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Late Season Applications of Nitrogen

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Interest in improving grain protein in hard red spring wheat (HRSW) with in-season applications of nitrogen (N) fertilizer usually peaks following years with large grain protein discounts/premiums. The current price outlook of N fertilizer and the desire to reduce overall fertilizer input costs indicates that in-season applications of nitrogen warrants some review.

There is an intuitive appeal to split apply N (N applied preplant and more N applied during the growing season) in HRSW since the crop takes up the majority of its N between jointing and flag leaf emergence. The practice of splitting the total N fertilizer gift in three or even four separate applications is commonplace in winter cereal production in the maritime regions of Europe, including the countries of Denmark, the Netherlands, the United Kingdom, and France. The objective of split N applications is to supply N when the crop needs it, improve N use efficiency, and consequently achieve maximum grain yield and/or grain protein with fewer N fertilizer inputs.

The current N recommendation for HRSW is based on the forecasted grain yield goal, a previous crop nitrogen credit, and the amount of nitrate-N already present in the top 24 inches of soil as estimated by a soil nitrate test. In other words:

$$N = (2.5 \times YG) - NPC - STN\ (0\text{-}24)$$

Where N= the amount of N fertilizer needed, YG = the yield goal, NPC= the previous crop credit, and STN (0-24) = the amount of nitrate-N in the top 24 inches of soil. This equation was derived from a large number of nitrogen response experiments that were conducted in the tri-state area. An example of such an experiment is Figure 1.

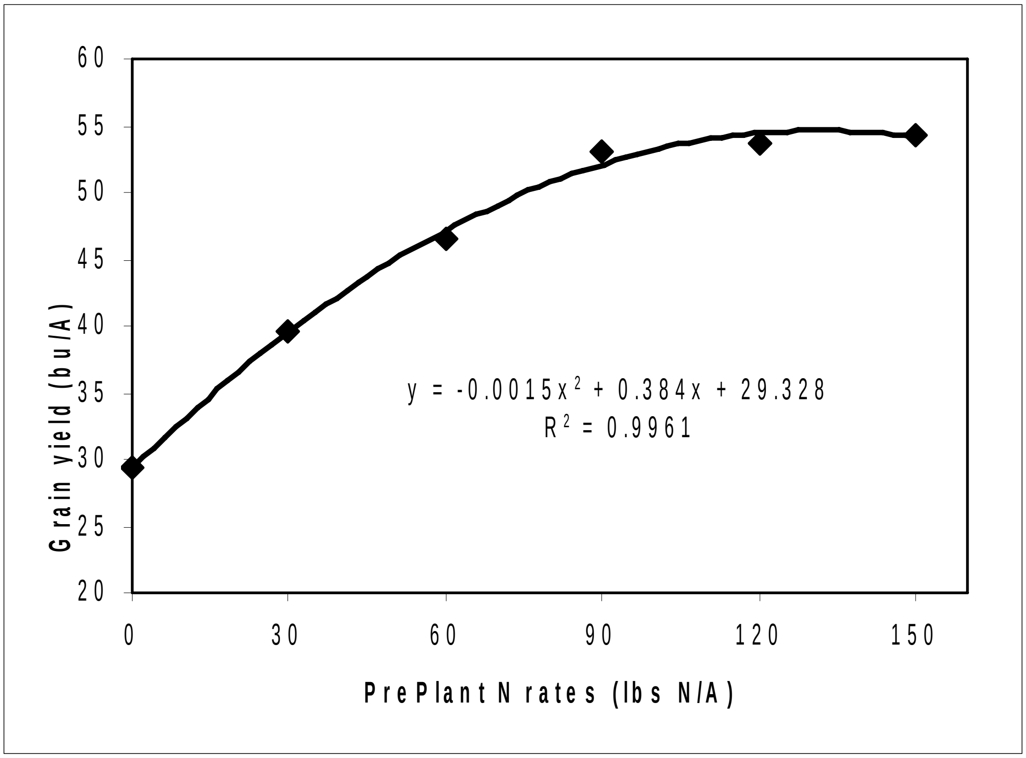

Figure 1 An example of a nitrogen rate experiment in HRSW in which grain yield is measured at 5 incremental increases of pre-plant nitrogen fertilizer. This particular experiment was conducted in Crookston, MN in 2005 (data and graph courtesy of Albert Sims and George Rehm)

Figure 1 is a classical quadratic response curve in which the grain yield response to N fertilizer increases in a decreasing manner as each additional amount of N fertilizer is added. That is, the grain yield increase to each increment of N fertilizer is less than it was to the previous increment of N. Ultimately, the yield plateaus and additional N does not result in any yield increase. At that point, N is no longer rate-limiting. Unfortunately, because of the market demands for HRSW, we also have to consider grain protein. The response of grain protein percentage to N fertilizer from the same experiment as Figure 1 is illustrated in Figure 2.

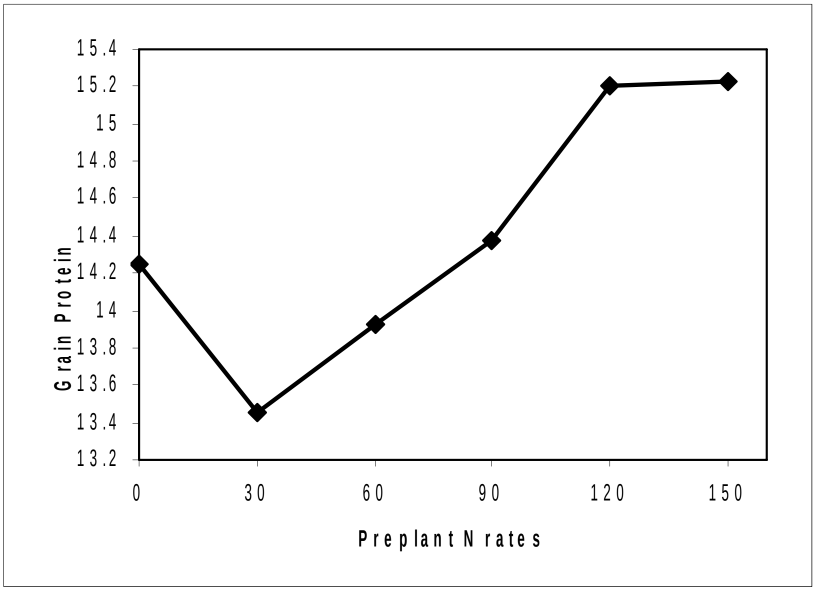

Figure 2 An example of a nitrogen rate experiment in HRSW in which grain protein percentage is measured at 5 incremental increases of pre-plant nitrogen fertilizer. This particular experiment was conducted in Crookston, MN in 2005 (data and graph courtesy of Albert Sims and George Rehm).

Comparisons of the two graphs reveal clear differences. Nitrogen will become rate limiting for grain protein at lower rates than for grain yield. Given this fact, what opportunities do we have to intervene and improve grain protein with split applications of N?

In the early 1990's, George Rehm and John Lamb evaluated the practice of split applications of N in HRSW production. They concluded that adequate pre-plant N resulted in maximum grain yield. Split applications or additional N at late tillering only increased grain yield if pre-plant N was insufficient. The split application of N also improved grain protein when the pre-plant N was insufficient (for a more detailed discussion of these trials see Minnesota Crop News 63 or Prairie Grains Issue 50). More recently, Joel Ransom, John Lukach, and Terry Gregoire evaluated split applications of N in HRSW. The second application of N was either granular urea or UAN solution at either the 3 leaf stage or the 6 leaf stage. This group also concluded that adequate pre-plant N sufficed for maximum grain yield and grain protein.

John Wiersma, at the University of Minnesota, evaluated whether HRSW grain protein could be increased with additional N applications even though pre-plant N was sufficient for the crop. Wiersma evaluated the effects of adding 30, 60, 90, and 120 lbs. N/A on grain protein in four HRSW varieties after 150 lbs. N/A had been available pre-plant. Supplemental N was applied as urea granules at planting, as a urea solution soil applied one week after anthesis, and as a urea solution applied foliar in four applications every four days beginning one week after anthesis. The research showed that:

1. Foliar applied N resulted in the largest increase in grain protein (Figure 3).
2. The four varieties responded equal to the supplemental nitrogen (Figure 4).
3. The supplemental N had no effect on test weight, kernel weight or grain yield (data not shown).
4. About 60 lbs. N/A applied foliar was needed to increase grain protein one percentage point (Figure 3).

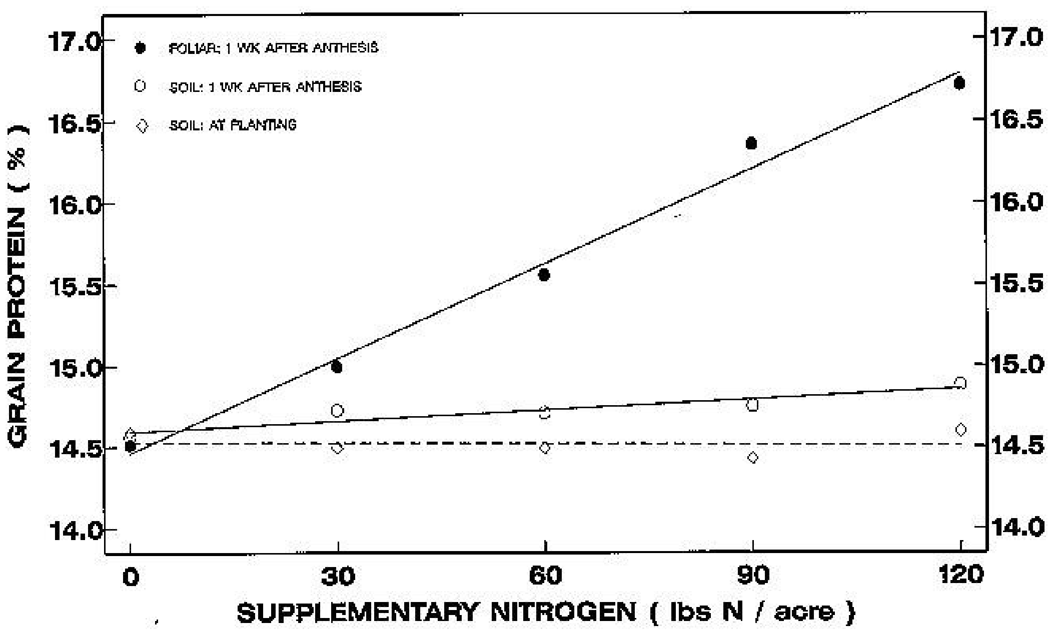

Figure 3 Increases in grain protein concentration with increasing N rate: Comparison of the method and timing of application, Crookston 1993 (data and graph courtesy of John Wiersma).

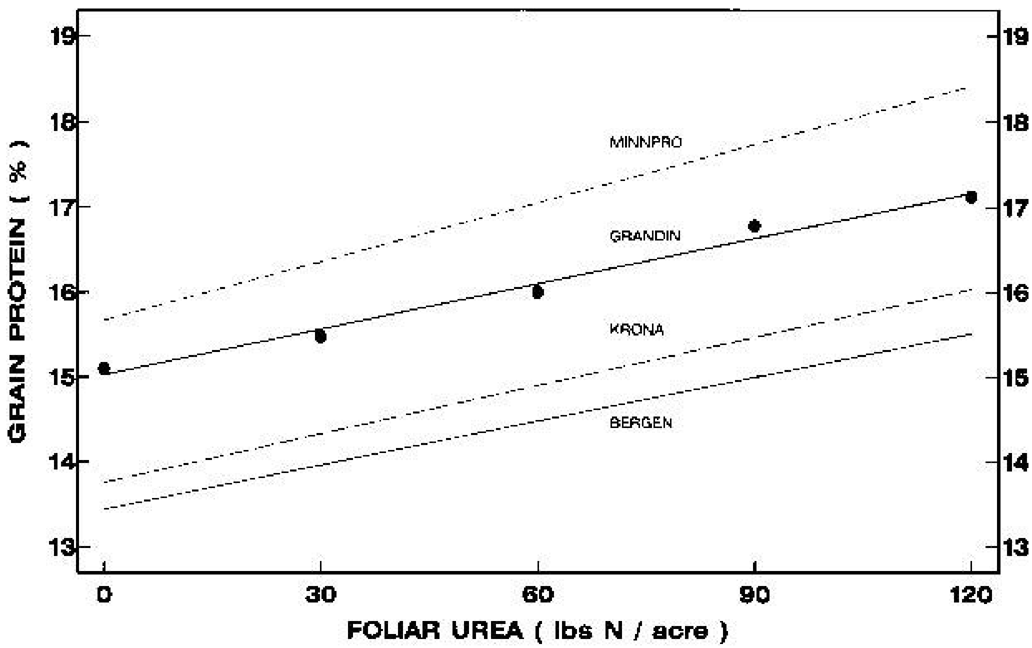

Figure 4 Grain protein responses of four HRSW varieties to foliar urea applied sequentially, beginning one week after anthesis, Crookston 1993 (data and graph courtesy of John Wiersma).

Greg Endres and Bill Schatz evaluated a solution of equal parts water and liquid UAN (28-0-0). Fifteen and 30 lbs. N/A were applied immediately after anthesis on six HRSW and two durum varieties. The experiment had 100 lbs. N/A available prior to planting. This research showed:

1. All varieties responded equal to the supplemental nitrogen.
2. The supplemental N had no effect on grain yield, test weight, or kernel weight.
3. The UAN solution caused significant leaf burn, with some cultivars burning more then others.
4. The 30 lbs. N/A increased grain protein one percentage point.

Grain yield in the Wiersma study averaged 57.5 bu/A and in the Endres and Schatz study 40.0 bu/A. In both cases, pre-plant N was sufficient to maximize grain yield. With sufficient pre-plant N to maximize grain yield, the supplemental N applied near anthesis increased grain protein in both studies. This finding is consistent with European research which has shown increased grain protein when supplemental N was applied at flag leaf emergence or later.

Foliar applications of N solutions during the early stages of grain fill seem to be an effective method of improving grain protein. The efficiency of the supplemental N for grain protein production can be determined by multiplying the actual yield, actual test weight, and the percent protein increase then dividing it by the amount of N applied. This efficiency was 0.47 and 0.93

in the Wiersma and Endres and Schatz studies, respectively. It is not clear, without further research, what may have contributed to the nearly twofold increase in efficiency with the Endres and Schatz study.

We have attempted to make a decision model that relates protein premiums with the price of supplemental N applied foliar immediately following anthesis. The assumptions of this decision model are:

1. The N to protein production efficiency is between 0.47 and 0.93.
2. The premium/discount per fifth point of grain protein is constant.
3. The expected total amount of grain protein to be gained from supplemental N is constant and thus the increase in grain protein percentage is smaller as grain yield increases.
4. A single application of 30 lbs. N/A is made with an application cost of $3.00/A.
5. No effects on grain yield, test weight, or kernel weight are expected.

Based on these assumptions, we can calculate when the application of supplemental N to improve grain protein will likely, possibly, and unlikely result in a positive net return (Figure 5).

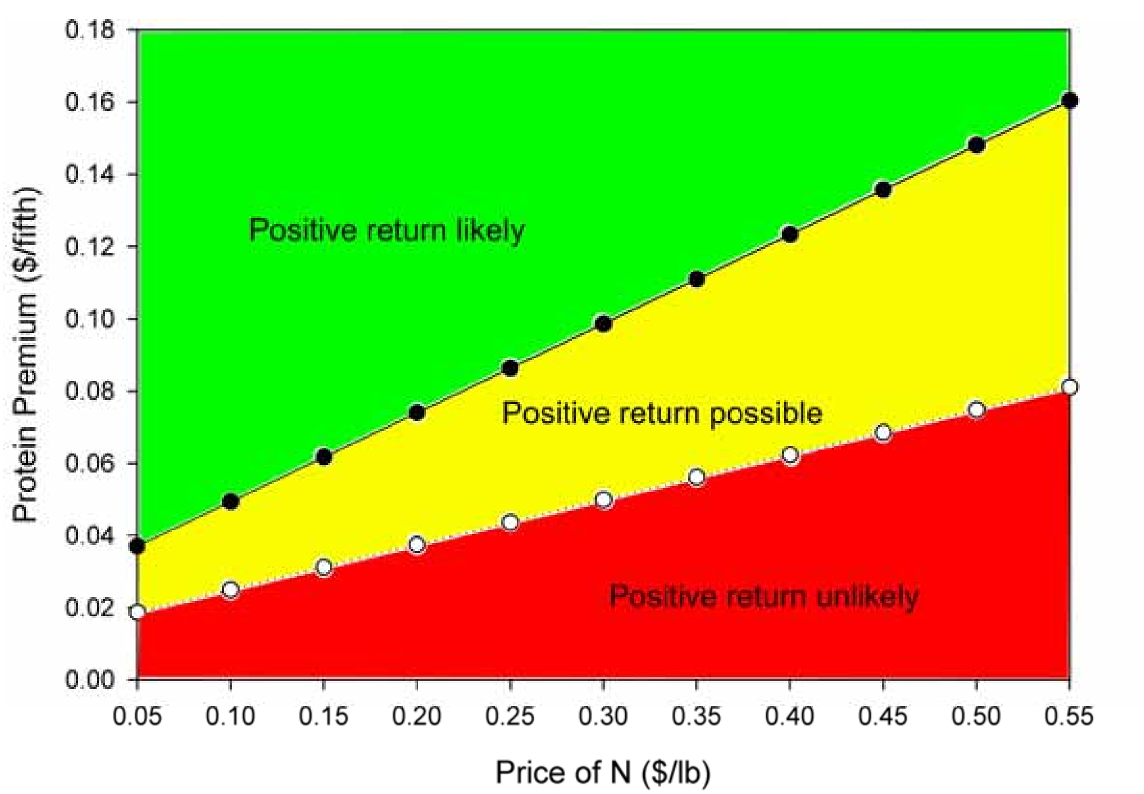

Figure 5 The likelihood of a positive net return for different N prices and protein premiums.

Within a reasonable range of grain yields (30 to 70 bu/A), the expected return for each fifth point protein is constant and independent of grain yield. As grain yield increases the total amount of grain protein produced by the additional N is divided over more bushels of wheat. If grain yield doubles, the increase in grain protein percentage is reduced by half (Table 1). Any premium per bushel attributed to increases protein percentage is paid to the entire grain yield.

Table 1 Expected increases in grain protein and estimated return for two N to protein production efficiencies (NPPE) at different yield levels.

Grain Yield	*NPPE 0.47*	*NPPE 0.93*
35	0.7	1.4
40	0.6	1.2
45	0.5	1.1
50	0.5	1.0
55	0.4	0.9
60	0.4	0.8
65	0.4	0.7
70	0.3	0.7
75	0.3	0.6

In the decision model we assumed that the protein premium per fifth point of protein is constant and consequently the net return is independent of the attained grain yield since the net return is the product of the premium per bushel times the number of bushels produced.

In 2005, we worked with AWG Farms and Ross Farms in Crookston and Fisher to apply late season supplemental N in a commercial field situation. Six fields were selected to apply the following 5 treatments:

1. An untreated control.
2. 30 lbs. N/A with stream bars just prior to anthesis.
3. 30 lbs. N/A foliar applied five days after anthesis
4. 15 lbs. N/A foliar applied five days after anthesis and an additional 15 lbs. N/A foliar applied ten days after anthesis.
5. 15 lbs. N/A with stream bars just prior to anthesis and an additional 15 lbs. N/A foliar applied five days after anthesis.

The source of N was a solution of equal parts water and UAN. Each treatment was applied in a single boom width (90 ft.) across the entire length of the field. Each treatment was replicated 3 times using a randomized complete block design. Leaf burn was estimated one day after the foliar treatments were applied. Grain was harvested with commercial combines equipped with yield monitors and grain yield data was derived from the generated yield map. Grain protein data was derived from either the grain protein data generated with a real-time Zeltec grain protein monitor in one of the two combines or from samples collected by hand from the combine hopper.

The amount of leaf burn varied between treatments and fields (Table 2). In field 1, 3, and 6 some leaf burn was detected in the untreated control. This is the likely the result of sampling error caused by leaf tip necrosis, a physiological disorder found in certain HRSW varieties including P2375 which was planted in Field 3.

Table 2 The percentage of leaf area with symptoms of fertilizer burn as a result of the application of late season supplemental N in 6 HRSW fields nearby Crookston, MN in 2005.

Treatment	*Field*						*Mean*[1]
	1	*2*	*3*	*4*	*5*	*6*	
1	3.3[3]	0.7	10.0	0.0	0.0	1.7	2.6
2	10.0	36.7	13.3	25.0	23.3	6.7	19.2
3	3.3	25.0	21.7	36.7	10.0	18.3	19.2
4	5.0	6.7	13.3	13.3	16.7	13.3	11.4
5	3.3	8.3	11.7	23.3	20.0	18.3	14.2
Mean[2]	5.0	15.5	14.0	19.7	14.0	11.7	13.3

[1] The LSD (0.05) to compare treatments means averaged across fields is 6.0.

[2] The LSD (0.05) to compare field means averages across treatments is 6.5.

[3] The LSD (0.05) to compare treatments means within and across fields is 14.6.

Across all fields, treatments 2 and 3 caused the most crop injury and treatment 4 the least amount of crop injury. The amount of leaf burn that resulted from the application of liquid N with stream bars was unexpected and can most likely be attributed to splashing of the N solution onto the canopy as the stream bars whipped back and forth in the canopy in combination with the time of day the application was made (mid-afternoon). The sequential application of the N solution in Treatment 5 reduced the amount of leaf burn from the stream bars.

The applications of supplemental N just prior to or post anthesis resulted in an average increase of 0.5% grain protein for treatment 4 (Table 3). Treatments 2, 3, and 5 gave an average grain protein increase of 0.25% across the six fields. Within fields, there were some large differences.

In Fields 1 and 5, no clear effect of the supplemental N was detected (Table 3). In the other fields, the foliar application of supplemental N improved grain protein between 0.4% and 1.0%. There was no effect on grain yield from any of the treatments (Table 4).

Table 3 The grain protein percentage as a result of the application of late season supplemental N in 6 HRSW fields nearby Crookston, MN in 2005.

Treatment	*Field*						*Mean*[1]
	1	*2*	*3*	*4*	*5*	*6*	
1	14.7[3]	15.3	14.0	14.9	13.9	15.5	14.7
2	14.6	15.4	14.4	15.3	13.9	16.3	15.0
3	14.6	15.7	14.4	15.3	13.7	16.2	15.0
4	14.7	15.8	14.7	15.5	13.9	16.4	15.2
5	14.6	15.4	14.4	15.0	13.8	16.5	15.0
Mean[2]	14.6	15.5	14.4	15.2	13.8	16.2	15.0

[1] The LSD (0.05) to compare treatments means averaged across fields is 0.2.

[2] The LSD (0.05) to compare field means averages across treatments is 0.2.

[3] The LSD (0.05) to compare treatments means within and across fields is non significant.

Table 4 The grain yield in 6 HRSW fields nearby Crookston, MN in 2005 in which late season supplemental N was applied.

Treatment	*Field*					
	1	*2*	*3*	*4*	*5*	*6*
1	53.8[1]	56.6	55.3	52.0	66.4	47.6
2	56.5	55.7	59.9	51.3	66.5	46.3
3	57.1	55.8	60.9	51.2	64.9	46.3
4	55.5	56.5	59.3	52.5	63.7	48.1
5	57.4	56.1	54.1	47.3	66.1	49.0
Mean	56.0	56.1	57.9	50.9	65.6	47.5

[1] No significant differences among treatments within and across fields or among fields averaged across fields.

The N to protein efficiency of the supplemental N varied from 0.45 to 0.93 in fields 2, 3, 4, and 6. These estimates are close to those calculated from the Wiersma and Endres and Schatz research mentioned above. The efficiency of the supplemental N in fields 1 and 6 was near 0.

In summary, grain protein can be increased with supplemental N when applied in a liquid form. Foliar applications just after anthesis will likely be the most effective and should not impact grain yield, test weight, or kernel weight despite the potential to cause substantial leaf burning. The likelihood of an economic return from this N management strategy can be estimated with the decision guide in Figure 5. However, it must be kept in mind that there is a risk that supplemental N will not increase grain protein as illustrated in one-third of the fields involved in the 2005 research.