

## Wheat Protein Enhancement With N

Cynthia Grant, AAFC, Brandon Research Centre, Brandon, MB R7A 5Y3 ([cgrant@em.agr.ca](mailto:cgrant@em.agr.ca))  
Adrian Johnston, Potash and Phosphate Institute of Canada, Saskatoon, SK, S7K 1J5  
([ajohnston@ppi-ppic.org](mailto:ajohnston@ppi-ppic.org))

### Abstract

Milling and baking quality of wheat generally improves with increased protein content. Therefore, customers are willing to pay premiums for high protein wheat. These premiums are passed on to the producer, creating interest in managing for high protein content. Since N is a primary building block of protein, N management will have a major effect on protein content of a crop. Proper N management can help to optimize protein content, while avoiding adverse effects on crop production and the environment.

Field studies were conducted at several locations in the Parkland region of Manitoba and Saskatchewan over four years to evaluate the effects of rate, placement, source and timing of N application on hard red spring wheat yield and protein content. SPAD metre and leaf N measurements were also evaluated for their effectiveness in predicting the need for in-crop N. Protein content increased with increasing level of N fertilization prior to seeding in both Katepwa and AC Barrie. Late in-crop applications of 15 kg of N per hectare in addition to the pre-plant N applications generally increased grain protein content, however increases recorded were relatively small. Soil-applied N was generally superior to foliar application except when applications occurred late in the season (flowering), particularly with late seeding. Use of NBPT improved the performance of in-crop applications of UAN and urea to increase protein. In-crop N applications may not be needed on soils that can supply enough N to the crop late in the season from mineralization of organic residues or reserves of nitrate-N. In-crop N applications may be useful to enhance protein content when N supply during the growing season is less than the N required by the crop for optimum yield and protein content.

### Protein Content Improves Grain Quality

Quality of wheat for producing both bread and pasta will generally increase as the protein content of the grain increases. This improves product quality and profitability for the end user. Therefore, customers are willing to pay a premium for high-protein wheat, which is now being passed on to the producer. Since the size of the protein premium can be very high in some years, producers are interested in understanding how they can economically produce both high yield and high protein content wheat.

### Nitrogen is Important for Grain Yield and Protein

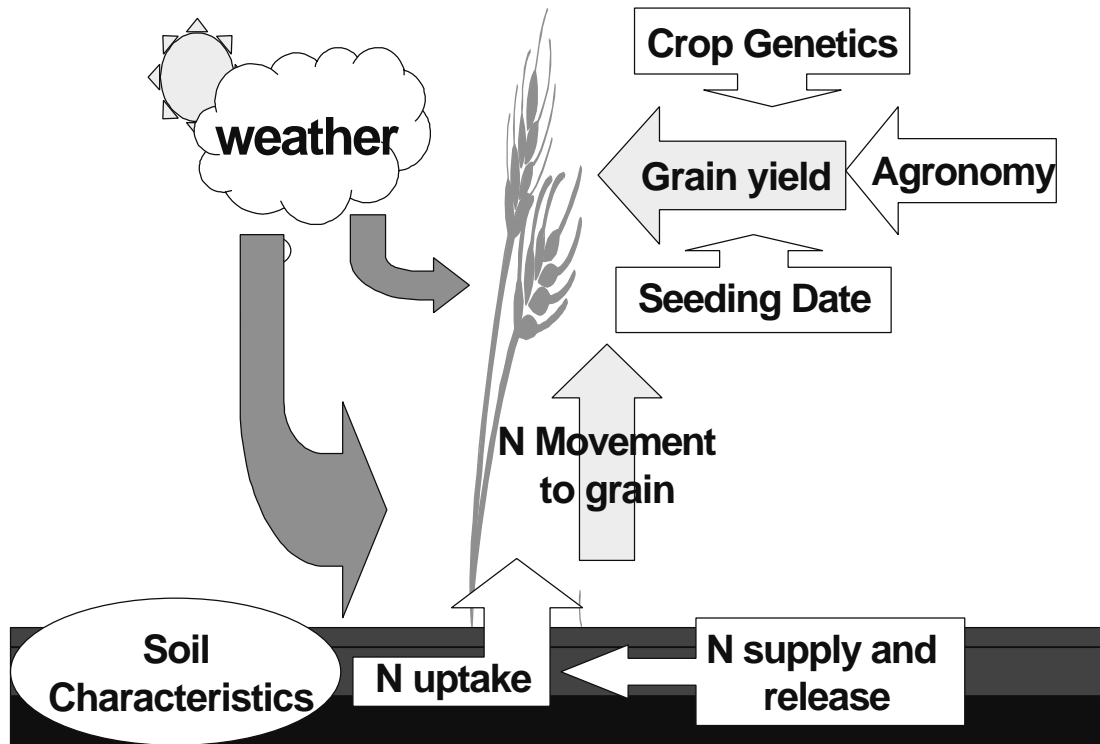
Nitrogen is the nutrient most commonly limiting to crop production in the prairies. As N comprises about 17% of protein, N is also the nutrient with the greatest effect on protein content. Excess applications of N are not economically efficient and can reduce crop productivity and create environmental problems, while deficiencies in N supply can reduce both crop yield and protein content. To produce a high-yielding, high quality wheat crop, the N supply must be balanced to the yield potential of the crop. Plant-available N is provided by mineralization of organic matter from summer fallowing, by release of N from high N residues or amendments such as legumes or manures, by accumulation of residual N in the soil, or through fertilizer application. If N in the soil is deficient, application of N fertilizer can increase both grain yield and protein content (Alkiers et al. 1972, Grant and Flaten 1998).

### Balance Yield Potential and Nitrogen Supply

The response of crop yield and protein to N applications depends on the balance between crop yield potential and N supply. Therefore, any factors which influence the yield potential of the crop or the amount of N supplied to the crop through the growing season will influence the yield and protein content of the crop (Figure 1). To optimize grain yield and protein content the N supply must be matched to the yield potential of the crop. Therefore, rates of application should consider the amount of N supplied by the soil, the available moisture and the target yield. Moisture supply may impact on crop yield potential

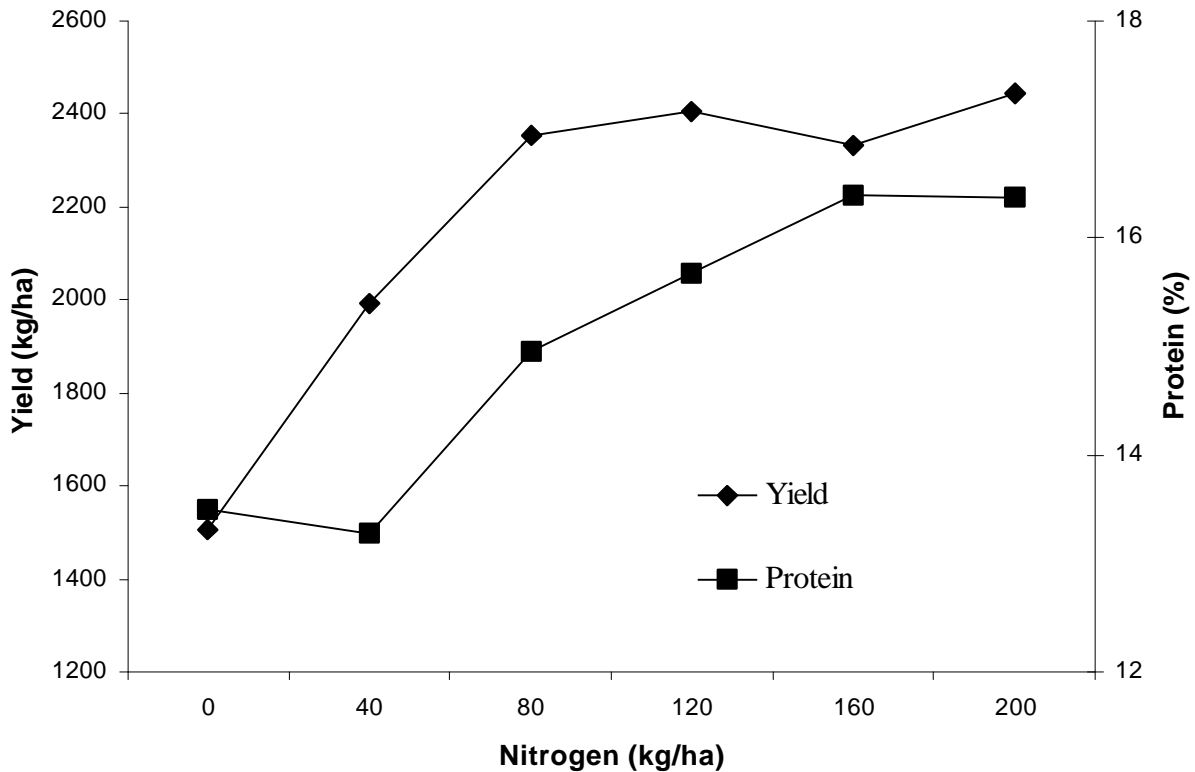
and the capacity for plant utilization of available N (Gauer et al. 1992). Under optimum moisture conditions, high rates of N are required to support the yield potential and produce adequate protein content. With low moisture, N fertilization will have minor effects on crop yield, since yield is more limited by moisture than by N supply; however, N may still increase grain protein content. Different cultivars may also differ in their yield and protein response to N application (Gehl et al. 1990). Low yielding cultivars will usually have a lower N requirement for optimal yield, so protein content will increase at lower N levels. Cultivars with high yield potential generally require higher rates of N fertilizer to optimize both yield and protein content.

**Figure 1: Factors Affecting Protein Content of Wheat**



If N supply is low relative to the yield potential of the crop, modest rates of additional N tend to have a large effect on grain yield and a lesser effect on protein concentration (Figure 2). As the N supply relative to grain yield potential increases, both yield and protein content can increase with N application. When N supply is high relative to yield potential so that N is no longer limiting to crop yield, yield will no longer increase with increasing N supply although protein content can continue to increase. If N supply is very high, neither yield nor protein content will increase with increasing N supply. Generally, a protein content less than 13-14 % in hard red spring wheat indicates that N supply was less than optimum for crop yield. Economically, payment of protein premiums provides a “buffer” in selection of optimum N application rates. Even where producers do not increase yield with additional N applications, they can still capture a higher return if they are paid for the higher grain protein content. However, as rate of N application increases, the efficiency of N use generally declines. High rates of N also lead to higher economic risk, increased danger of lodging and increased risk of nitrate leaching and gaseous N loss.

Figure 2: Response of wheat grain yield and protein content to nitrogen application



### Manage for Efficient Nitrogen Use

Management practices should be used to improve the efficiency of N application. Both yield and protein content can increase with improved fertilizer efficiency. Therefore, it is important to use best management practices for N fertilization, suited to the environmental conditions of the area. This includes selecting a combination of N source, placement and timing that balances fertilizer use efficiency, agronomic benefits and logistical, economic and environmental considerations. For example, while banding generally results in improved fertilizer use efficiency, moisture loss from the banding operation may under some conditions negate any yield benefits from in-soil placement. Therefore, it is important to make fertilizer management decisions based on information from an area with a similar environment to your own.

### Nitrogen Timing Influences Crop Response

Timing of N supply can also influence grain protein content. Nitrogen that is accessed by the crop early in the growing season generally has a major effect on vegetative growth and crop yield while the effect on grain protein content may be low, due to the biological dilution effect of the higher yield. Conversely, late season supplies of N generally affect protein more than yield. Since there is little impact of late N supply on crop yield, there is less dilution of the protein produced by the enhanced grain production. In addition, N accessed later in the season may be more effectively channelled to the grain, as it is not immobilized in vegetative parts.

Nitrogen may be supplied to the crop late in the season from mineralization of organic matter supplied through legume forage breaking, pulse crop residues, manure application, or a long history of

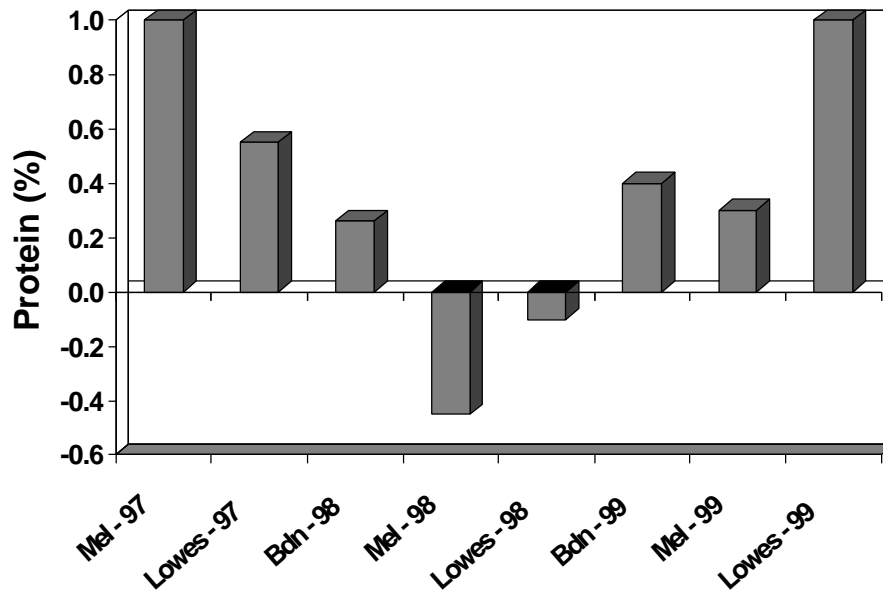


Figure 3: Change in protein content by 15 kg N per ha as AN applied at boot as compared to at seeding (with base rate of 60 kg N per ha applied at seeding)

balanced fertilization with return of crop residues. Long-term mining of the soil through fallow will reduce the potential for late-season mineralization and production of high protein wheat, unless N management is enhanced. Potential N supply from mineralization will be higher on soils with a high concentration of active organic matter and will be restricted in dry or cold soils.

Nitrogen may also be supplied late in the growing season through fertilizer applications. Timing of N supply must still be early enough in plant development to allow sufficient time for plant uptake and translocation. Applications from the boot stage until slightly after anthesis have been effective in increasing protein content in wheat. In-crop N may be applied as foliar sprays, broadcast applications, surface dribble-bands, or as in-soil applications, if the equipment is available.

In studies conducted over a four-year period near Brandon, MB and Melfort, SK, the effectiveness of applying a 15 kg per ha portion of N during the growing season as compared to applying all of the N at the time of seeding varied considerably from year to year (Figure 3). When the in-crop N was applied as ammonium nitrate at the boot stage, which tended to be one of the most effective source-timing combinations, protein content ranged from approximately 1% higher to 0.6% lower than when all the N was applied at the time of seeding.

Relative effectiveness of in-crop N applications varied with N source and timing of N application. Application of a portion of the N as urea or UAN tended to be less efficient than application of all N at the time of seeding, when averaged over 4 site-years (Figure 4). Protein content was higher when the N was applied at anthesis than at either tillering or boot. Protein content was also higher with soil-applied urea than with foliar-applied UAN. The advantage of urea over UAN tended to be greater at the earlier growth stages. The low efficiency of in-crop N may have been partially due to volatilization losses of the urea

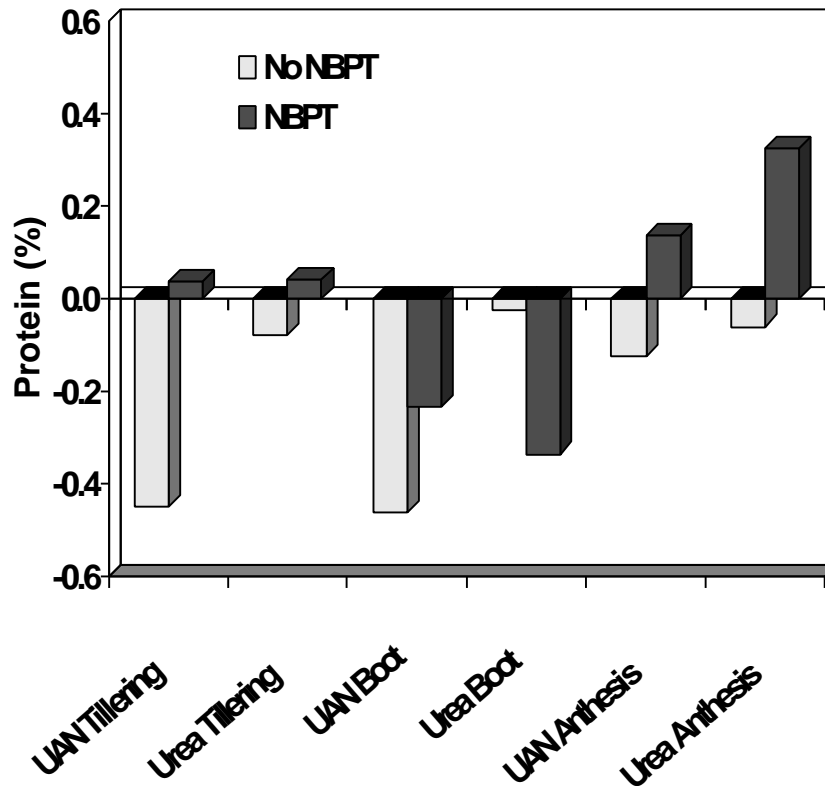


Figure 4: Effect of application of 15 kg N per hectare as urea ammonium nitrate (UAN) or urea with or without NBPT at tillering, boot or anthesis with 60 kg N ha<sup>-1</sup> applied at seeding as compared to application of 75 kg N ha<sup>-1</sup> at seeding (mean of 4 site-years).

portion of the fertilizer and partly due to limited foliar uptake of the UAN. Use of NBPT led to higher protein contents with in-crop N applications.

Soil-applied ammonium nitrate also tended to perform better than foliar applications of UAN, when the wheat was seeded in late April or early May (Figure 5). When seeding was delayed until late May or early June, ammonium nitrate produced higher protein content than UAN when applied at tillering, but produced lower protein content than UAN when applied at boot or anthesis (Figure 6). When application is delayed later in the season, when soil is frequently dry and there is less time for N uptake and translocation, soil -applied N may not be taken up effectively by the plant. Under those conditions, foliar-applied UAN may have a greater impact on grain protein content than soil-applied sources.

The generally poor performance of foliar applications of UAN is likely because little of the N is actually absorbed through the leaf. The majority of the “foliar-applied” N is accessed by roots once the fertilizer washes off and reaches the soil (Figure 7) (Alkier et al. 1972, Rawluk et al., 2000). Soil-applied dribble-banded or broadcast in-crop N tends to be more effective than foliar application, if there is sufficient moisture for the N to be dissolved and moved into the root zone. Soil application of in-crop N will also reduce the risk of crop damage due to leaf burn.

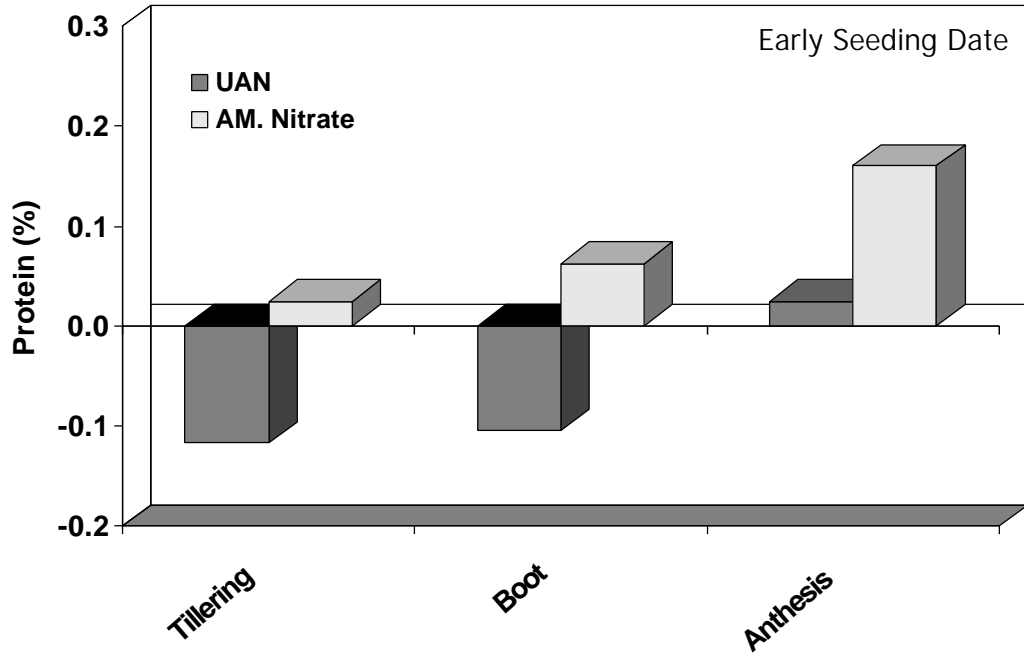


Figure 5: Effect of application of 15 kg N per hectare as urea ammonium nitrate (UAN) or ammonium nitrate at tillering, boot or anthesis, with 60 kg N ha<sup>-1</sup> applied at seeding as compared to application of 75 kg N ha<sup>-1</sup> at seeding – early seeding date (mean of 4 site-years).

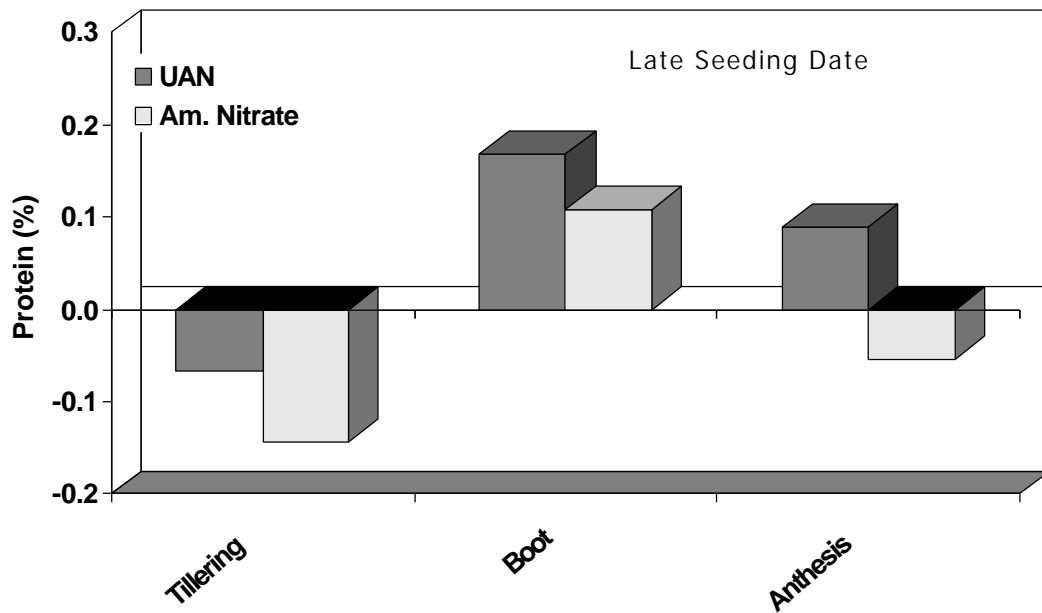


Figure 6: Effect of application of 15 kg N per hectare as urea ammonium nitrate (UAN) or ammonium nitrate at tillering, boot or anthesis, with 60 kg N ha<sup>-1</sup> applied at seeding as compared to application of 75 kg N ha<sup>-1</sup> at seeding – late seeding date (mean of 4 site-years).

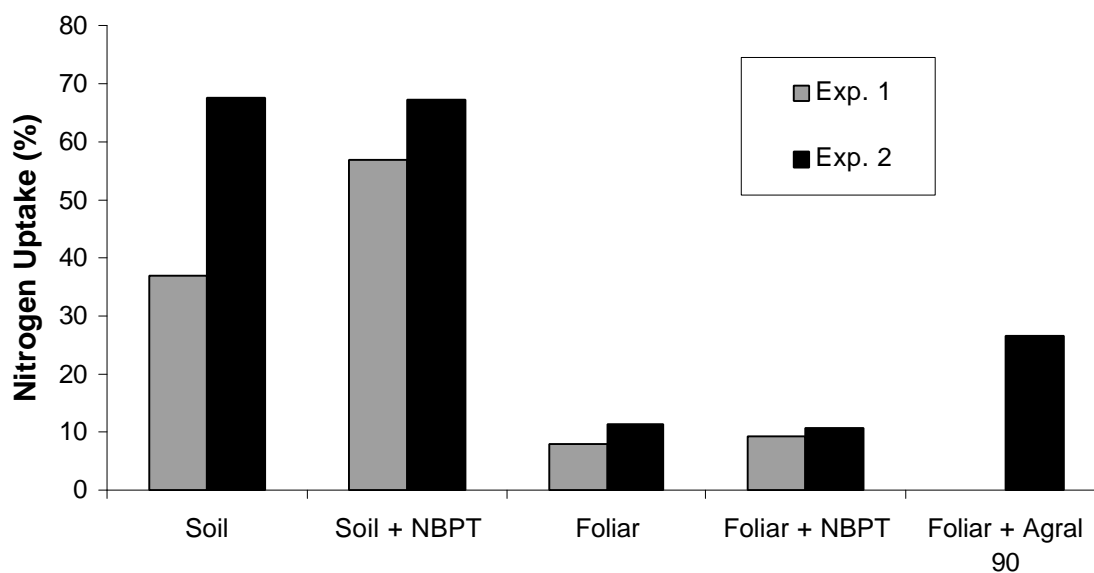


Figure 7: Effect of placement of urea solution and addition of NBPT OR Agral 90 on absorption of nitrogen by wheat (Rawluk et al. 2000).

In spite of the limited absorption, foliar applications of N may be beneficial, particularly with late applications on dry soil. The small amount of N that is absorbed through the leaf with foliar applications may still be able to increase protein content under dry conditions, where soil-applied fertilizer may be stranded at the soil surface, as was seen in Figure 6. While in-crop applications of N can be used to increase protein content, there are some problems associated with this technology. In-crop applications of N will not always increase protein content. Increases are less likely when initial levels of N for the crop are relatively high or when growing conditions reduce the yield potential and hence the N requirements of the crop. Granular applications of N on dry soil will be ineffective if rainfall does not occur and the fertilizer is stranded on the soil surface. Foliar applications can cause leaf burn and lead to a yield decrease. In-crop applications also require another operation with extra labour and expense.

### Predicting Nitrogen Requirements

In-crop N applications will not always increase grain protein content (Figure 3). If N supply from the soil is sufficient and the crop is not N-deficient, the likelihood of attaining an economic increase in protein content with in-crop N application is relatively low. An effective test for N status of the growing crop would help predict if the crop was N-deficient and if an in-crop N application would be likely to increase protein content.

Use of a Spad chlorophyll metre or leaf N analysis were both effective tools for prediction of N status of a growing wheat crop, where the N supply ranged from deficient to high (Figure 8). Under these conditions, both chlorophyll content and leaf N were highly related to the final grain protein content. In contrast, where N supply was high, Spad metre readings and leaf N content did not differ very much among treatments and the relationship with protein content was poor.

### Remember “Best Management Practices”

If initial applications of N at or prior to seeding are high enough to ensure optimal yield, then protein concentrations should be in the range of 13-14%. If higher levels of protein are desired, it may be more beneficial to increase early season N application, where there may be an impact on yield and protein content, rather than to rely on in-crop N applications. This is especially true if protein levels have been low in this past, as this may be an indication that insufficient N has been applied to optimize crop

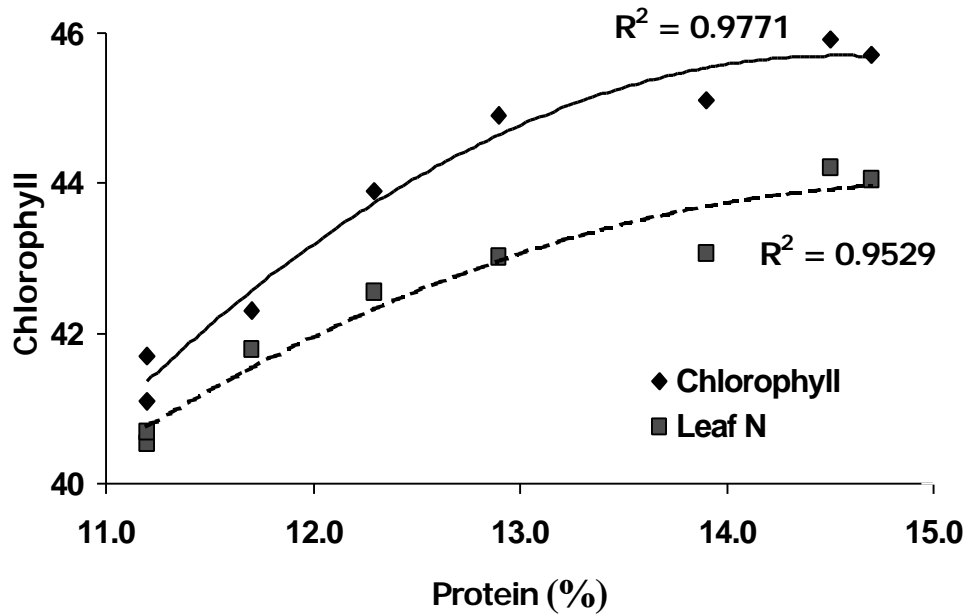


Figure 8: Protein Content and Leaf N Content as Related to Spad Meter Readings

yield. Fertilization for a reasonable target yield and use of “best management practices” for N management to minimize N loss and optimize fertilizer use efficiency are key steps in production of high protein wheat.

### Summary

Protein is a critical quality factor in wheat and it is important to maintain adequate protein levels in our crop to satisfy market demands. Improving protein content can help to maintain Canadian markets and also provide direct benefits to the producer in terms of protein premiums.

While environmental factors such as moisture and temperature have large effects on protein content, production practices such as cultivar selection, seeding date and fertility management can also influence protein content. Balancing N supply with yield potential can optimize both crop yield and protein content. Selection of an effective combination of nitrogen source, placement and timing can improve fertilizer use efficiency. In-crop nitrogen applications can increase protein content, but are not a substitute for adequate levels of N applied prior to or at seeding. Careful management can improve both the protein content of wheat and the economics of crop production.

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