

Optimum Use of Nitrogen Fertilizers to Maximize Spring Wheat Grain Yield and Protein Concentration

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Research Questions

The objective of this project was to identify optimum nitrogen (N) fertilizer management practices that can maximize hard red spring wheat (HRSW) grain yield and protein concentration; and subsequently net economical profits to producers.

Results

In this trial, we wanted to determine the effects of applying 30 lbs. N ac⁻¹ as a foliar application at either the tiller or immediately after the anthesis growth stages. This N would be in addition to the pre-plant N applied. Optimum N was determined as 150 lbs. N ac⁻¹ (soil residual nitrate-N plus 127 lbs. fertilizer N). To test whether any effect of the foliar N was due to its application time or the additional 30 lbs. N, an additional treatment was established that supplied optimal N plus 30 lbs. N ac⁻¹ applied pre-plant with no additional foliar N. There was no difference in grain yield, grain protein, or test weight between the optimal pre-plant N and the optimal plus 30 lbs. N pre-plant N treatments. This confirmed our selection of the optimal N rate and allows us to focus our attention on the foliar application of N. Subsequent statistical analyses and discussion dropped the optimal plus 30 lbs. pre-plant N treatment.

Applying fertilizer N did increase grain yield and grain protein compared to the 0 N control (Table 1). However, there were no significant differences in these variables whether pre-plant fertilizer N was supplied as PCU or urea (Table 1). Grain yields were 44, 72, and 73 bu ac⁻¹ in the control, PCU and urea treatments, respectively. Grain proteins were 12.2, 13.3 and 13.1% in the control, PCU, and urea treatments, respectively. Grain test weight was not affected by the source of fertilizer N, but the application of fertilizer N increased test weight relative to the 0 N control (Table 1).

As originally designed, this trial was to include a normal spring time applied pre-plant fertilizer N application with normal planting and a later planting. An additional set of treatments included late season fertilizer application and planting. This was to replicate the potential of weather conditions delaying planting after the fertilizer was applied or perhaps delaying both fertilization and planting. Unfortunately in 2014, everything was delayed due to weather so the normal planting in this trial was actually May 21, which would typically have been close to our late planting

and fertilizing target. So, instead of waiting 4 weeks for the delayed, or late, planting and fertilizing, as originally specified, the late planting and fertilization happened on June 9.

Plant stand count was measured at the three leaf stage, but no significant differences were found among the treatments (Table 1). Whole plant tissue sampling was conducted at soft dough stage to determine if any of the treatments impacted the tissue biomass accumulation or tissue N concentration. Tissue biomass accumulation significantly decreased when planting was delayed whether fertilization was delayed or not compared to normal planting and N fertilization (Fig. 1A). However, we found normal planting and N fertilization had significantly lower tissue N concentration compared to late planting and fertilization treatments (Fig. 1B).

Delayed planting, with or without delayed N fertilization, significantly reduced grain yield and grain test weight, but resulted in significantly greater grain protein (Fig 1C, 1D and 1E). Most of the effects were caused by delayed planting, but delayed fertilization did have some affect (comparisons of treatment 1 and 2 in Fig 1). It suggest that differences found in tissue biomass accumulation and N accumulation at soft dough stage due to delayed planting and delayed N fertilization translated into differences in grain yield and grain protein concentration. Previous research found that cold, dry early season conditions resulted in lower grain yields and higher grain protein when PCU was used as the N source compared to urea (Farmaha and Sims, 2013a, 2013b). One of the questions from those previous trials was whether we would see a similar difference in N sources if the PCU was applied a few weeks prior to when the wheat was planted. In 2014, the wet early season conditions that delayed both fertilizer application and planting apparently neutralized any potential differences between these two N sources.

Thirty pounds of N were applied via foliar applications at tiller or immediately after anthesis. There were no interactions between foliar N or pre-plant N source (Table 1). There was no significant effect of foliar application on stand count and tissue biomass accumulation but it did increase tissue N concentration measured at soft dough stage (Table 1). Timing of foliar application did not make a difference in tissue N concentration (Fig. 2A). Previous research found that 30 lbs. N Ac⁻¹ at tillering increased grain yield and at anthesis increased grain protein (Woolfolk et al., 2002; Bly and Woodard, 2003). In this study, grain

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yield was not affected by an application of N at the tiller growth stage (Fig 2B). There was a slight, but significant decrease, in grain yield when N was applied at the anthesis growth stage (Fig 2B). It is suspected that part of this grain yield decline was caused by burning of the upper canopy leaves caused by the foliar N spray. Though the spray was applied during the cooler part of the day, those particular days were quite warm which can enhance leaf burning. Compared to only pre-plant N, foliar N applied at both tiller and anthesis increased grain protein, with the greatest increase occurring with the anthesis application (Fig 2C). Similar results with foliar application rate and timing on hard red spring wheat were observed in South Dakota by Bly and Woodard (2003). There was, however, a slight decline in grain test weight with foliar N application (Fig 2D).

Material and Methods

This experiment was conducted in 2014 at Northwest Research and Outreach Center (NWROC), Crookston, MN. Treatments included two N fertilizer sources- PCU (polymer coated urea) and urea; three pre-plant N application and planting combinations (normal fertilization and normal planting, normal fertilization and late planting, and late fertilization and late planting), and three foliar N applications (none, tillering, and anthesis). Pre-plant N was 127 lbs. N Ac⁻¹ plus soil residual nitrate-N, which was considered an optimal N rate for this location. Foliar N treatments added an additional 30 lbs. N Ac⁻¹ at either tillering or anthesis. Two additional treatments were added, a 0 N control and an optimal N plus 30 lbs. N Ac⁻¹ applied pre-plant. In 2014, prolonged wet spring conditions delayed N fertilization and planting. Normal N fertilization and planting was done on 05/21/2014 and delayed N fertilization and planting was done on 06/09/2014. Albany, a high-yielding and low protein cultivar was seeded on 36 plots on 05/21/2014 and on 72 plots at 06/09/2014. Each plot contained 10 seeded rows spaced 6 inches apart and measured 5 ft. wide by 18 ft. in length. Fertilizers were hand broadcasted and incorporated in the soil to a 10 cm depth using a field cultivator. Whole plant samples were collected from each plot (four rows, 3ft. in length) at soft dough growth stage to measure dry biomass accumulation and N concentration. At physiological maturity, plots were harvested using a small plot combine to measure grain yield and protein concentration. Plots seeded earlier were harvested on 08/26/2014 and seeded later were harvested on 09/17/2014.

Economic Benefit to a Typical 500 Acre Wheat Enterprise

This study suggested no yield penalty was realized when PCU was used as the N source when the spring conditions were sufficiently moist that PCU-N was released to the soil. Of course, most growers would not use PCU as the sole source of N because of the risk in yield lag if soil conditions are drier and the extra expense of PCU-N. But, this study did confirm that foliar applications of N can be beneficial to increasing grain protein concentration. Whether it is economically beneficial will be determined by the potential low protein discounts and what the yield potential of the crop is. Wiersma and Sims (2014) have developed a decision making tool comparing N costs and protein discounts to help growers make that decision. Unfortunately there is yet a tool developed to diagnose the potential grain protein in time for a foliar N application to be beneficial.

Related Research

The current experiment addresses questions raised based on the findings from our previous experiments (Farmaha and Sims, 2012a and 2012b). We had two separate experiments in 2013 that showed that delayed planting due to the wet spring conditions can significantly reduce grain yield but the amount of loss depends upon how late the crop was planted. 2013 was an abnormal growing season so data from this year alone was not sufficient to comment whether the effect of treatments on grain yield and protein concentration was stand alone or was confounded with the environmental issues. Therefore, the current experiment was planned but with few modifications in the treatments.

Recommended Future Research

This experiment should be conducted for one more year and may be under different environments.

Appendix

Table 1. Significance of *F*-values of fixed effects on stand count, whole plant tissue biomass accumulation, tissue N concentration, wheat grain yield, protein concentration, and grain test weight measured at physiological maturity (Zadok's scale 92).

Source of variation	Stand count	Tissue biomass accumulation*	Tissue N concentration	Grain yield	Protein concentration	Test weight
	<i>P</i> value					
Fert_Planting	0.5569	<0.0001†	<0.0001	<0.0001	<0.0001	<0.0001
NSource	0.3900	0.0982	0.1814	0.7262	0.4298	0.9888
Fert_Planting x NSource	0.1747	0.9685	0.5335	0.8261	0.2838	0.3794
Foliar	0.6742	0.2655	<0.0001	0.0353	<0.0001	0.0007
Fert_Planting x Foliar	0.1870	0.3354	0.0203	0.0939	0.3104	0.1603
NSource x Foliar	0.9954	0.7598	0.4027	0.5949	0.5081	0.5105
Fert_Planting x NSource x Foliar	0.5499	0.6649	0.8482	0.7382	0.6720	0.6236

* Samples to measure tissue biomass accumulation and nitrogen concentration were collected at soft dough stage.
 † Value less than 0.05 indicates that effect is significant.

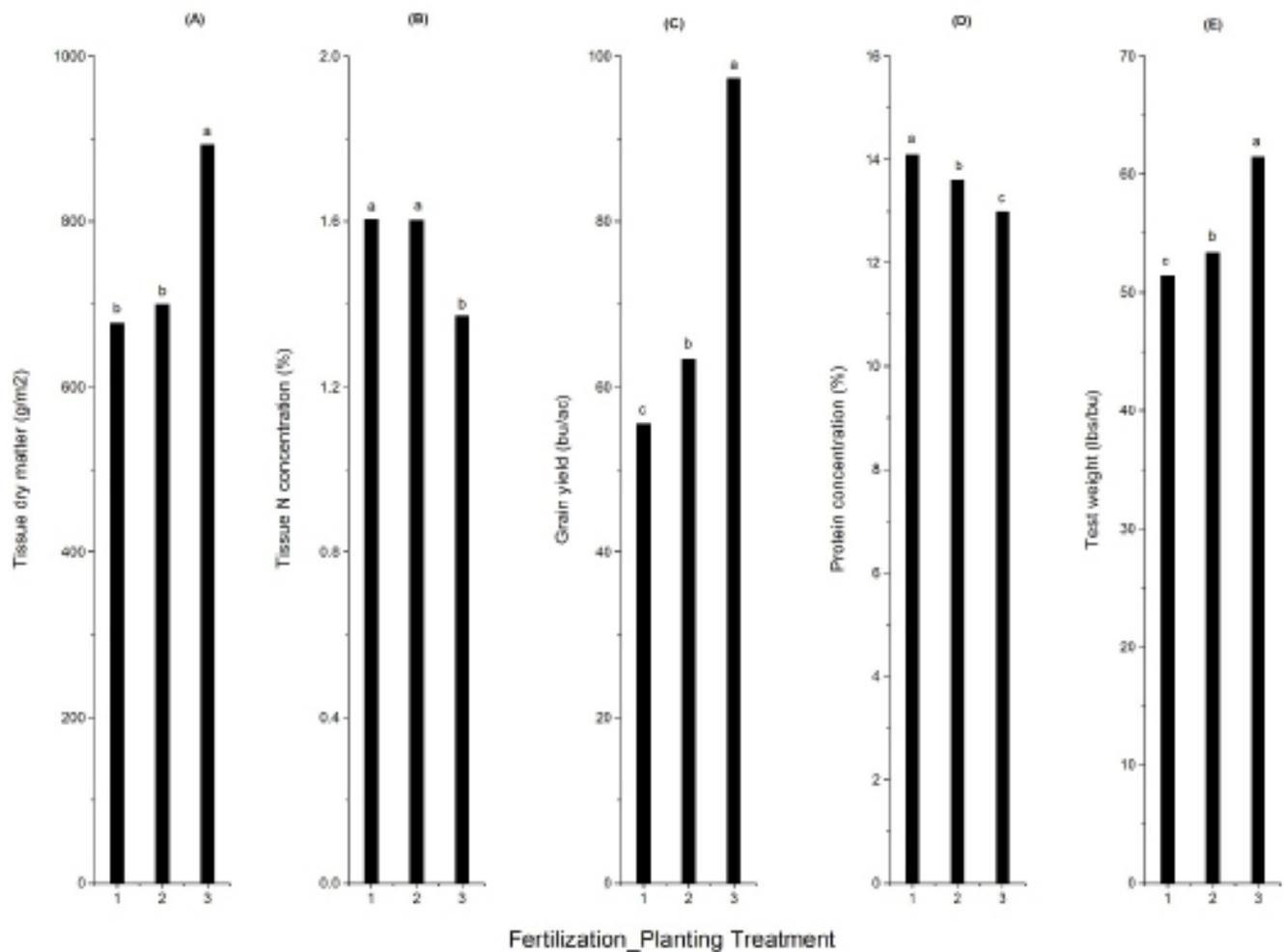


Fig. 1. Effect of N fertilizer application time and planting time on soft dough tissue dry matter accumulation (A) and tissue N concentration (B), grain yield (C), protein concentration (D), and grain test weight (E). Same lowercase letters indicate no significant difference fertilization_planting treatments for the given variable. Treatment 1: Late planting, Late fertilization; 2: Late planting, normal fertilization; 3: Normal planting, normal fertilization. Normal N fertilizer application and planting was done on 5/21/2014 and late N fertilizer application and planting was done on 6/09/2014.

Appendix (continued)

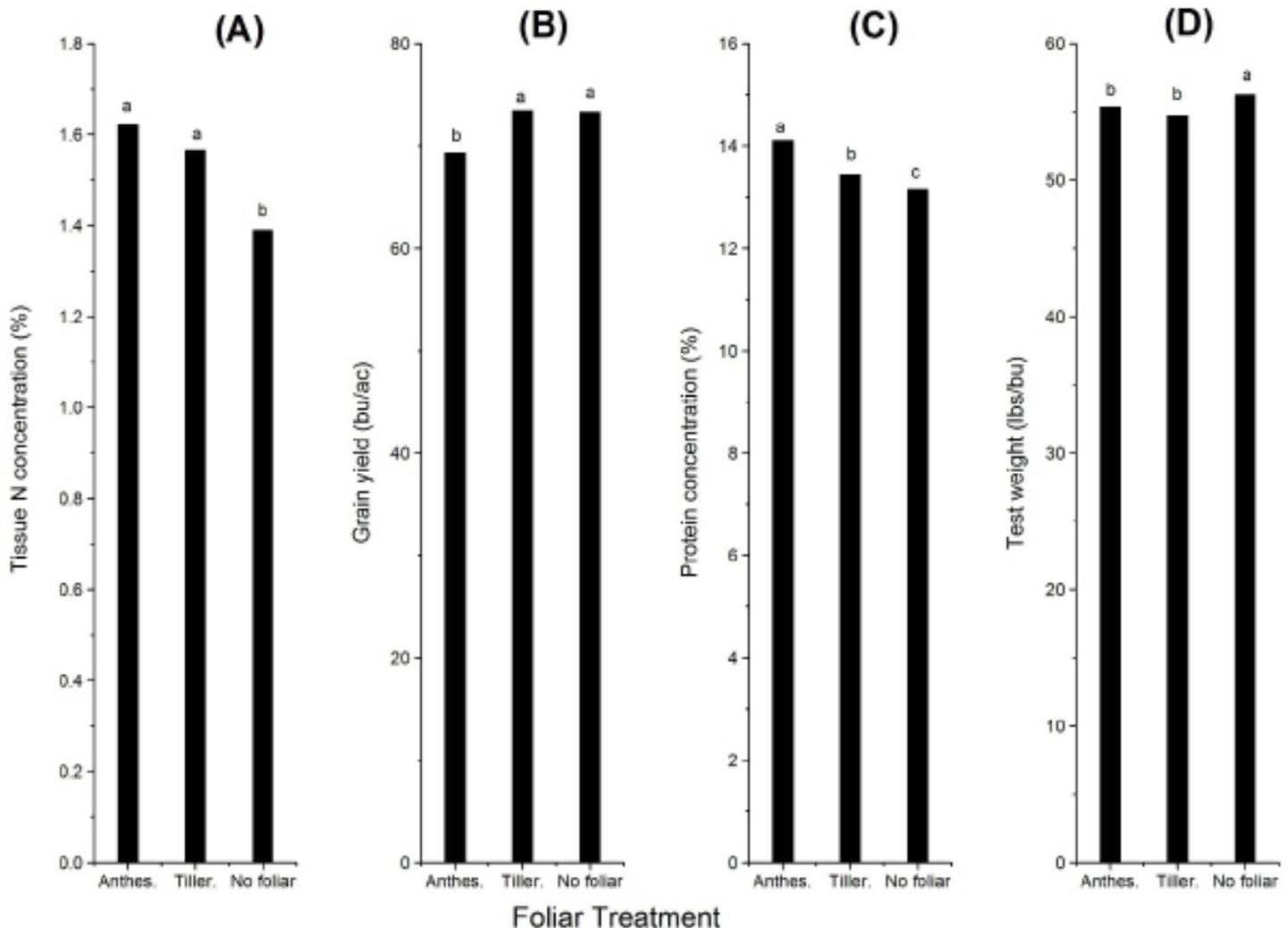


Fig. 2. Effect of nitrogen foliar application (30 lbs N/ac) on soft dough tissue N concentration (A), grain yield (B), protein concentration (C), and grain test weight (D). Same lowercase letters indicate no significant difference foliar treatments for the given variable. Anth., Till., and No fol. are foliar N application at the time of anthesis (Zadok's scale 60), foliar N application at the time of tillering (Zadok's scale 23), and no foliar application, respectively.

Publications

- Bly, A.G., and H.J. Woodard. 2003. Foliar nitrogen application timing influence on grain yield and protein concentration of hard red winter and spring wheat. *Agron. J.* 95:335–338.
- Farmaha, B.S., and A.L. Sims. 2013a. Yield and protein response of wheat cultivars to polymer-coated urea and urea. *Agron. J.* 105:229–236. Erratum (2013) 105:555–555.
- Farmaha, B.S., and A.L. Sims. 2013b. The influence of PCU and urea fertilizer mixtures on spring wheat protein concentrations and economic returns. *Agron. J.* 105:1328–1334.
- Wiersma, J. and A.L. Sims. 2014. Late season applications of nitrogen in spring wheat. *Minnesota Crop News*. July 3, 2014. Minnesota Extension, U of M, St. Paul, Minnesota.
- Woolfolk, C.W., W.R. Raun, G.V. Johnson, W.E. Thoma son, R.W. Mullen, K.J. Wynn, and K.W. Freeman. 2002. Influence of late-season foliar nitrogen applications on yield and grain nitrogen in winter wheat. *Agron. J.* 94:429–434.