Increasing yield and grain protein content are prime concerns for wheat growers. Management practices that supply adequate nitrogen (N) during the early vegetative stage boost hard red spring wheat (HRSW) yields while sustaining adequate N supply at the late vegetative or later growing stages increases HRSW grain protein content. Hard red spring wheat N use efficiency is the function of N losses due to denitrification, leaching, and volatilization. Supplying adequate sulfur shares a synergistic relationship with N in promoting grain protein content. The main objective of this study was to assess the impact of fertilizer source and application rate on HRSW yields and protein content in the Red River Valley region of North Dakota and Minnesota.

Field trials were conducted on poorly drained Beardean silty clay loam soil during the growing season near Prosper, ND in 2013 and near Glyndon, MN in 2014. A randomized completely block design (RCBD) with four replicates and a factorial arrangement of fertilizer source and application rates was used. Individual treatment plots measured 10 ft wide and 30 ft long. Four fertilizer sources used in these studies were: (1) Agrotain-treated urea (stabilized with urease inhibitor NBPT), (2) Amidas (a homogeneous blend of urea and ammonium sulfate), (3) a physical blend of urea (80%) plus ammonium sulfate (20%), and (4) urea alone. Each of these fertilizer or fertilizer combinations were applied at four rates (70, 100, 130, and 150 lb/ac) in 2013, and two rates (120 and 150 lb/ac) in 2014. Control plots (no N addition) were also included in each growing season to see the response of HRSW to N fertilization. Basic physical and chemical properties of the soil under study were presented in Table 1.

Fertilizer treatments were broadcast-applied and incorporated, and HRSW variety Glenn was planted on May 20, 2013 and May 16, 2014, respectively, at the seeding rate...
of 2 bu/ac using an 8-inch-wide, small-plot-sized grain drill. At physiological maturity, the middle five rows of each plot were harvested using the small-plot combine harvester on August 28, 2013 and August 25, 2014, respectively. Wheat grains were dried at 140°F for three days and adjusted to 14% moisture level before recording grain yield. Grain protein content was analyzed using Infratec 1241 Grain Analyzer (FOSS analytical AB, Hongan, Sweden).

Statistical analyses were performed using PROC-GLM procedure for RCBD with factorial arrangement in SAS 9.3 (SAS Institute Inc, Cary NC). Comparisons of means were conducted at \( P \leq 0.05 \) using Fisher’s least significance difference method.

**Grain yields**

Wheat grain yields, across fertilizer sources and application rates, averaged 59.1 bu/ac in Prosper and 50.4 bu/ac in Glyndon during the years 2013 and 2014, respectively. Similarly, the average grain yields in the control plots (no N addition) were 47.5 bu/ac in Prosper and 42.2 bu/ac in Glyndon. Despite having a similar soil type at both sites, higher grain yield in both fertilized and control plots at Prosper was due to relatively high rainfall in May and June followed by warm and dry conditions in July and August in 2013 (Table 2). Adequate precipitation and cooler temperatures during the early growing season facilitated better stand development, prolonged vegetative growth, enhanced grain filling, and increased number of grains per spikelet, thereby increasing yields (Otteson et al., 2007; Farmaha and Sims, 2013). Moreover, it also triggered soil N mineralization by changing the soil dynamic properties such as soil moisture content and soil temperature.

Grain yield was not significantly affected by source rate interaction in both years (Table 3). The effect of fertilizer source on grain yield was variable across site-years. Crop yield was statistically influenced by fertilizer source in 2013 but not in 2014. Averaged across application rates, Agrotain-treated urea significantly increased yield by 7.4 % compared with Amidas, as well as urea plus ammonium sulfate, and by 10% as compared with urea alone in 2013 (Table 3). This is attributed to the presence of the urease inhibitor NBPT in the Agrotain-treated urea, which inhibits ammonia volatilization loss by slowing urea hydrolysis and helps synchronize N availability during the peak crop N demand. Significant yield advantage with the urea treated with Agrotain only in 2013 suggests that this may enhance HRSW yield in years with adequate rainfall over the growing season.

Grain yield was significantly influenced by fertilizer application rates in 2013 only (Table 3). Averaged across fertilizer sources, application of 150 lb/ac N significantly increased grain yield by nearly 5 and 3 bu/ac, respectively, compared with 70 and 100 lb/ac N. There were comparable HRSW yields at application rates of 130 and 150 lb/ac in 2013 and at 120 and 150 lb/ac in 2014, suggesting that application of N fertilizer at the current recommended rate of 120 to 130 lb/ac is sufficient enough to meet N requirements of HRSW in the Red River Valley area, irrespective of N source. However, the grain yield of HRSW fertilized with Agrotain-treated urea (62 bu/ac) at the rate of 70 lb/ac was nearly equal or higher than the yield of HRSW fertilized with urea plus ammonium sulfate (62 bu/ac), Amidas (60 bu/ac), and urea alone (58 bu/ac), applied at 150 lb/ac (Fig. 1). This suggests that Agrotain-treated urea might optimize HRSW yields even at lower application rates.

**Grain protein content**

Adequate grain protein content is an important criterion for determining milling and baking quality of wheat. Farmers often receive premium payments when their wheat grain contains >14% protein (Farmaha and Sims,
2013). Grain protein content of HRSW was affected by fertilizer source but not by application rates in 2014 (Fig. 2). Averaged across application rates, Agrotain-treated urea yielded significantly higher ($P < 0.05$) grain protein content (14.1%) compared with Amidas (13.4%) and urea alone (13.6%). This can be explained by the ability of the urease inhibitor added to urea to prolong N supply to wheat. By delaying urea hydrolysis, it may also have facilitated crop N uptake in intact urea form, which eventually deposited as protein at less energy compared with inorganic N forms (Dawar et al., 2011).

### Summary

Our results demonstrated that Agrotain-treated urea had the potential to increase grain yield and protein content of HRSW compared with Amidas, urea plus ammonium sulfate, and urea alone. Addition of sulfur sources like Amidas and ammonium sulfate did not result in a yield advantage over urea alone. Urea treated with Agrotain may optimize HRSW yields even at rates lower than the current fertilizer recommendation. Thus, we conclude that the proper selection of fertilizer source and redefining application rates, depending upon the environmental conditions prevailing over the growing season, may help farmers to increase N use efficiency.

### References

