizer use. A high N application rate masks the benefits of soil N derived from cover crops and appears to have limited effects on crop yields.

While this study did not quantify microbial biomass and activity, it has been observed that plots with summer cover crops had a greater number of earthworms than plots without the cover crops. This finding suggests that greater biological activity in plots with cover crops may contribute to N release from cover crop residues into the soil. Studies have shown that N derived from cover crops can be readily mineralized through biological activity and made available as nitrates for the subsequent crops with little or no loss of N through leaching. Fertilizer management (rate and timing) of sorghum and wheat and precipitation input can be critical to optimize the use of N derived from cover crops.

The soil organic content does not only stimulate crop growth through nutrient cycling but also through improvement in soil physical properties. It reduces soil compactibility (soil's susceptibility to compaction), promotes macroaggregation, increases water retention capacity, increases water infiltration, and absorbs and filters nutrient loss in runoff. The results of the current study support recent emphasis on enhancing the soil organic content pool in agricultural ecosystems for increasing crop yields, improving soil properties, and addressing food insecurity. Similar to soil organic content, the strong positive correlation of yield with soil total N concentration indicates that cover crops can increase crop yields by supplying N.

Table 2. Plant height and residue yield of two summer cover crops for each rotation cycle at Hesston, KS. Nitrogen fertilizer was applied to main crops consisting of winter wheat-grain sorghum rotation.

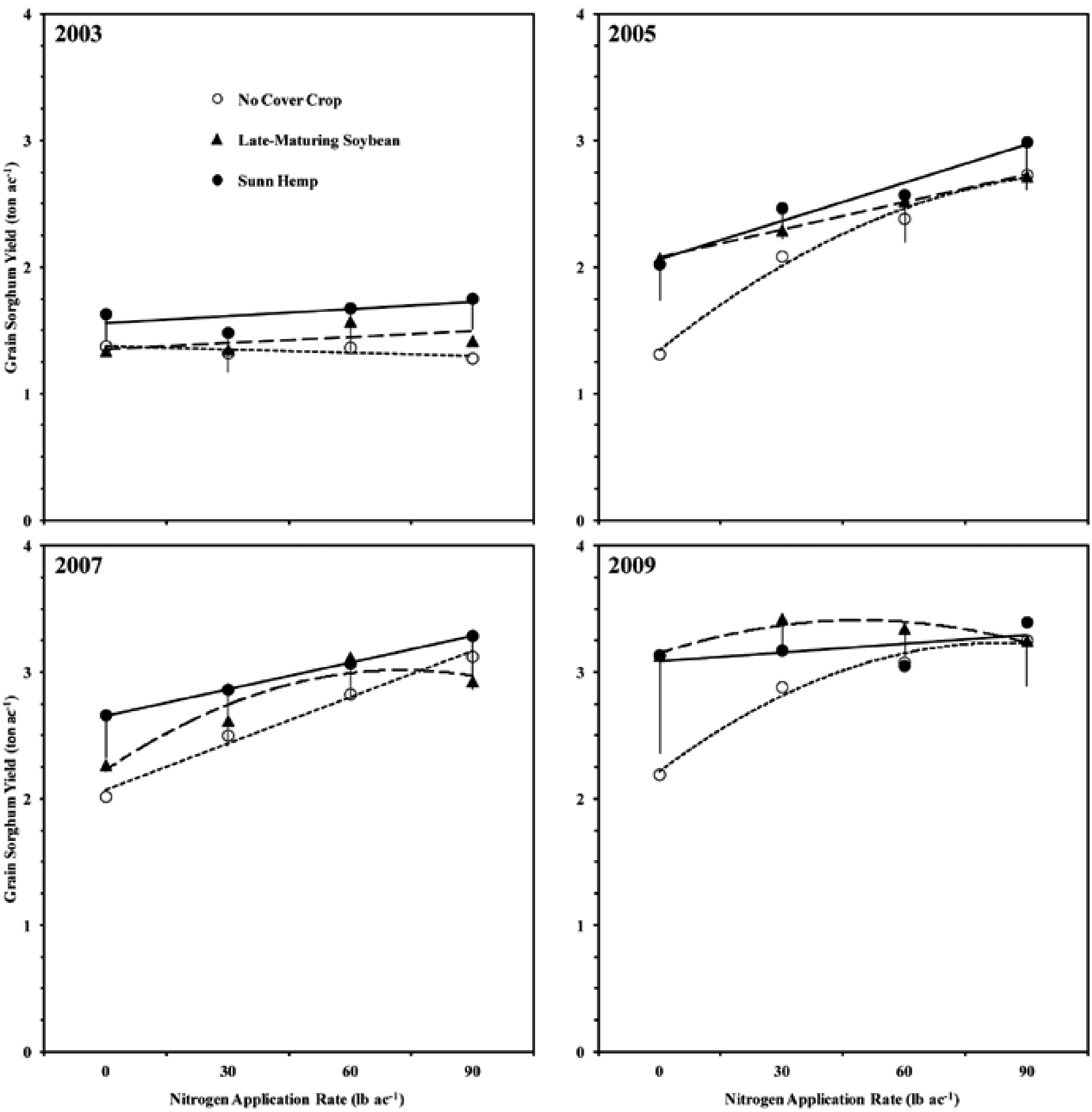
Summer cover crops	Nitrogen rate	Statistics	Year 2002	2004	2006	2008
	lb/ac					
			Plant height, ft			
Sunn hemp	0		6.7	5.9	4.3	7.9
	30		6.6	6.0	4.5	8.0
	60		6.9	6.1	4.4	7.9
	90		6.9	6.1	4.5	8.0
Late-maturing soybean	0		2.9	2.1	1.6	3.0
	30		2.9	2.0	1.5	2.9
	60		3.1	2.0	1.6	3.1
	90		2.9	1.8	1.6	3.0
		LSD 0.05	0.2	0.1	0.1	0.1
			Residue yield, tons/ac			
Sunn hemp	0		3.9	2.9	1.9	4.4
	30		3.4	3.1	2.1	3.8
	60		3.3	3.3	2.4	3.9
	90		3.4	3.5	2.0	4.3
Late-maturing soybean	0		3.5	2.3	1.1	3.8
	30		4.0	2.0	1.4	3.6
	60		3.9	2.5	1.4	3.9
	90		4.2	1.6	1.4	3.5
		LSD 0.05	ns†	0.4	0.3	0.4

† ns, not significant.

The positive correlation of wheat and sorghum yield with a cover crop-induced increase in soil water content and the negative correlation with a cover crop-induced decrease in spring soil temperature corroborate the critical importance of soil water and temperature for crop production. It is important to clarify that, in this study, soil water content and soil temperature were measured only once during spring time (one and a half years after cover crop termination). The significant correlations show the influence of cover crop residue mulch on soil water and temperature. In this study, plots mulched with cover crop residues had greater soil volumetric water content and lower soil temperature in spring than plots without cover crops. The increased soil warming in plots without cover crops probably accelerated evaporation and reduced the volumetric water content relative to plots mulched with cover crop residues.

While growing cover crops use soil water and may reduce available moisture for subsequent crops, particularly in semiarid regions, cover crops can maintain or increase soil water content by increasing precipitation capture through increased water infiltration and reduced evaporation. In this study region, precipitation is, in general, adequate for crop production, and thus, use of cover crops may not cause water shortage for subsequent crops. However, in regions with limited precipitation such as the semiarid Great Plains, impacts of cover crops on soil water storage and yields of subsequent crops deserve further scrutiny. Early termination, selection of appropriate cover crops species, and other site-specific management strategies should be developed for the successful use of cover crops in semiarid regions.

Soil temperature influences several physical, chemical, and biological processes in the soil. It affects seed germination, root growth, evaporation, soil moisture content, microbial processes, nutrient cycling, and other processes. The results of this study suggest that because soil water content and temperature are a function of the amount of surface vegetative cover, the addition of residues to the soil surface cover through cover crops can rapidly alter the soil water and temperature dynamics. Crop residue mulch insulates the soil and buffers the abrupt fluctuations of soil temperature. It regulates the near-surface radiation energy balance and the dynamics of heat exchange between the soil and the atmosphere. An increase in surface residue cover with cover crops in no-till fields

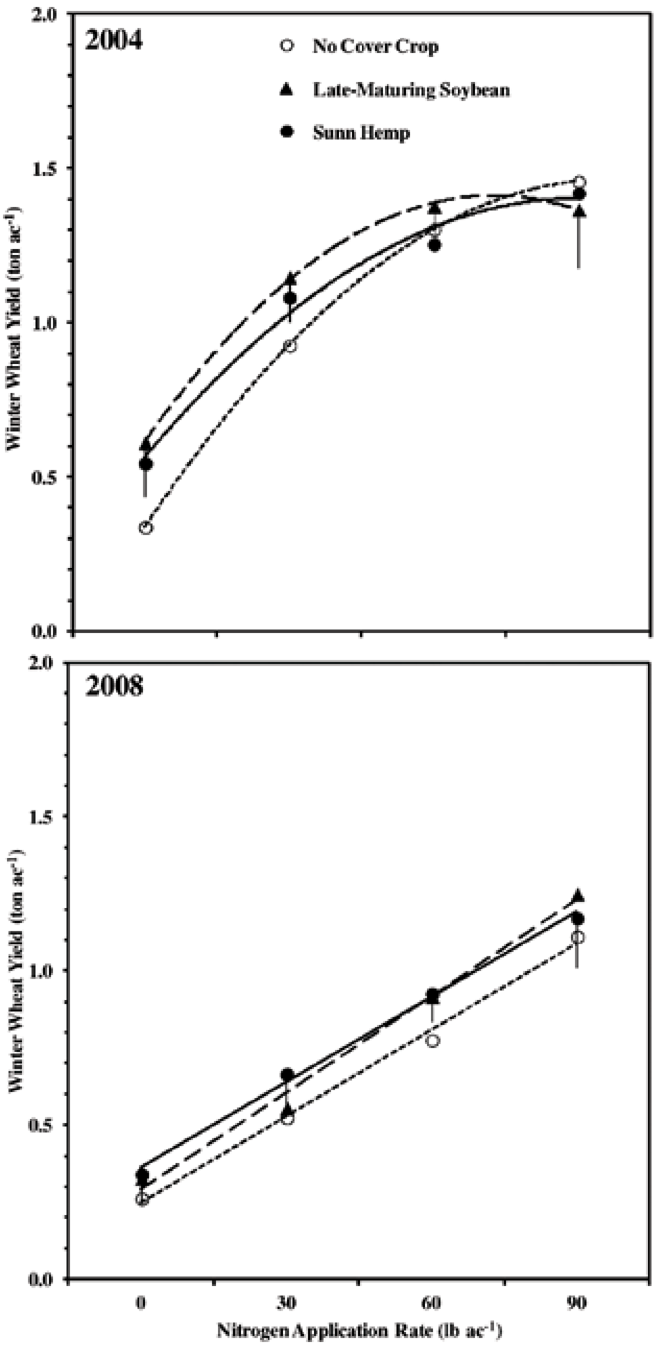


may create different microclimatic conditions favorable for crop production.

Fig. 1. Mean grain sorghum yield as affected by three cover crop treatments for 2003, 2005, 2007, and 2009. The error bars represent LSD values to compare cover crop treatment effects on yield within each level of N application.

Conclusions

Sunn hemp and late-maturing soybean used as summer cover crops in a no-till cropping system rapidly increased wheat and sorghum yields on an Udic Argiustoll. These summer cover crops also fixed significant amounts of N in the soil compared with non-cover crop plots, suggesting that they can supplement N especially in cropping sys-



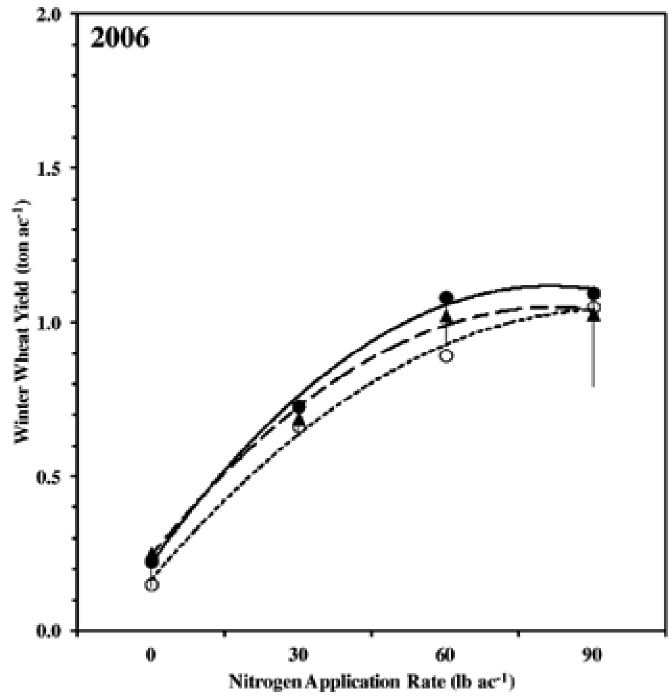


Fig. 2. Mean winter wheat yield as affected by three cover crop treatments for 2004, 2006, and 2008. The error bars represent LSD values to compare cover crop treatment effects on yield within each level of N application.

tems with limited inorganic N input. Cover crop-induced changes in soil properties were partly responsible for the increase in crop yield. Changes in soil maximum compactibility, soil organic content, and soil total N concentration, aggregate stability, field soil water content, and soil temperature were significantly related to crop yields.

The results suggest cover crops increase crop yields and improve soil–crop relationships.

Based on these results, sunn hemp and late-maturing soybean may be potential summer legume cover crops for no-till wheat–sorghum rotations in the study region. Results also indicate that inclusion of summer legume cover crops in no-till systems can reduce N fertilizer requirements while improving soil physical properties and increasing soil organic content and N concentration. Overall, summer cover crops can be one of the best management practices to diversify and intensify cropping systems, manage N requirements, balance crop production and soil and environmental quality, and contribute to land stewardship and overall long-term sustainability of agricultural production systems.

Adapted from the Agronomy Journal *article, "Summer Cover Crops Fix Nitrogen, Increase Crop Yield, and Improve Soil–Crop Relationships," by Humberto Blanco-Canqui, M.M. Claassen, and D.R. Presley. 2012. Agron. 104:137–147*

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May–June 2012 self-study quiz

Summer cover crops fix nitrogen, increase yields and improve soil–crop relationships (no. SS 04263)

This quiz is worth **1 CEU in Crop Management**. A score of 70% or higher will earn CEU credit.

Directions

After carefully reading the article, answer each question by clearly marking an "X" in the box next to the best answer. Complete the self-study quiz registration form and evaluation form on the back of this page. Clip out this page, place in an envelope with a $20 check made out to the American Society of Agronomy (or provide your credit card information on the form), and mail to: ASA c/o CCA Self-Study Quiz, 5585 Guilford Road, Madison, WI 53711. Or you can save $5 by completing the quiz online at www.certifiedcropadviser.org/certifications/self-study.

1. What type of cover crop mentioned in the article may have more rapid and greater effects on increasing crop yields and improving soil properties?

- ❑ a. high-biomass-producing and high-N-fixing summer or tropical legumes.
- ❑ b. low-biomass-input and low-N-intake grasses.
- ❑ c. cold-tolerant, fall-planted oilseed crops.
- ❑ d. heat-tolerant, summer pulses with aggressive tap roots.

2. Which of the following is NOT mentioned in the article? Summer legumes can

- ❑ a. potentially increase yields of subsequent crops.
- ❑ b. provide an effective protective cover to soil.
- ❑ c. decrease wet aggregate stability.
- ❑ d. supply significant amounts of N to subsequent crops.

3. In this experiment, summer cover crops

- ❑ a. were never terminated early.
- ❑ b. were always terminated early.
- ❑ c. were usually irrigated.
- ❑ d. were always irrigated.

4. Crop yield data in Fig. 1 and 2 suggest that summer cover crops supplement N at

- ❑ a. excessive levels of N application.
- ❑ b. optimum levels of N application.
- ❑ c. low levels of N application.
- ❑ d. both low and optimum levels of N application.

5. It has been observed that plots with summer cover crops had greater ____ than plots without the cover crops.

- ❑ a. numbers of earthworms.
- ❑ b. numbers of nematodes.
- ❑ c. soil compaction.
- ❑ d. soil temperatures.

6. In this study, the greater wheat yield increase with N fertilization suggests

- ❑ a. wheat may scavenge more N from the soil than sorghum.
- ❑ b. more cover crop-derived N may have been available for wheat than for sorghum.
- ❑ c. less cover crop-derived N may have been available for wheat than for sorghum.
- ❑ d. sorghum may scavenge less N from the soil than wheat.

7. In this study, the cropping system was

- ❑ a. wheat no-till planted into sorghum stubble in the fall with the cover crops planted after wheat.
- ❑ b. sorghum planted into wheat stubble in the spring with cover crops planted in the fall.
- ❑ c. sorghum no-till planted into sunn hemp in August and wheat planted the following spring.
- ❑ d. cover crop planted in the fall after wheat harvest followed by planting early maturing soybean in the spring.

Quiz continues next page

8. The cover crops used in this study

- ❑ a. increased soybean yields on an Udic Argiustoll.
- ❑ b. were planted in the fall after soybean harvest.
- ❑ c. fixed significant amounts of N in the soil compared with non-cover crop plots.
- ❑ d. increased wheat yields but had no change on sorghum yields.

9. Soil water content and temperature are a function of

- ❑ a. surface vegetative cover.
- ❑ b. microbial processes.
- ❑ c. soil compaction.
- ❑ d. seed germination.

10. Crop residue mulch regulates the near-surface radiation energy balance and the

- ❑ a. relationship between heat and moisture.
- ❑ b. dynamics of water exchange between the soil and the crop.
- ❑ c. dynamics of heat exchange between the soil and the atmosphere.
- ❑ d. relationship between crop water uptake and evapotranspiration.

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This article addressed the stated competency area and performance objective(s): 1 2 3 4 5

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