**University of Kentucky College of Agriculture**
**New Crop Opportunities Center**

# Understanding the Roles of Soil and Fertilizer Nitrogen Management on Grain Protein Levels in Soft Winter Wheats

*John H. Grove and Antonio A. Marchi, Department of Agronomy*

## Introduction

Soft red winter wheat is an important component of row crop rotations in Kentucky. Markets, especially export markets, for soft red winter wheat appear to be limited. Soft white wheat is taking some of those markets. High protein is desired in certain end uses (crackers) for soft white wheat. Nitrogen management is the key to the successful management of grain protein levels in soft wheat. While it is well known that late-season (after Feekes 8) application of fertilizer nitrogen (N) to wheat will tend to raise grain N (protein) concentrations, an effective system of predicting the need for such a late fertilizer N application does not exist for Kentucky's wheat producers. Our hypothesis is that the need for late fertilizer N applications is related to soil nitrogen levels, tillage induced mineralization of N from organic matter, and that this release of soil N can be managed by monitoring the crop's seasonal N status, utilizing either the chlorophyll meter or tissue N analysis. With such information, Kentucky producers would be in position to better serve high protein soft wheat markets.

## Specific Objectives

1. To develop an understanding of the relationships between early fertilizer N levels, leaf tissue N concentrations, at-heading fertilizer N rates and grain protein levels for several soft wheat cultivars.
2. To examine these relationships in the several soils associated with major Kentucky wheat production regions.
3. To examine the role of soil nitrogen availability, as influenced by previous crop and late-season fertilizer N timing under no-tillage soil management, on these relationships.

## Research Approach

The research has been conducted for two winter wheat production seasons (2000-01 and 2001-02), and a third (2002-2003) is underway. There have been two components to the work, both performed in small plot experiments. The first component addressed Objectives 1 and 2, above, and was established at locations alongside small grain variety trial sites in Western Kentucky to determine soil-environment, cultivar and basic N rate management aspects of the response. The second component focused on Objective 3 and consisted of a single experiment established at Spindletop (in Lexington) to determine previous crop and late N timing aspects of the response.

The field study located at the Western Kentucky sites consisted of two cultivars (two soft white), three levels of early N (75, 105 and 135 lb N/acre; 33% at Feekes 2-3 and 67% at Feekes 5) as urea, and three rates of late N (0, 20 and 40 lb N/acre at Feekes 10), also as urea. Top yielding cultivars were selected using information from University of Kentucky variety trials. Urea was used because it is widely available and is often the cheapest source of N for topdressing wheat in the spring. Four replications (blocks) were used in each experiment. As genetics was of lesser importance, wheat cultivar was the

main plot, while a complete factorial in the N management treatments was randomly assigned to split plots within each of the main plots.

The second component experiment involved an existing crop rotation trial, where no-tillage wheat is grown after both full season soybean and corn, which was the main plot. Wheat cultivars (one soft red and one soft white) served as split plots. The split-split plot treatments consisted of a factorial combination of three rates of late season N (0, 20 and 40 lb N/acre as urea) at four times of application (Feekes 9, Feekes 10, Feekes 10.2, and seven days after Feekes 10.2). Basal N management consisted of 75 lb N/acre. Four replications (blocks) already existed in the crop rotation trial.

**Results and Discussion – Component 1**

In general, there was little difference in grain yield between the two cultivars (Table 1). Yield responded positively to the early N rate at two sites, but the increment in yield was generally small, about 5-6 bushels/acre (Table 1). Late N rate also tended to raise yields, but the response was statistically significant only once (Table 1). In general, N nutrition was sufficient for near maximum yields in these studies.

The 25W33 always exhibited less grain protein than the 25W60, although chlorophyll (SPAD) meter readings taken on flag leaves at Feekes 10 were usually higher (Table 2). Cultivar differences like this have been observed previously. Greater early N resulted in increased grain protein at several locations, but was not dramatically improved at all sites (Table 2). The chlorophyll meter readings were more responsive to early N than was grain protein (Table 2). Late N rates resulted in much more dramatic increases in grain protein (Table 2), and those increases tended to be larger when the chlorophyll meter reading was lower. At this point, the results support the hypothesis that the chlorophyll meter can be used to guide late, near-flowering fertilizer N applications intended to raise grain protein in these soft white cultivars.

**Results and Discussion – Component 2**

In both years, wheat after corn exhibited erratic tillering and stand development and was not used in the protein study. In 2001, but not 2002, there was an interaction between cultivar and previous crop (Table 3). There was little difference between the two varieties when grown after soybean in either year, but in 2001 Pioneer 2540 yield declined more (-22 bu/acre) when planted after corn than did Pioneer 25W33 (-13 bu/acre).

The first of the late N applications to wheat after soybean was made between flag leaf emergence and “boot” growth stages (Feekes 9.5). The second was made during flowering (Feekes 10.2), while the third and fourth were made one and two weeks after flowering. All late N was broadcast over the top of the crop. Late fertilizer N addition positively influenced yield (Table 2), but there was no difference due to cultivar or the date that the late N application was made. Grain protein was positively related to late N application rate, was generally greater for the soft red wheat (Pioneer 2540), but was not affected by late N application date (Table 2).

There were significant interactions between cultivar and both late N application date and rate on grain protein concentration (Table 3). Pioneer 2540 was more sensitive to the other treatment factors than Pioneer 25W33. First, grain protein concentrations in P2540 rose over the first three application dates, while that for P25W33 did not (Table 3).

Second, as the rate of late N was increased, the grain protein concentration in P2540 increased more (+2.1%) than did that for P25W33 (+1.5%). It is not clear why P2540's grain protein concentrations were more sensitive to the timing of the late N. We observed that leaf chlorophyll levels (measured with a chlorophyll meter) were generally higher in P2540 and were raised more by 40 lb N/acre late N rate (data not shown). The P25W33 may not have been as able to recover the late N from the soil, or, more likely, its demand for grain protein N was being met by retranslocation from vegetative tissues. It is clear from this research that the grower's choice of cultivar can play a large role in the response to late N management. The research will be repeated in the 2002-2003 wheat production season.

The first of the late N applications to wheat after soybean was made between flag leaf emergence and "boot" growth stages (Feekes 9.5). The second was made during flowering (Feekes 10.2), while the third and fourth were made one and two weeks after flowering. All late N was broadcast over the top of the crop. Late fertilizer N rate positively influenced yield (Table 4) in 2001, but not 2002. This was somewhat surprising because it has generally been believed that such late N nutritional supplements have no yield benefit. The timing of the late N application had no impact on yield in either year (Table 4). Grain protein was not influenced by the timing of the delayed N application in either year, but responded positively to the rate of the late N both years (Table 4). There was no interaction between late N fertilizer rate and cultivar or the date that the late N application was made.

**Conclusion**

The results demonstrate that the late (at-flowering) application of urea can substantially increase the grain protein level of the soft winter wheats grown in Kentucky. The degree of protein response was negatively influenced by the N nutritional status of the crop at flowering, but only modestly. The chlorophyll meter provided additional predictive information regarding the degree of response to be expected. The research demonstrates that there is considerable potential for Kentucky's soft wheat producers to meet future protein specifications.

Table 1. Main Effects of Early and Late-Season N Nutrition on Yield of Two Soft White Winter Wheats

| Cultivar | Early Fertilizer N Rate | Late Fertilizer N Rate | Grain Yield 2001 McLean | 2001 Warren | 2002 Caldwell | 2002 Warren |
|---|---|---|---|---|---|---|
| | lb N/acre | lb N/acre | bu/acre | | | |
| P25W33 | | | 94.7a | 93.6a | 97a | 97a |
| P25W60 | | | 95.4a | 84.1b | 96a | 99a |
| | 75 | | 92.5b | 88.8a | 94a | 95b |
| | 105 | | 95.2ab | 89.2a | 97a | 99ab |
| | 135 | | 97.5a | 88.5a | 99a | 101a |
| | | 0 | 94.1a | 89.4a | 95a | 96b |
| | | 20 | 95.2a | 87.7a | 98a | 100a |
| | | 40 | 95.9a | 89.5a | 98a | 99ab |

Table 2. Main Effects of Early and Late-Season N Nutrition on Protein and SPAD Readings in Two Soft White Winter Wheats

| Cultivar | Early Fertilizer N Rate | Late Fertilizer N Rate | 2001 McLean Grain Protein | 2001 McLean SPAD Reading | 2001 Warren Grain Protein | 2001 Warren SPAD Reading | 2002 Caldwell Grain Protein | 2002 Caldwell SPAD Reading | 2002 Warren Grain Protein | 2002 Warren SPAD Readin |
|---|---|---|---|---|---|---|---|---|---|---|
| | lb N/acre | lb N/acre | % | | % | | % | | % | |
| P25W33 | | | 12.0b | 41.7a | 13.5b | 49.5b | 11.1b | 41.3a | 10.7b | 41.2a |
| P25W60 | | | 12.9a | 40.9a | 14.4a | 51.7a | 11.8a | 40.0b | 11.5a | 40.9a |
| | 75 | | 12.1c | 39.9c | 13.9a | 49.7b | 11.4a | 40.0b | 10.7b | 40.4b |
| | 105 | | 12.4b | 41.3b | 14.0a | 51.0a | 11.3a | 40.4ab | 11.2a | 40.7b |
| | 135 | | 12.8a | 42.7a | 14.0a | 51.2a | 11.3a | 41.5a | 11.3a | 41.9a |
| | | 0 | 11.1c | | 13.4c | | 10.8c | | 10.4c | |
| | | 20 | 12.5b | | 14.0b | | 11.4b | | 11.0b | |
| | | 40 | 13.7a | | 14.5a | | 12.1a | | 11.8a | |

Table 3. Effect of Previous Crop and Cultivar on Yield of No-Tillage Wheat

| Previous Crop | 2001 Wheat Cultivar | 2001 Grain Yield | 2002 Wheat Cultivar | 2002 Grain Yield |
|---|---|---|---|---|
| | | bu/acre | | bu/acre |
| corn | P25R40 | 63.5c | P25R37 | 48.0b |
| | P25W33 | 74.4b | P25W33 | 45.7b |
| soybean | P25R40 | 85.3a | P25R37 | 62.3a |
| | P25W33 | 87.3a | P25W33 | 67.2a |

Table 4. Main Effects of the Rate and Timing of Late Fertilizer N on Yield and Protein for No-Till Wheat Following Full-Season Soybean

| 2001 Late N Date | 2001 Late N Rate | 2001 Grain Yield | 2001 Grain Protein | 2002 Late N Date | 2002 Late N Rate | 2002 Grain Yield | 2002 Grain Protein |
|---|---|---|---|---|---|---|---|
| | lb N/acre | bu/acre | % | | lb N/acre | bu/acre | |
| 1-May | | 90.8a | 12.7a | 26-Apr | | 64.8ab | 13.2a |
| 10-May | | 91.1a | 12.8a | 3-May | | 61.9b | 13.5a |
| 16-May | | 89.5a | 12.7a | 10-May | | 66.6a | 13.6a |
| 23-May | | 88.2a | 12.5a | 22-May | | 64.9ab | 13.5a |
| | 0 | 86.3b | 11.7c | | 0 | 64.7a | 12.0c |
| | 20 | 90.7ab | 12.7b | | 20 | 66.2a | 13.8b |
| | 40 | 92.7a | 13.5a | | 40 | 62.7a | 14.5a |