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Wheat Grain Yield and Protein Response to Nitrogen and Sulfur Rates

B. R. Jaenisch
Kansas State University, bjaenisch5@ksu.edu

R. P. Lollato
Kansas State University, lollato@ksu.edu

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Abstract

Winter wheat is often double-cropped after soybeans in no-tillage systems. The soybean crop removes large quantities of sulfur (S), which might unbalance ratios of nitrogen (N) to S for the following wheat crop. Our objective was to evaluate the responses of two wheat varieties to three N and four S rates representing a range of N:S ratios. The experiment was arranged as a complete factorial with a split-split-plot design. Variety was the whole-plot, N the sub-plot, and S the sub-sub plot. Nitrogen rates were 50, 100, and 150% of the recommended rate for 60 bu/a, which corresponded to ~45, 87, and 130 lb N/a. Sulfur rates were 0, 10, 20, and 40 lb S. The two locations (Manhattan and Belleville) were conducted under no-till and data were pooled for the statistical analysis. Nitrogen by S interactions occurred for grain yield and protein. The 45 lb N/a with 0, 10, or 40 lb S yielded similarly, while 20 lb S reduced yield by 4 bu/a. The 87 lb N/a increased yield by 9 bu/a from the 45 lb N/a with all S rates yielding similarly. The 130 lb N/a increased yield by 18 bu/a from the 45 lb N/a with 10 lb S resulting in the lowest yield, with 0 and 20 lb S yielding the highest. Zero and 40 lb S resulted in similar yields across all N rates. The 45 and 130 lb N/a with 10 lb S produced protein of 10.9% and 11.9%, respectively. However, 130 lb N/a with 0 or 10 lb S increased protein to 12.6–12.8%. This research will be continued for two more years at three locations per year to better explore the interactive effects of N, S, and variety.

Keywords

wheat, nitrogen, sulfur, yield, protein

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Cover Page Footnote

We thank Andrew Esser, Keith Thompson, and Dustin Ridder for helping us with project establishment, management, and harvest at the experiment fields. We also thank the Kansas Wheat Commission for the funding to allow us to conduct this research. We also acknowledge the Kansas State University Winter Wheat Production Program staff for their hard work and assistance in the project.

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Abstract

Winter wheat is often double-cropped after soybeans in no-tillage systems. The soybean crop removes large quantities of sulfur (S), which might unbalance ratios of nitrogen (N) to S for the following wheat crop. Our objective was to evaluate the responses of two wheat varieties to three N and four S rates representing a range of N:S ratios. The experiment was arranged as a complete factorial with a split-split-plot design. Variety was the whole-plot, N the sub-plot, and S the sub-sub plot. Nitrogen rates were 50, 100, and 150% of the recommended rate for 60 bu/a, which corresponded to ~45, 87, and 130 lb N/a. Sulfur rates were 0, 10, 20, and 40 lb S. The two locations (Manhattan and Belleville) were conducted under no-till and data were pooled for the statistical analysis. Nitrogen by S interactions occurred for grain yield and protein. The 45 lb N/a with 0, 10, or 40 lb S yielded similarly, while 20 lb S reduced yield by 4 bu/a. The 87 lb N/a increased yield by 9 bu/a from the 45 lb N/a with all S rates yielding similarly. The 130 lb N/a increased yield by 18 bu/a from the 45 lb N/a with 10 lb S resulting in the lowest yield, with 0 and 20 lb S yielding the highest. Zero and 40 lb S resulted in similar yields across all N rates. The 45 and 130 lb N/a with 10 lb S produced protein of 10.9% and 11.9%, respectively. However, 130 lb N/a with 0 or 10 lb S increased protein to 12.6–12.8%. This research will be continued for two more years at three locations per year to better explore the interactive effects of N, S, and variety.

Introduction

Sulfur plays many roles within the plant, from the synthesis of amino acids to formation of chlorophyll. Sulfur is supplied to plants through rainfall, soil organic matter and crop residue mineralization, or as part of organic or mineral fertilizers. Wheat takes up approximately 80% of the S before anthesis. Winter wheat planted after soybeans has become the preferred crop rotation in recent years for many producers in north-central Kansas. Due to the high removal of S by soybeans, lower organic matter mineralization in the spring, and the declining S deposition in the rainfall, symptoms of S deficiency are increasingly common in north-central Kansas. Requirements of S for wheat are generally low (80 bu/a crop removes 7 lb of S in the grain and another 15 lb of S in the straw). However, soybeans remove approximately 25 lb of S in the grain and stover in a 60 bu/a grain crop. Research is needed to determine the effects of S on wheat yield and grain quality in Kansas soils.

Proper N fertilization increases probability of higher tiller number and grain yield (Jaenisch et al., 2019; Lollato et al., 2019). Winter wheat is generally sink limited, and kernels per foot is a coarse regulator of increasing wheat grain yield. Potential kernels per meter are determined by Feekes 6 in the winter wheat growing season, and N deficiency at this time will result in decreased yield potential. Thus, matching N application with this critical growth stage is important for maximizing kernels per foot. Likewise, N concentration within the plant changes throughout the growing season according to biomass levels; therefore, N dilution curves help determine N deficiencies in crops. Research is needed to determine the optimal N concentration and N:S ratios in plant tissue to maximize grain yield and quality in Kansas.

Procedures

The experiment was established in the fall of 2017 at the Kansas State University North Central Experiment Field in Belleville (moderately well-drained Crete silt loam, 0–1% slopes) and Agronomy North Farm in Manhattan (Kahola silt loam, rarely flooded, 0–1% slopes). No-till has occurred for 11 and 6 years in Manhattan and Belleville, respectively. Both locations were grown under rainfed conditions and were chosen as no-till wheat, which is commonly sown into soybean stubble at these locations in Kansas.

Treatments included four S rates (0, 10, 20, and 40 lb S) and three N rates (50, 100, and 150% of K-State recommendations for a 60 bu/a yield) which were applied to two wheat varieties (SY Monument and LCS Mint) in a 2 × 3 × 4 (variety × N rate × S rate) complete factorial structure. The experiment was arranged in a split-split-plot design with four replications. The varieties SY Monument and LCS Mint were selected for their differences in N uptake and N use efficiency. Nitrogen was applied as urea ammonium nitrate (28-0-0) and S was applied as ammonium thiosulfate (12-0-0-26S) using a pressurized CO_2 back sprayer with a three-nozzle spray boom. The specific streamer nozzles (SJ3-02-VP - SJ3-05-VP) varied due to the change in N and S rates. The N and S were applied in combination for specific treatments and application occurred at Feekes 4.

Wheat was sown no-till into soybean stubble directly after harvest with a Great Plains 506 no-till drill (7 rows spaced at 7.5 inches) with plot dimensions of 4.375-ft wide × 30-ft long at all locations. Seed was treated with 5 oz Sativa IMF Max across the whole study so fungicide or insecticide was not a limiting factor. Likewise, both varieties were sown at 1.5 million seeds due to the later planting date.

In 2017, soil samples were taken at sowing at each location for soil nutrient analysis. Samples were taken by a hand push probe at two depths, 0–6 and 6–24 in., and a total of 15 cores were pulled per depth and combined to represent a composed sample at each location. Weeds were controlled to ensure they were not limiting factors by a pre- and post-emergence herbicide application. Insect pressure was not experienced in 2018.

Results

Weather

The 2017–18 wheat growing season can be classified as a cold and dry winter, to a cold and dry early spring, to a hot and dry late spring/early summer. The drought and cool temperatures kept the wheat crop dormant until late April. Likewise, the reduced rainfall in the spring reduced spring tillering and fertilizer incorporation, thus decreasing spikes per foot. For the season, 60 and 49% of the annual rainfall was received for Belleville and Manhattan, respectively. Temperatures were above normal for May and June, accelerating crop development and decreasing the grain filling period. Wheat yields ranged from 64–76 bu/a in Belleville and Manhattan.

Wheat Grain Yield

Across locations, increasing N rate increased wheat grain yield (Figure 1) and the N by S rate interaction was measured. The 45 lb N/a with 0, 10, or 40 lb S resulted in the highest grain yield of 67 bu/a and the addition of 20 lb S decreased yield to 64 bu/a. The 87 lb N/a and all S rates yielded similarly to 73 bu/a. At the highest N rate (137 lb N/a), 0 or 20 lb N/a resulted in the highest grain yield of 79 bu/a; however, 10 or 40 lb S/a reduced grain yield to 76 bu/a.

Grain Protein

Following the same trend as grain yield, an increasing N rate increased grain protein. Likewise, the S rate also increased protein but did not follow a linear trend as compared to N rate (Figure 2). The N by S rate interaction for protein concentration was measured. The 45 lb N/a with 10 lb S resulted in the highest protein concentration of 10.9%, and the addition of 0, 20, or 40 lb S decreased protein concentration to 10.6%, perhaps as a dilution effect from slightly higher grain yield. The 87 lb N/a with 10 lb S resulted in the highest protein concentration of 11.9%, and the addition of 0, 20, or 40 lb S decreased protein concentration to 11.6%. The highest N rate of 137 lb N/a with 0, 10, or 40 lb S resulted in the highest protein concentration of 12.6-12.8%; however, 20 lb S reduced protein concentration to 12.5%, again, perhaps due to increased yield in this treatment.

Preliminary Conclusions

Due to limitations of sites and years, it is difficult to make strong conclusions. However, with significant N by S rate interactions for both grain yield and protein concentration, the preliminary data suggest that a balanced nutrition is needed for both nutrients to maximize yield and protein. One existing trend was that increasing N increased grain yield and protein concentration, suggesting that N rate could have been further increased to maximize yield in the studied sites. However, Staggenborg et al. (2003) measured grain yield to plateau at 75 lb N/a in wheat planted after summer crops. Therefore, this warrants additional research to understand whether further increasing N is economically viable, and to better characterize N × S × variety interactions.

Acknowledgments

We thank Andrew Esser, Keith Thompson, and Dustin Ridder for helping us with project establishment, management, and harvest at the experiment fields. We also thank the Kansas Wheat Commission for the funding to allow us to conduct this research. We also acknowledge the Kansas State University Winter Wheat Production Program staff for their hard work and assistance in the project.

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Table 1. Treatment description for the trials established at Manhattan and Belleville, KS, in 2018

Winter wheat varieties	Nitrogen rate, lb N/a	Sulfur rate, lb S/a
SY Monument	45	0
LCS Mint	87	10
	130	20
		40

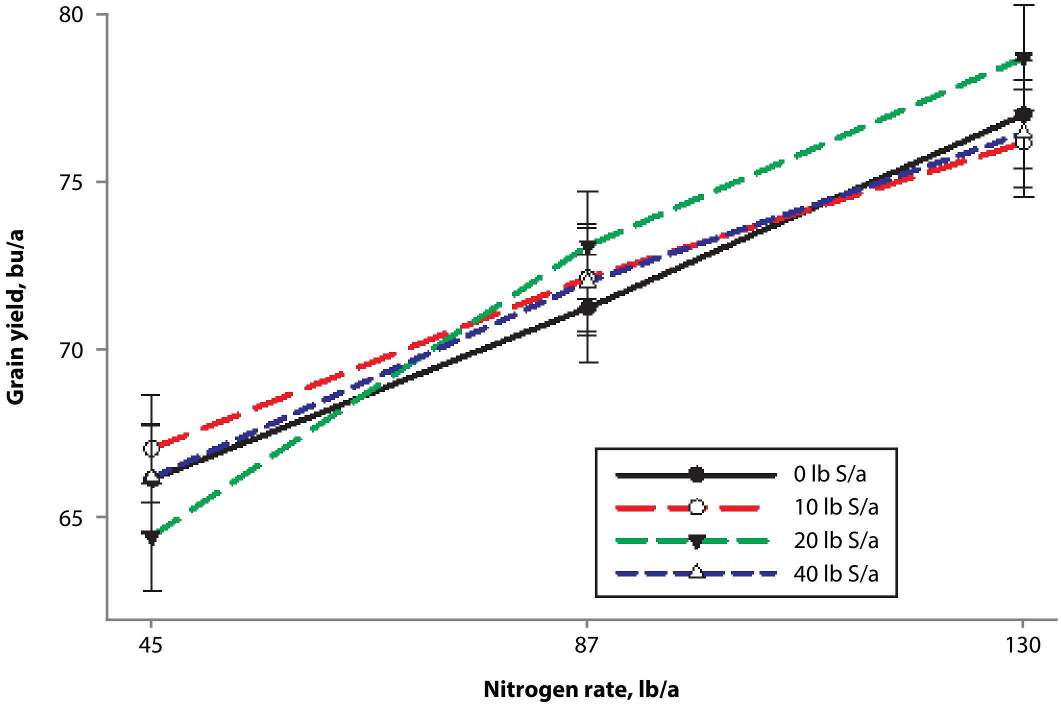

Figure 1. Average wheat grain yield (bu/a) response to three N rates (45, 87, and 130 lb N/a) and four S rates (0, 10, 20, and 40 lb S/a) across both winter wheat varieties for combined locations of Belleville and Manhattan, KS, in 2018.

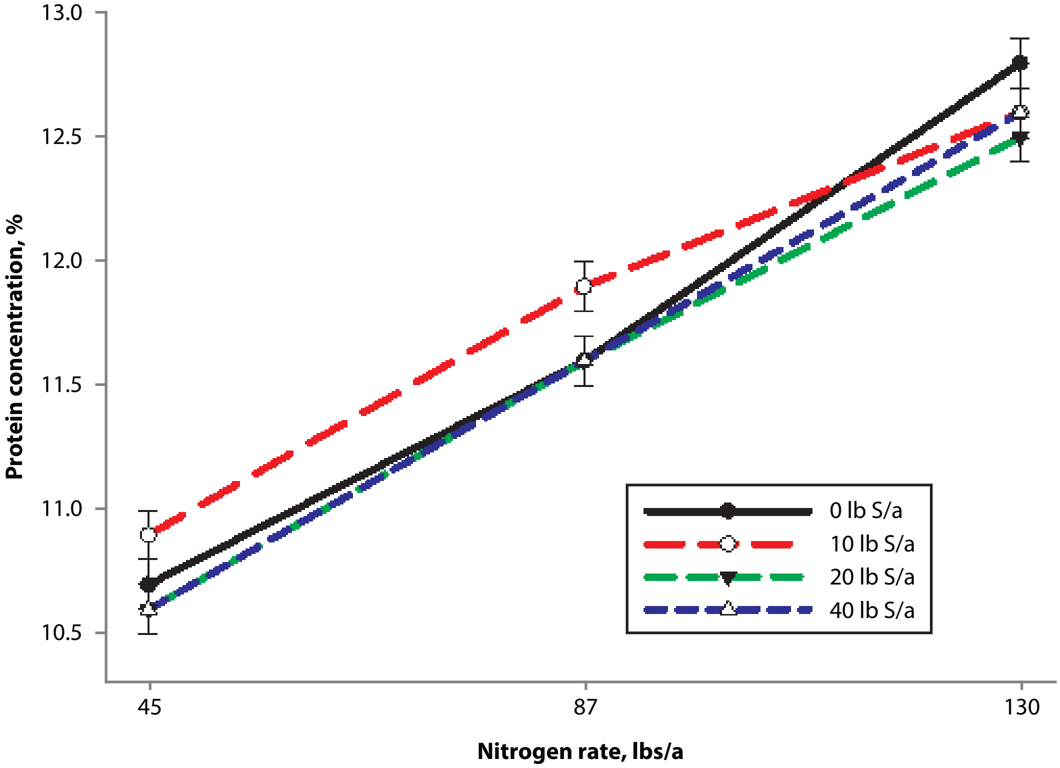

Figure 2. Average wheat grain protein concentration (%) response three N rates (45, 87, and 130 lb N/a) and four S rates (0, 10, 20, and 40 lb S/a) across both winter wheat varieties for combined locations of Belleville and Manhattan, KS, in 2018.