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Seeding and Nitrogen Rates Required to Optimize Winter Wheat Yields Following Grain Sorghum and Soybean

By S.A. Staggenborg, D.A. Whitney, D.J. Fjell, and J.P. Shroyer

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Harvested winter wheat in Kansas has declined 21% from 1990 to 2000. Despite this decline, winter wheat remains an important crop in most cropping systems throughout the state. Including winter wheat in crop rotations with summer crops improves control of problem summer annual and perennial weeds, reduces the incidence of residue-borne fungal diseases and is an excellent source of residue cover for reduced-tillage systems.

Improved economics associated with intensifying crop rotations has been a motivating factor in the adoption of no-till systems in Kansas. Adoption of no-till planting of winter wheat immediately following summer crop harvest was one of the first changes made to intensify crop rotations. Planting winter wheat immediately after summer crop harvest eliminates an 11-month fallow period, thus reducing the duration of the transitional period from summer crops to winter wheat. However, planting no-till winter wheat behind summer crops presented problems, such as later planting dates and managing heavy summer crop residue if the previous crop was corn or grain sorghum. Using soybean as the previous crop addresses the residue issue, but with the dominance of corn and grain sorghum in Kansas, management strategies are needed that address issues impeding successful wheat production following these summer crops in no-till systems.

Proper management of late-planted wheat after a summer crop is complicated by factors that are influenced by the previous crop as well as the environment that the wheat crop is subjected to as a result of delayed planting. The recommended winter wheat planting window for Manhattan, KS, is from Sept. 25 through Oct. 20. When following a summer crop, harvest often delays wheat planting through early November, suggesting that higher seeding rates are needed to maximize yields.

Wheat yields may also be influenced by factors such as soil water content, allelopathy and N availability. Previous-crop influence on N availability to the following wheat crop in a no-till system complicates N management. Increased residue levels of grain sorghum compared with soybean have the potential to decrease N availability to the subsequent wheat crop through N immobilization. The relative N contribution by soybean to the subsequent wheat crop is less clear than the effects of available N by sorghum residue.

Little data exists to guide producers in managing double-crop winter wheat planted in a no-till system in Kansas. Therefore, the objective of this study was to determine if the optimal seeding rates and N rates for wheat are different when wheat is no-till planted immediately following grain sorghum compared with soybean.

MATERIALS AND METHODS

To initiate the previous-crop residue treatments, grain sorghum and soybean were planted in a randomized complete block design on the Agronomy Farm near Manhattan, KS, in the spring of 1997, 1998 and 1999. Soil type at this location is a Reading silt loam. Recommended cultural practices for these crops were followed, but grain yields were not recorded. The winter wheat variety 2137 was no-till planted into the existing summer crop residue on Oct. 20, 1997, Oct. 30, 1998, and Oct. 25, 1999. Seeding rates of 67, 101 and 134 kg ha^{-1} were used in 1997 and an additional seeding rate of 168 kg ha^{-1} was added in 1998 and 1999. These seeding rates correspond to approximately 1.8, 2.7, 3.6 and 4.5 million seed ha^{-1} for the four seeding rates of 67, 101, 134 and 168 kg ha^{-1}, respectively, based on an average seed weight of 37.3 g 1000^{-1} seed. All plots were planted with a plot drill in 0.25-m row widths. Nitrogen rates of 0, 45, 90 and 134 kg ha^{-1} were applied as ammonium nitrate after planting in the fall each year. A split-split plot arrangement of a randomized complete block design with four replications was used with previous crops as main plots, seeding rates as subplots and N rates as sub-subplots. Sub-subplots were 6 m long and 1.5 m wide.

Soil test results indicated that levels for pH, P and K were within the optimal ranges for winter wheat production. Therefore, no additional soil amendments were applied during the study. No herbicide applications were required for the first two growing seasons, but 26 g a.i. ha^{-1} flucarbazone-sodium was applied March 6, 2000, for control of winter annual grasses.

To assess N uptake by the plant and to determine if final uptake levels were adequate, plant N content was determined from whole-plant samples taken at anthesis, and grain N levels were determined from grain samples taken at harvest.

Because the number of seeding rate treatments differed in 1998 from 1999 and 2000, a single-year analysis of variance was conducted for data from 1998. An F test indicated homogenous variances among 1999 and 2000 data; therefore, a combined-year analysis of variance was conducted. Single degree-of-freedom contrasts were used to test N rates and seeding rate effects.

Significant linear or quadratic responses were characterized using regression analysis. Nitrogen or seeding rates that produced maximum yield, leaf N content or grain N content for all quadratic responses were determined by solving the first derivative for zero.

RESULTS AND DISCUSSION

Growing conditions varied from year to year throughout this study. Precipitation was below normal and temperatures were near normal for the 1997–1998 growing season. Rainfall received in early June during grain fill improved yields, which averaged 3848 kg ha^{-1}. During the fall of 1998, rainfall and temperatures were above normal. Above-average rainfall was received in the spring of 1999 with near-normal temperatures. These spring conditions resulted in leaf rust infestations that reduced yields, resulting in an average yield of 1,895 kg ha^{-1}. Above-average temperatures and extremely low rainfall amounts in the fall of 1999 resulted in poor fall growth. Above-average temperatures during grain fill in late May and early June of 2000 reduced grain yields, resulting in an average yield of 2,678 kg ha^{-1}.

Grain Yields. Grain yields were influenced by seeding rate in two of three years of the study as indicated by the significant seeding rate main effect in 1998 and significant seeding rate x year interaction in 1999 and 2000. Because no seeding rate x N rate or seeding rate x previous crop interactions were found, data are presented as main effects within each year. Grain yields responded in a linear manner to increasing seeding rates in 1998, in a nonlinear manner in 1999, and did not respond to seeding rates in 2000. In 1998, grain yield increased at a rate of 5.1 kg ha^{-1} per kilogram per hectare of seed. The quadratic yield response to seeding rates in 1999 was the result of low yield at the 67 kg ha^{-1} seeding rate compared with the three higher rates. Grain yield increased at a rate of 23.1 kg ha^{-1} per kilogram per hectare as seeding rates increased from 67 to 101 kg ha^{-1} and 3.5 kg ha^{-1} per kilogram per hectare as seeding rates increased from 101 to 168 kg ha^{-1}. The optimal seeding rate in 1999 was determined to be 150 kg ha^{-1}.

Based on the two years in which wheat yield responded to seeding rates, seeding rates of $\geq$134 kg ha^{-1} were needed to reach maximum yields. This is approximately 35 kg ha^{-1} higher than the recommended seeding rate for continuous wheat in Kansas. Wheat yield response to increasing seeding rates was lower than expected, especially considering the late planting dates in this study. A 1993 study reported maximum wheat yields at seeding rates of approximately 90 kg ha^{-1} when planted in early September. However, when planting was delayed until late September, seeding rates from approximately 120 to 170 kg ha^{-1} were needed to maximize wheat yields. In 1998 and 1999, a seeding rate of $\geq$101 kg ha^{-1} was needed for maximum yield with a late-October seeding date.

Others have reported inconsistent wheat yield responses to seeding rates as well. They reported that when early-season growing conditions were unfavorable, tiller production was limited and unable to compensate at the lower plant densities. As a result, yields increased as seeding rates increased as a result of higher spikes per square meter at the higher seeding rates.

Early-season growing conditions varied throughout this study and influenced yield responses to seeding rates. October and November temperatures were near average in 1997 and above average in 1998 and 1999. Adequate early-season growing conditions occurred in the fall of 1997 and 1998, the two years when yields responded to seeding rates. October and November precipitation was above average in 1998, and despite being below average in 1997, the precipitation was received over a period from 13 days before planting through seven days after planting. Coupled with the near-normal temperatures in 1997, early-season growing conditions were adequate.

The 1999–2000 growing season began with a precipitation deficit in October. November precipitation was near normal but was received in one large storm. This coupled with above-average temperatures reduced overall growth. Under these conditions, a seeding rate response would have been expected. However, above-average temperatures and high-velocity winds during late May in 2000 hastened maturity and reduced overall yield potential. This stress and reduction in yield potential may have masked any seeding rate differences.

Wheat yield response to N fertilizer was influenced by the previous crop in this study, as indicated by the significant N x previous crop interactions. Both linear and quadratic responses were significant for each previous crop, except following soybean in 1999 when only the quadratic response was significant. In 1998 and 1999, wheat planted after grain sorghum required higher N rates to maximize yields but produced lower maximum yields than wheat planted after soybean. In 1998, maximum wheat yield after grain sorghum of 3,760 kg ha^{-1} occurred at 112 kg N ha^{-1}, whereas maximum wheat yield after soybean was 4,059 kg ha^{-1} and required 94 kg N ha^{-1}. In 1999, the maximum wheat yield of 2,043 kg ha^{-1} after grain sorghum required 94 kg N ha^{-1}, and maximum wheat yield after soybean of 2,333 kg ha^{-1} occurred at 70 kg N ha^{-1}. A 1983 study reported a similar trend with wheat following soybean requiring approximately 30 kg ha^{-1} less N to maximize yields compared with wheat following grain sorghum.

In 2000, wheat yield response to N fertilizer also varied by previous crop, with wheat yields after soybean exceeding those after grain sorghum by 675 kg ha^{-1}. However, the optimal N rates for each previous crop were inverted compared with the previous two years, with the yields maximized at 128 kg N ha^{-1} following soybean and 85 kg N ha^{-1} following grain sorghum. One possible explanation for these results may be the differences in soil-available water at wheat planting as a result of the previous crop. The 1999–2000 growing season began with a precipitation deficit that continued throughout the growing season. It is reasonable to assume that less soil water was available to the wheat crop following grain sorghum compared with soybean for several reasons. In Kansas, soybean matures (leaf drop) approximately 14 days earlier than grain sorghum. Also, grain sorghum's perennial growth habit results in it continuing to use water until the plant is terminated by subfreezing temperatures. The difference in cessation of grain growth between soybean and grain sorghum coupled with grain sorghum's perennial growth habit would reduce the amount of water available for the subsequent wheat crop following sorghum. During a dry year such as 1999–2000, these differences would likely result in lower yields and a potentially different response to N applications between the two crops. Under such conditions, the higher N rate treatments following grain sorghum may have developed a denser canopy during early spring, which resulted in greater stress in late May when above-average temperatures and high-velocity winds were experienced.

Less N was required to maximize wheat yields after soybean compared with grain sorghum in 1998 and 1999, which was expected. The expectations are that soybean contributes N to the system that is beneficial to the subsequent wheat crop and/or grain sorghum reduces N availability for the subsequent crop.

It is not likely that soybean contributes N to the subsequent wheat crop. Based on soil temperatures required to release 95% of the N immobilized in soybean residue reported by a study in 1995, organic N release by soybean residue would occur most years in mid to late May in Kansas, which is late enough to have minimal impact on the subsequent wheat crop. In fact, current recommendations in Kansas for wheat following soybean do not consider N credits from the soybean on the subsequent wheat crop.

The more plausible explanation for higher N requirements for wheat following grain sorghum compared with wheat after soybean would be associated with grain sorghum residue and N immobilization. Studies in 1983 and 1984 reported lower tissue N, lower yields and a higher fertilizer N requirement for wheat planted after grain sorghum compared with soybean. Both studies attributed these differences to the low residual N content (<10 g kg^{-1}) of sorghum residue, which produced a sink for N immobilization and reduced the amount of N available for uptake by the wheat crop. A study in 1993 reported that wheat yields and N uptake were 39 and 36% lower, respectively, when wheat no-till planted after grain sorghum was compared with wheat yield and N uptake in a continuous wheat system. An additional 15 kg N ha^{-1} was required to maximize wheat yield following grain sorghum compared with wheat grown in the absence of grain sorghum residue. In 1998 and 1999, our differences between the two crops averaged 21 kg N ha^{-1}. They also attributed the lower N use efficiency to N immobilization by the grain sorghum residue. A 1977 study reported that grain sorghum residue could immobilize as much as 62 kg N ha^{-1}.

Leaf and Grain Nitrogen Content. Wheat leaf N concentration was affected by seeding rate in 1999 and 2000. Leaf N concentration declined as seeding rates increased ($y = 2.12–0.00543x + 0.0000154x^2$, $P < 0.05$). Nitrogen application rates consistently increased N content in leaf and grain. A quadratic response best described leaf N content at heading as a function of applied N in 1998 ($P < 0.05$) and 1999 ($P < 0.05$). In 1999, differences in leaf N content following soybean and grain sorghum increased as applied N rates increased, with leaf N content being greater following soybean. In 1998 the maximum leaf N rate of 17 g kg^{-1} occurred at 120 kg N ha^{-1}. In 1999 maximum leaf N level following soybean was 22 g kg^{-1} and occurred at 134 kg N ha^{-1}, and the optimal leaf N level following grain sorghum was 21 g kg^{-1} and also occurred at 134 kg N ha^{-1}. The rate of leaf N increased more rapidly after soybean than after sorghum. Based on the equations derived, the calculated maximum leaf N contents for wheat occurred at 140 kg after soybean and 170 kg after grain sorghum. Although these values exceed the limits of the data collected, they do illustrate the relative differences in the amount of N fertilizer needed to achieve maximum leaf N values.

In 2000, differences in wheat leaf N content following soybean and grain sorghum also increased as applied N increased, with leaf N content after grain sorghum being greater. The leaf N content response to applied N was linear, rather than quadratic as in 1998 and 1999. Studies in 1995 and 1983 reported increased leaf N content with increasing applied N rates. Both reported higher leaf N content following soybean than grain sorghum, as did our result in two of the three years of the study (1998 and 1999).

Grain N was only influenced by applied N and increased as applied N rates increased all three years. In 1998 and 2000, grain N increased in a quadratic manner as applied N increased, whereas in 1999, the response was linear. In all three years, the applied N rate required to maximize grain N was greater than the N rate required to optimize grain yields. Several studies report increased grain N as applied N increased and a study in 1998 also reported higher N rates required to optimize grain N than N rates required to maximize grain yield.

CONCLUSIONS

No-till planting winter wheat immediately after summer crops such as soybean and grain sorghum requires different management practices for each previous crop. Seeding rates of ≥ 134 kg ha^{-1} were required to maximize grain yields, regardless of the previous crop. This is approximately 35 kg ha^{-1} higher than the recommended seeding rate for continuous wheat. Previous crop influenced N management, with wheat following grain sorghum requiring approximately 21 kg ha^{-1} more N fertilizer to maximize yields than wheat following soybean. The higher N requirement following grain sorghum was attributed to the higher residue levels produced by grain sorghum and greater N immobilization by the residue. However, allelopathy cannot be completely dismissed. Leaf and grain N levels were affected by applied N fertilizer rates throughout the study, with tissue N levels increasing with increasing N rates. Previous crop affected leaf N content in two of the three years, but the results were inconsistent. These results suggest that when winter wheat is planted immediately after summer crop harvest, seeding rates should exceed 134 kg ha^{-1} and N rates should be increased an additional 24 kg ha^{-1} following grain sorghum compared with N rates used following soybean.

Editor's note: *Content was adapted from the paper "Seeding and Nitrogen Rates Required to Optimize Winter Wheat Yields following Grain Sorghum and Soybean," which was published in Agronomy Journal, Vol. 95, March-April 2003, and is courtesy of S.A. Staggenborg, D.A. Whitney, D.J. Fjell and J.P. Shroyer.*

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Seeding and Nitrogen Rates Required to Optimize Winter Wheat Yields Following Grain Sorghum and Soybean

December Self-Study Examination

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1. Including winter wheat in crop rotations with summer crops:

[ ] a. increases the yield of summer crops.
[ ] b. encourages summer annual and perennial weeds.
[ ] c. increases the incidences of residue-borne fungal diseases.
[ ] d. is an excellent source of residue cover for reduced-tillage systems.

2. When following a summer crop, harvest often delays wheat planting through early November, suggesting:

[ ] a. the need for more efficient harvesting techniques.
[ ] b. the need for a winter wheat with a later planting window.
[ ] c. that higher seeding rates are needed to maximize yields.
[ ] d. winter wheat may not be a suitable rotation.

3. Wheat yields may be influenced by factors such as:

[ ] a. soil water content.
[ ] b. soil structure.
[ ] c. field microclimates.
[ ] d. P management.

4. Increased residue levels of grain sorghum compared with soybean have the potential to decrease N availability to the subsequent wheat crop through:

[ ] a. N immobilization.
[ ] b. mineralization.
[ ] c. leaching.
[ ] d. denitrification.

5. Soil type at the study location is Reading:

[ ] a. loam.
[ ] b. clay loam.
[ ] c. silt loam.
[ ] d. sandy loam.

6.Soil test results indicated that:

[ ] a. soil pH was out of the optimum range.
[ ] b. P fertilizer was needed.
[ ] c. soil pH, P and K were within optimum ranges.
[ ] d. K fertilizer was needed.

7. To reach maximum yields regardless of previous crops, seeding rates of:

[ ] a. 125 kg/ha (111 lb/A) were needed to reach maximum yields.
[ ] b. 134 kg/ha (119 lb/A) were needed to reach maximum yields.
[ ] c. 140 kg/ha (125 lb/A) were needed to reach maximum yields.
[ ] d. 145 kg/ha (129 lb/A) were needed to reach maximum yields.

8. To maximize yields, seeding rates of:

[ ] a. 110 – 160 kg/ha (98 – 143 lb/A) were needed.
[ ] b. 120 – 170 kg/ha (106 – 151 lb/A) were needed.
[ ] c. 130 – 180 kg/ha (116 – 160 lb/A) were needed.
[ ] d. 140 – 190 kg/ha (125 – 169 lb/A) were needed.

Over

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9. In leaf and grain, nitrogen application rates:

[ ] a. consistently increased N content.
[ ] b. consistently decreased N content.
[ ] c. could not be determined.
[ ] d. were the same for grain sorghum and soybeans.

10. Wheat following grain sorghum required approximately:

[ ] a. 15 kg/ha (13 lb/A) more N fertilizer to maximize yields than wheat following soybeans.
[ ] b. 21 kg/ha (19 lb/A) more N fertilizer to maximize yields than wheat following soybeans.
[ ] c. 26 kg/ha (23 lb/A) more N fertilizer to maximize yields than wheat following soybeans.
[ ] d. 30 kg/ha (27 lb/A) more N fertilizer to maximize yields than wheat following soybeans.

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