NITROGEN MANAGEMENT FOR HARD WHEAT PROTEIN ENHANCEMENT

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INTRODUCTION

Prices for hard red spring (HRS) wheat have exceeded soft wheat prices in most years since 1982, especially if hard reds were marketed with 14% protein or higher. The relative returns for soft whites and hard reds can be calculated using annual market prices in Portland for soft whites and hard reds at 13, 14, and 15% since 1982. We assumed hard reds are 95% as productive as soft white spring wheat that yields 96 bu/A. If 14% HRS wheat were marketed each year since 1982 the average gross return would be $44 per acre higher than for soft white spring wheat. For 13% HRS the difference was only $18 per acre, which shows the importance of avoiding the low protein discounts. For 15% HRS, the gross return exceeded the return for soft white by $54 per acre. Avoiding the discounts below 14% is more critical than gaining the premium above 14%. Discounts per bushel in the past year alone have been as much as three times the premium.

The last five years have been particularly favorable for HRS production. The interest in HRS is reflected by the consecutive increases in acreage of HRS in the last three marketing years. Whereas there has always been a significant HRS acreage in eastern Idaho, this acreage has increased at the expense of soft white spring wheat. A number of western Idaho growers are also planting HRS that have limited experience with the HRS market class. There would be even greater acreage of HRS were it not for a uniform concern about producing HRS with acceptable protein. Understanding the issues related to HRS protein is critical for growers to avoid or minimize low protein discounts and maximize their economic returns.

IMPORTANCE OF N

All protein consists of combinations of amino acid building blocks. Nitrogen (N) is critical for amino acid synthesis as it is part of the basic structure of all amino acids. Without adequate N, amino acids aren't synthesized and available for protein synthesis.

Available N is arguably the most important factor for marketing high protein HRS in southern Idaho irrigated production. Variety selection, water management, weed and insect control, and other crop management practices all impact protein in harvested wheat. Failure to understand the importance of N and its proper management for enhancing protein is typically the single most common reason for low protein discounts and grower disappointment in marketing HRS wheat. While the focus of this presentation will be late season applied N, effective N management throughout the season plays a critical role in producing high protein high quality HRS wheat.

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NITROGEN, YIELD, AND PROTEIN RELATIONSHIPS

The inverse relation of yield and protein is well known in dryland production systems. As available moisture increases due to higher rainfall, yield increases while protein decreases. Protein decreases because the plant's requirement for N increases as yield increases, and wheat will use limited available N primarily for increasing yield by increasing head number, seed number, or seed size. Even under irrigation, the first increment of N, when available N is low, is used by wheat for increasing yield at the expense of seed protein. It is not unusual under low N conditions for the first increment of N added to actually reduce grain protein. Only when most of the N required for yield has been supplied will further N additions raise protein. At this point, when additional N increases protein, the protein increase is directly related to the amount applied.

Failure to reach 14% protein is commonly due to underestimating the amount of N necessary for satisfying the N required for yield. Roughly 1.6 to 1.8 lbs of total available N are necessary for each bushel of wheat produced under well managed conditions with no other limiting factors to production. Total available N includes residual soil N, mineralized N and applied fertilizer N. Many producers may not be accustomed to using this much N for irrigated wheat production.

Wheat protein surveys suggest that roughly a third of the soft white wheat in western Idaho is under fertilized with N, and about the same fraction is over fertilized. This comes as little surprise given the relatively low percentage of soil testing done for irrigated wheat. Without knowing the residual N available, it's difficult to know how much needs to be applied for satisfying the N required for yield, much less the N required for raising protein to acceptable levels. Effective N management starts with a representative soil sample and the measurement of residual N available for the crop.

A recent survey of 48 fields in Oregon suggested that 2 lb of applied N/bu were necessary for producing 14% HRS. No other sources of N were considered, so the actual available N (including residual and mineralized soil N) required to produce 14% protein HRS was likely even greater under their conditions. Only six of the fields received late season N at heading and wheat from two of these fields tested less than 14% protein despite late season applied N.

LATE SEASON N FOR INCREASING PROTEIN

Applying N between the boot and flowering growth stages is a common practice for increasing HRS protein. To the extent that protein is increased and steep discounts avoided, this can be a good investment. If late season N is used by the plant to increase both yield and protein all the better. But N used by wheat to increase yield will normally come at the expense of the protein increase. Protein levels of 13% or less following late season applied N suggests either that the N requirement for yield was not entirely satisfied or that more late season N was required than was made available to the wheat.

The amount of late season N required for increasing protein to acceptable levels is, in part a function of yield. For example, the protein N involved in raising protein from 13 to 15% in 40 bu/A wheat is about 7.5 lb/A, but 22.5 lb protein N/A for 120 bushel wheat. The protein N in 40 bu wheat is about 50 lb/A, but is 150 lb/A for 120 bu wheat. The higher the yield, the more N required to change protein. Failure to reach 14% protein can be due to too little N applied for the yield involved.
Late season N is most conveniently applied through sprinkler systems with injection units. If the N can’t be injected through the lines, it can be applied as a dry N fertilizer and then watered in with sprinkler irrigation. Applying N through the lines reduces application costs, assures adequate N incorporation for root uptake, and allows higher N rates to be used than can be used with concentrated foliar sprays. Sprinkler irrigation provides more flexibility in managing late season N for protein enhancement than any of the alternatives.

Providing late season N without sprinklers is more of a challenge. Concentrated foliar sprays can be applied by air and are as effective as sprinkler applied N for increasing protein at harvest. But there is a limit on how much foliar N can be applied without incurring leaf burn. Appreciable burning of the upper leaves of wheat can reduce yield, as these leaves are critical for providing photosynthates or starch for the developing seed. We have reduced yield in research trials using as little as 30 lb N/A applied as a foliar treatment in 30 gallons/A of solution. Solution 32, or Uran, caused more leaf burn and reduced yield more than comparable amounts of soluble urea applied in the same manner. The two N sources did not differ in the protein increase that resulted from their application in three years of testing.

Under furrow irrigation, top-dressed dry N fertilizers can be less effective applications because they depend primarily on rainfall to move the N deep enough to be taken up by roots. Rainfall is sporadic, infrequent, and generally too little to adequately incorporate surface applied N. Also, subsequent furrow irrigation not only fails to adequately incorporate topdressed N, it may exacerbate volatile losses of surface applied ammonium N fertilizers such as urea. Thus, topdressing dry N sources late in the season to furrow irrigated HRS wheat involves more risk than N applied through the lines.

**FACTORS INFLUENCING THE PROTEIN RESPONSE TO N**

A number of factors can conceivably influence the protein response to late season N. Theoretically, any cultural practice which affects yield can influence protein at harvest. In general, factors other than low available N that reduce yield would be expected to increase protein. But the influence of these factors on the protein increase from late season N is not commonly evaluated. We have examined some of these factors at the Parma Research and Extension Center.

The most obvious factor governing the protein increase is the rate of late season N used. In several research trials the protein response to late season N was linear up to as much as 80 lb/A, the highest rate evaluated. A linear protein response means basically that the protein increase per unit of N applied was consistent throughout the range of N evaluated.

In research made possible by the Idaho Wheat Commission, we found planting dates and varieties to have appreciable effects on grain yield and protein at Parma. The most productive HRS wheat was actually late fall planted. But in 1999, the first year of testing, there was no effect of planting dates or varieties on the protein increase from late season N. Protein increased about 0.3% for each 20 lb/A of N applied at heading regardless of planting date or variety.

A common perception is that moisture stress during late grain filling increases protein. We evaluated late season moisture stress in four seasons at Parma. Late season moisture stress did increase protein when yield was limited by the stress. But 14% protein was easily gained without inducing the stress (and sacrificing yield) if adequate late season N was effectively incorporated at heading. It should not be necessary to sacrifice yield for the sake of getting acceptable protein.
The late season stress imposed by withholding water had little influence on the protein response to late N. But maintaining soil moisture during later grain fill, so that wheat roots could continue to access soil N, increased protein regardless of the late season N rate.

Some growers have asked if receiving excessive late season moisture, especially as rainfall or sprinkler irrigation can reduce protein at harvest. Little research has addressed this question. Current late season moisture studies in the Magic Valley by Dr. Howard Neibling may shed light on this question. Soft wheat protein was reduced by late season sprinkler irrigation in one of two years at Parma. But more research needs to address this issue. We do know that sprinkler irrigation of soft white wheat during later stages of grain fill can reduce quality by increasing black tip and lodging and reducing test weight.

In some areas known to be sulfur (S) deficient, S can be a limiting factor for both yield and for increasing protein with late season N. Providing adequate S earlier in the season for yield should not limit the protein increase to late season N.

**RELATION OF PROTEIN INCREASE TO WHEAT QUALITY**

There is doubt in some quarters that the protein increase from late season N actually results in any improvement in bread baking quality. We examined bread baking quality in samples collected from the four year late season stress study at Parma. Quality was evaluated using standard procedures by the University of Idaho Aberdeen Wheat Quality Lab.

Whenever protein increased from 13 to 14%, or even 15% from late season N there were associated increases in bake loaf volume, one of the most critical quality parameters. If protein was already at 15% protein, further increasing protein with late N did not consistently increase bread making quality. There is good reason why the HRS market provides better compensation for higher protein wheat, regardless of the means used to provide it. HRS wheat with protein increased to 14 and 15% with late season N is better for bread making.

**PREDICTING PROTEIN FROM FLAG LEAF N**

Plant analysis has long been used to indicate in season N needs of Idaho's sugarbeet and potato crops among others. Plant analysis can also be used to indicate in season N requirements for HRS wheat. We have evaluated several wheat tissues at various growth stages for estimating protein in the grain at harvest. Of these tests, flag leaf total N contents at heading or flowering have been the most closely related to grain protein. Most of the N to be taken up by wheat is in the plant by this point. The final protein in the grain is largely a function of the N in the plant that can be translocated to the developing grain from the biomass at heading. Flag leaf total N is directly related to the total N in the biomass.

Flag leaves are the upper most leaves of the plant prior to heading. Flag leaf total N concentrations of 4.2% were associated with 14% protein in HRS wheat in irrigated Aberdeen studies conducted for three years with two varieties. The protein increase from late season N was greater the lower the flag leaf total N. If flag leaf total N was above 4.5% there was little protein increase from 20 or 40 lb/A of late season N. The results from this research also indicated that 40 lb/A of late season N was not adequate for increasing protein to 14% when flag leaf N was as low as 3.0%. Yield was also limited by low N when flag leaf N was this low. Late season N in excess of 40 lb/A may be necessary for gaining 14% at harvest.
It is critical to collect flag leaves as close to heading as possible, or to carefully document the growth stage after full flag leaf emergence that samples are collected. Flag leaf N decreases as the plant continues to develop, assuming only small quantities of available N are available to the plant. It may be possible to collect flag leaves prior to heading and as late as flowering, but the critical flag leaf N values necessary for acceptable protein are higher when sampled before heading and lower when sampled after heading.

Flag leaf N was monitored at flag leaf emergence, heading, and flowering in three Treasure Valley fields during the 1999 season by Ben Simko, OSU Extension Educator. Flag leaf N dropped from 4.62 and 4.24% N at flag leaf emergence in two fields to 4.1 and 4.02% N at 50% head emergence. The change at flowering was even greater, decreasing 1.6 to 1.7% total N from the concentrations at heading. Therefore, knowing the growth stage at which samples are collected is critical for correct interpretation.

Sampling earlier than heading has the advantage of providing additional time for the analysis to be done and the results related to the grower or fieldman. It also provides additional time for the N to be applied, especially useful if it takes several days to apply late season N through the lines with several different sets. Unfortunately, flag leaf N levels at flag leaf emergence associated with 14% protein are less well documented than at heading. From the limited sampling done to date it appears that critical flag leaf N will be 0.2 to 0.5% total N higher at flag leaf emergence than at heading. In any case, if flag leaf N at the early sampling is no greater than 4.2%, the critical level for the heading stage, additional N should be considered since the concentration is not likely to increase or remain the same at heading without additional N applied.

Flag leaf N seems to work well in controlled research studies where collecting representative samples of both the leaves and grain is relatively easy given the small scale on which the trials are conducted. Successful use of flag leaf N in grower fields to predict harvest protein and supplemental N needs will depend on the care to which representative samples are collected. This is no mean accomplishment given the wide variation in available N, soils, and yields within fields.

**FACTORS RESPONSIBLE FOR LOW PROTEIN**

Despite the best efforts of growers to manage N for high protein, there are invariably cases where protein is still below 14% at harvest and low protein discounts. There are several reasons why protein at harvest can be lower than desired, even with late season N applied.

Perhaps the most common reason for low protein is inadequate N available for meeting the requirements for yield. If late season N must be used to satisfy the N required for yield it occurs at the expense of protein enhancement. Furthermore, the late season N applied for increasing protein may not be enough for the yields and N deficit in the plant.

Excessive watering and leaching of N from the root system during the season can effectively reduce N available for both yield and protein. Conversely, late season N applied as topdressed dry fertilizer without adequate movement into soils can be less available to wheat. Dry moisture conditions where the N is positioned in soils will limit root activity and reduce the uptake of N from those depths.

Since yield and protein are inversely related, favorable environmental conditions that appreciably increase yield can result in lower than desired protein. It is not uncommon for county yield averages to differ year to year as much as 10-20% from the long term average.
Commonly grown varieties are used primarily for their yield potential. They may not be the highest protein varieties available for specific planting conditions.

**SUMMARY**

HRS market prices are currently considerably higher than soft white prices, as they have been for several years. Increased interest in HRS wheat production is reflected in the consecutive increased acreage the last three years. Successful irrigated HRS production and marketing depends on avoiding low protein discounts. Effective N management throughout the season is essential for assuring both adequate production and high protein. Late season N in particular may be necessary for many producers to avoid low protein discounts. Flag leaf total N can be useful for predicting whether additional N is required for high protein, but representative samples are critical for accurately estimating late season N requirements.