Nitrogen and Sulfur Fertilization for Improved Bread Wheat Quality in Humid Environments

By W.E. Thomason, C.A. Griffey, and S.B. Phillips

Bread wheat cultivars with high grain protein provide a higher value market for growers. However, limited knowledge of fertility management strategies exists for these types of cultivars for producers in the Mid-Atlantic region. We evaluated three bread wheat cultivars over nine site years in Virginia and found that application of 30 to 40 lb N/A between Zadoks growth stage (GS) 45 and 54 likely will result in consistent increases in grain protein concentration. Availability of S and a desirable N:S ratio in tissue is critical when considering the positive interaction between N and S on grain protein quantity and quality.

The wheat milling capacity in the Mid-Atlantic region of the U.S. is nearly 3.2 million tons of grain per year (World-grain.com, 2006). Most of this grain is purchased from other wheat growing areas, because relatively high grain protein levels are needed for good quality bread production and the soft red winter wheat (SRWW) cultivars grown in the Mid-Atlantic are typically lower in grain protein than the hard wheat grown in other regions. Because a higher value market exists for bread wheat, producers are seeking adapted cultivars and the agronomic techniques needed to grow good quality bread wheat in the humid, high rainfall Mid-Atlantic region.

The ability to increase grain protein concentration using late-season foliar N application has been demonstrated in bread wheat in other regions and has only recently been examined in more humid areas (Kratochvil et al., 2005). However, increased grain protein concentration does not always result in increased bread making quality because of the imbalance in N and S content as protein level increases.

The objectives of this study were to evaluate the effect of late-season foliar N and S applications on bread wheat yield and grain protein and to determine the optimum rate and timing for late-season N applications for bread wheat production in the humid Mid-Atlantic region.

Methods

Field experiments were conducted during the 2001 crop season in Virginia at Mt. Holly on a State fine sandy loam soil (Fine loamy, Typic Hapludult) and from 2002 to 2003 at Warsaw on a Kempsville loam (Fine-loamy, Typic Hapludult) and at Painter on a Bojac sandy loam soil (Coarse-loamy, Typic Hapludult). A split-plot design with eight replications was used to evaluate late-season N rates and timing. Sulfur, the main plot factor, was applied at a rate of 30 lb S/A to four of the eight replications at Zadoks GS 30 (Zadoks et al., 1974) in each year.

At Painter and Mt. Holly, treatments were applied only to the French bread wheat cultivar Soissons, a semi-hard wheat with moderate protein content. In the studies at Warsaw, two additional wheat cultivars…Heyne and Renwood 3260…were planted and evaluated along with Soissons. Heyne is a hard white winter wheat cultivar with high protein content and Renwood 3260 is a high protein, SRWW.

Spring N was split-applied to the entire test area at GS 25 (40 to 55 lb N/A) and again at GS 30 (45 to 75 lb N/A). Late-season foliar N treatments consisted of 0, 20, 30, and 40 lb N/A applied as dissolved urea solution at 45 gal/A at GS 37, GS 45, or GS 54. Plots were harvested with a small plot combine and grain sub-samples were analyzed for protein content.

Harvesting wheat plots in Virginia.

Results

Grain Yield Grain yields of all three cultivars varied from 59 to 130 bu/A over site years. However, a consistent relationship between late-season N application and grain yield was not observed. This lack of yield response to late-season N where N was not a yield-limiting factor is similar to that reported by Varga and Svecnjak (2006). Application of late-season N up to 40 lb N/A also did not decrease grain yield; thus, late-season N applications can be made to enhance grain protein concentration without a detrimental effect on yield.

Sulfur applied at 30 lb S/A at GS 30 had no effect on grain yield regardless of N treatment for any of the cultivars. Plant S levels at each site year were adequate, which may explain the lack of yield response. The ratio of N:S in plant tissue was generally not affected by S fertilization, which is similar to results reported by other researchers.

Grain Protein Averaged over years and locations, grain protein concentration of Soissons was not altered significantly with the addition of 30 lb S/A at GS 30 without late-season N. However, grain protein concentration increased an average of 0.2% when N was applied in conjunction with S (**Figure 1**). Based on the curvilinear response observed when both N and S were applied, a greater incremental advantage of S was

Abbreviations and notes for this article: N = nitrogen; S = sulfur.

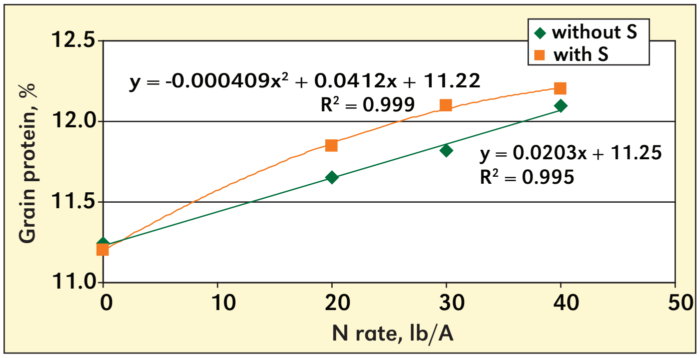

Figure 1. Mean grain protein response of Soissons wheat to late-season N with and without S applied at GS 30, at Mt. Holly, Warsaw, and Painter, Virginia, 2001-2003.

observed at lower N rates (20 and 30 lb/A). Late-season N alone increased grain protein concentration, but to a lesser extent than when the same N rate was applied to plots receiving S. This response agrees with the findings of Hocking (1994), who reported that remobilization of S from tissue to spring wheat grain was much lower than for N, indicating a continued need for S supply from outside the plant. Kratochvil et al. (2005) also reported that late season N (GS 37-50) was necessary to achieve the highest grain protein.

A significant linear increase in wheat protein concentration with increasing N rate was obtained in all site years (**Table 1**). This effect was also documented in prior studies with hard red winter wheat in the Mid-Atlantic region (Kratochvil et al., 2005). Averaged across site years, Soissons wheat protein concentration was 10.5, 11.1, 11.3, and 11.5% for the 0, 20, 30, and 40 lb N/A treatments, respectively (**Table 1**). Increases in grain protein concentration with application of 40 lb N/A versus the control treatment at Warsaw in 2002 and 2003 varied from 0.75 to 1.38% for Heyne, 0.83 to 0.85% for Soissons, and 0.43 to 0.70% for Renwood 3260. This variation indicates that the inherent genetic potential and composition of a given cultivar has a major impact on the magnitude and biological significance of the effects that a fertility management regime likely will have on grain, flour, and end-use quality characteristics. In five of nine comparisons, higher wheat protein concentrations were obtained with N application at GS 54 (**Table 1**).

Grain samples were analyzed for protein content.

Conclusions

Late-season foliar N applications up to 40 lb N/A did not result in consistent increases in wheat grain yield among the three cultivars, nor did they reduce grain yields of any cultivar. Similarly, application of 30 lb S/A at GS 30 did not affect grain yield of any cultivar. In contrast to yield, grain protein concentration of all three cultivars was consistently increased with late-season foliar N applications up to 30 to 40 lb N/A. Application of S to Soissons wheat in experiments conducted at Mt. Holly and Painter resulted in a significant increase in grain protein concentration when applied in conjunction with late-season N. Growth stage (45 versus 54) of late-season N application generally did not differ regarding the effect on grain protein, which affords producers a broader window of opportunity for late-season N applications.

In summary, application of 30 to 40 lb N/A between GS 45 and 54 to winter bread wheat cultivars grown in humid, high rainfall areas likely will result in consistent increases in grain protein concentration. Availability of S and a desirable N:S ratio in tissue is critical when considering the positive interaction between N and S on grain protein quantity and quality. BC

Dr. Thomason is Assistant Professor and Extension Grains Specialist, Department of Crop and Soil Environmental Sciences, Virginia Tech, e-mail: wthomaso@vt.edu. Dr. Griffey is Professor of Small Grain Genetics and Breeding, Department of Crop and Soil Environmental Sciences, Virginia Tech. Dr. Phillips is Director, Southeast Region, IPNI.

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Additional details on this study can be found in: Thomason, W.E., et al. 2007. Cereal Chem. 84(5):450-462.

Table 1. Wheat grain protein (%) following late-season foliar N applications.

	Mt. Holly 2002	Warsaw 2002	Warsaw 2003	Painter 2002	Painter 2003	Warsaw 2002	Warsaw 2003	Warsaw 2002	Warsaw 2003
	------ Soissons ------					----- Heyne -----		-- Renwood 3260 --	
N rate									
0	10.3	11.7	11.3	8.9	10.4	13.1	10.6	13.3	11.8
20	11.0	12.1	11.9	9.3	11.1	13.7	11.6	13.6	12.1
30	11.4	12.3	11.9	9.6	11.3	13.9	11.8	13.8	12.2
40	—	12.5	12.1	9.8	11.5	13.9	11.9	13.7	12.5
Growth stage[1]									
45	10.9	12.3	11.9	9.6	11.3	14.0	11.7	13.5	12.2
54	11.4	12.2	12.1	9.6	11.3	13.7	11.9	13.8	12.3
Contrasts									
N linear	*[2]	*	*	*	*	*	*	*	*
GS	*	*	*	ns[3]	ns	*	*	*	*

[1]Zadoks et al. (1974), [2]significant at $p<0.05$, [3]not significant.