# USE OF NEAR INFRARED (NIR) REFLECTANCE FOR IMPROVING NITROGEN MANAGEMENT IN SPRING WHEAT [1/]

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## INTRODUCTION

Advancements in agricultural technology are providing both producers and researchers with improved tools for farm management decision making. Reduced profit margins are requiring farm managers to use these advanced tools to optimize input management in order to improve profit levels.

Fertilizer nitrogen (N) is a major input for spring wheat in the Great Plains. Each year, many farmers fertilize spring wheat with nitrogen to improve seedling vigor and plant development. Nitrogen is a major nutrient for spring wheat development and is essential for dry matter production as well as for yield and protein content.

The maximum economic yield (MEY) concept has challenged producers to become more precise in their management practices. Producers using MEY practices in spring wheat are paying closer attention to their total production system. Since fertilizer management is part of the total production system, many producers are becoming more aware of the benefits of nitrogen management and are evaluating new techniques to help them decide if additional nitrogen treatments during the growing season to enhance yield and protein are warranted and economically feasible.

A group of innovative farmers from the Economic Producers MEY club in Hettinger County, North Dakota indicated an interest in exploring new techniques for improving nitrogen management in spring wheat. Their specific idea was to estimate the yield potential at Haun stage 6.0 using data collected at Mandan, North Dakota [5], which in turn would help them decide if the yield potential warranted an additional application of foliar nitrogen.

This paper describes the use of near infrared reflectance for determining the nitrogen content in ground spring wheat samples. A procedure for on-farm plant sampling is presented along with a discussion of future research needs.

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## BACKGROUND

Significant research has been done regarding the influence of nitrogen on yield and protein content in spring wheat [1] [2] [3] [6]. Recent research has shown that split nitrogen applications help control lodging and increase grain yield and protein content in spring wheat [6]. Research conducted by Jenny and Spilde [6] indicates that foliar applied nitrogen at Feekes growth stage 3 increased grain yield as well as protein content.

Bauer and Black [2] report that nitrogen concentration in leaves decreases linearly at about 0.293% for each unit increase in growth stage from an initial concentration of about 7.0% (Figure 1). Peak N content in leaves occurs at about Haun stage 9.0.Combined peak N content in leaves and stems was less than the total N in the head at ripe stage, thus indicating about 75% of head N content at ripe stage is translocated from leaves and stems.

Bauer and Black [2] further report that in cases of impending N deficiency during grain filling, their findings indicate that fertilizer N for yield maximization should be supplied shortly before the flag leaf stage, since leaves make up 50% of the total plant mass at this stage, and contain the largest amount of N to be translocated to the head.

Peak N concentration in grain occurs within the first 4 to 5 days after anthesis (heading), during which time final nitrogen (protein) concentration is likely determined [3]. Although this study conducted by Bauer et. al. cannot be used to determine precisely how late available N can be applied in the plant development cycle, assuring the necessary supply of N prior to anthesis appears to be essential. For example, if 3.25% of grain N concentration (dry basis) at harvest is acceptable (16.3% protein at 12% moisture), as expressed by regression presented by Black and Bauer [2] (Figure 2), it would appear that N concentrations exhibited in various plant parts could be considered the critical N concentrations at the specific growth stage to achieve this grain protein level.

Similar research with regard to critical N concentration has beenconducted on winter wheat [1]. Alley et. al. [1] found that Zadoks growth stage 30 (Haun stage 5.4) is probably the most critical period for providing optimum N fertilization, since it is at this stage that head development is occuring. Alley et. al. [1] further reported that it is possible to relate the percent N in tissue at Zadoks stage 30 with the amount of additional N required to produce the most efficient yield (Figure 3). Although more data is needed in this area of research, using percent N at Zadoks stage 30 as a guide to N rate is far better thansimply guessing. Intuitively, a method to determine the N content in the plant parts at a given growth stage must be developed to help producers make management decisions regarding foliar N applications to enhance protein and yield.

Near infrared (NIR) technology is currently used to determine protein content in spring wheat. NIR technology, when combined with statistical treatment, can be used to predict the percent of a desired consituent concentration in a given grain sample [8]. Research has proven that different constituents absorb light energy at different wavelengths. For

example, protein absorbs the 2.18μm band of near infrared light. By irradiating a sample with specific wavelengths of near infrared light, it is possible to predict the percent concentration by measuring the energy that is reflected [8]. Many country elevators have near infrared analysers for determining the protein content of spring wheat and other grains.

Noaman et. al. [7] found that NIR could be used to estimate protein concentrations in different above ground portions of the wheat plant at various growth stages. Above ground plant samples of Newana spring wheat were taken at anthesis, early dough, hard dough, and ripe stages, and were separated into flag leaf, peduncle, and head. Plant samples were dried to constant weight at 60 degrees Celsius and ground in a Udy cyclone mill (0.5 mm screen). The ground samples were analysed for N using the macro Kjeldahl procedure, with percent N multiplied by 6.25 for conversion to percent protein. These samples of known protein concentration were then used to calibrate the NIR instrument. Multiple regression analysis was used to select the best set of NIR filters for use in determining the percent protein by NIR. A significant coefficient of simple determination ($r2 = 0.96$) between the Kjeldahl and NIR methods proved that NIR can be a valuable tool for studying protein concentrations of various wheat aerial tissues during the growing season. Based upon this research, NIR should prove to be a useful tool for determining critical N concentrations at various plant development stages, thushelping the farm manager in deciding whether or not additional N applications are warranted based upon the crops yield potential.

Producers that are considering foliar applications of nitrogen are typically interested in determining whether they havesufficient yield potential to warrant a foliar application, and if the yield potential exists, how much additional N should theyapply to help insure the yield and protein potential are not limited by N supply.

## OBJECTIVES

The previous discussion indicates that NIR technology could be a useful tool for farm managers in deciding whether or not additional N applications are warranted. Since this is a single purpose investigation, the major objectives of this research paper are to:

1. Determine if NIR technology provides a statistically accurate method of determining percent nitrogen content in the aerial portion of ground spring wheat plant tissue.

2. Develop calibration coefficients to determine the percent N content in ground plant tissue by NIR through comparison with percent N as determined by standardized Kjeldahl procedures.

3. Describe a proposed on-farm sampling procedure to prepare spring wheat samples for NIR analysis.

## PROCEDURE

Above ground samples of spring wheat plants were taken at Haun development stage 4.6 for the purpose of calculating an NIR calibration

at this development stage. These plant samples were partof a fertility research experiment conducted at the USDA/ARS research station at Mandan, North Dakota during the 1988 growing season (Table 1). Four samples were taken from each subplot. The entire above ground portion of the plant (leaves and stems) was used. All plant samples were dried in a walk-in drying oven for 24 hours at 100 degrees F. Dried plant samples were then ground in a Wiley mill (2 mm screen), then ground further in a Udy cyclone mill (1 mm screen). All samples were placed in individual plastic ziplock storage bags to reduce the risk of additional moisture accumulation in the sample.

Table 1. Identification and description of plant samples taken for NIR calibration in 1988 growing season (samples from USDA/ARS, Mandan, North Dakota).

| PLOT ID | SAMPLE # | LBS N/ACRE |
|---|---|---|
| EHV 40N | 1 | 40 |
| | 2 | 40 |
| | 3 | 40 |
| | 4 | 40 |
| EHV 80N | 5 | 80 |
| | 6 | 80 |
| | 7 | 80 |
| | 8 | 80 |
| EHV 120N | 9 | 120 |
| | 10 | 120 |
| | 11 | 120 |
| | 12 | 120 |

The Dickey-John Instalab 800 NIR product analyser was used for obtaining NIR reflectance values on the ground plant samples. This instrument was made available from the Dickey-John company at no charge. Calibration instructions provided in the operations manual of the NIR instrument were used to obtain the reflectance values from the ground plant samples. Calibration mode 1.0 provided the best range of reflectance values (logarithms) for the six filters in the NIR instrument. Logarithm reflectance values between -20 and 400 are usable and will not adversely affect machine accuracy [8].

Total nitrogen content (protein + nitrate nitrogen) for each ground plant sample was determined using a macro Kjeldahl procedure. These known percent N values were then used with the logarithm reflectance values obtained from each ground plant sample to calibrate the instrument to determine the percent nitrogen content. The SAS (Statistical Analysis Systems) regression program was then used to solve the following equation:

Nitrogen (%) = K1(log 0) + K2(log 1) + K3(log 2) + K4(log 3) +

K5(log 4) + K6(log 5) + K0

where K0 is the intercept, K1 through K5 represent the calculated regression coefficients, and log 0 through log 5 represent the logarithm reflectance values obtained from the ground plant samples.

## RESULTS AND DISCUSSION

The analysis of variance (ANOVA) and parameter estimates for the multiple regression procedure are shown in Table 2. Filters 2 and 3 provided the best model for the range of data collected (R2 = 0.85). The R2 value indicates that a high degree of correlation exists between NIR and the Kjeldahl laboratory method for determining percent nitrogen content.

Table 2. ANOVA and regression coefficients for calibration of NIR instrument.

Analysis of Variance

| Source | DF | Sum of Squares | Mean Square | F Value | Prob>F |
|---|---|---|---|---|---|
| Model | 2 | 0.83700 | 0.41850 | 24.995 | 0.0002 |
| Error | 9 | 0.15069 | 0.01674 | | |
| C Total | 11 | 0.98769 | | | |

| | | | |
|---|---|---|---|
| Root MSE | 0.12940 | R-square | 0.8474 |
| Dep Mean | 4.51917 | Adj R-sq | 0.8135 |
| C.V. | 2.86325 | | |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | T for H0: Parameter=0 | Prob > \|T\| |
|---|---|---|---|---|---|
| INTERCEP | 1 | 1.037123 | 2.94586700 | 0.352 | 0.7329 |
| LOG2 | 1 | 0.301571 | 0.05800347 | 5.199 | 0.0006 |
| LOG3 | 1 | -0.280545 | 0.04230930 | -6.631 | 0.0001 |

NOTE

THIS MODEL INCLUDES ONLY THE DATA FROM THE 1988 PLANT SAMPLES RECEIVED FROM DR. ARMAND BAUER, USDA/ARS, MANDAN, NORTH DAKOTA. PLANT SAMPLES WERE TAKEN AT HAUN STAGE 4.5 TO 4.7.

In order to evaluate the accuracy of NIR, the parameter estimates given in table 2 were programmed into the Dickey-John Instalab 800, and percent N from the ground plant samples was determined using NIR and compared to laboratory Kjeldahl values. The results from this comparison are given in Table 3.

Table 3. Comparison of percent N in ground plant tissue at Haun stage 4.6 between Kjeldahl and NIR.

| SAMPLE ID | %N (KJELDAHL) | %N (NIR) |
|---|---|---|
| 1 | 3.97 | 4.17 |
| 2 | 4.14 | 4.28 |
| 3 | 4.26 | 4.42 |
| 4 | 4.17 | 4.32 |
| 5 | 4.56 | 4.83 |
| 6 | 5.33 | 4.62 |
| 7 | 4.72 | 4.72 |
| 8 | 4.35 | 4.34 |
| 9 | 4.84 | 4.93 |
| 10 | 4.73 | 4.71 |
| 11 | 4.84 | 4.78 |
| 12 | 4.74 | 4.74 |
| AVERAGE: | 4.55 | 4.57 |

A statistical analysis (t-test) performed on the means in Table 3 indicates no significant difference ( p = 0.05). This comparative analysis indicates that NIR is an effective method for determining percent nitrogen content in above ground portions of spring wheat. However, in order for this type of information to be useful to the farm manager, an on-farm sampling procedure mustbe developed as well as a table of guidelines to help the farmer determine if application of post-applied N is necessary and economically feasible based upon the crops yield potential.

ON-FARM SAMPLING PROCEDURE

Although the farm manager will not typically have the laboratory equipment that a researcher has available, an acceptable on-farm sampling procedure has been proposed that should help the farm manager conduct a test for determining critical nitrogen concentration in the above ground portion of his spring wheat plant. This on-farm sampling procedure, part of which is adapted from Alley et. al. [1], is outlined as follows:

1. Collect above ground plant samples from 3 random sites in the field at Haun development stage 4.5 to 5.0. A computer program entitled GROWTH STAGE [4] can be of great assistance in determining the development stage of spring wheat. The

samples must represent the majority of the field and thus unusual spots should be avoided. The area to be sampled should be selected by tossing a 3-foot long stick at least 10 feet in front of the individual taking the sample, orienting the stick with the row, and taking the sample [1]. Use a scissors to cut the plants just above the soil surface.

2. Dry the plant samples in a conventional household convection oven at 100 degrees Fahrenheit for a period of 3 hours. This will remove moisture from the plant samples.

3. Grind the dried plant samples in a conventional food processor until plant parts can no longer be identified. The sample must be ground as fine as possible in order to determine the percent nitrogen content by NIR.

4. Take the sample to the local elevator for further grinding in aUdy cyclone mill using a 1 mm screen. Most country elevators have a Udy cyclone mill for use in grinding small grain samples prior to determining protein content.

5. Determine the percent nitrogen content in the plant sample through use of an NIR analyser. Most country elevators have this instrument for determining protein content in small grains.

This sampling procedure should provide the farmer with a simple but reliable method of preparing the plant samples for analysis. Plant samples can then be analysed for percent nitrogen content.

SUMMARY

Advancements in agricultural technology are providing farm managers with improved tools for managing production inputs. The use of NIR technology is one such advancement.

The purpose of this study was to draw general conclusions concerning the use and accuracy of NIR technology for determining the percent nitrogen content in ground spring wheat samples. Although further research is needed to more accurately predict the economic feasibility of additional N applications, the following conclusions can be drawn at this point:

1. NIR analysis provides an accurate method of determining the percent nitrogen in ground spring wheat samples as evidenced by the data presented in tables 2 and 3. Limited sample numbers indicate other development stages have different percent N levels and NIR can detect these differences.

2. Farmers currently have the necessary resources available for preparing spring wheat plant samples for analysis.

Obviously, more research is needed in this area in order to build a database of critical nitrogen concentration levels at various plant development stages and across different yield levels for spring wheat varieties. As this database is built, tables and curves can be developed

to assist the farm manager in determining how much additional nitrogen to apply based upon the cropyield potential as estimated by farm managers using North Dakota research [5]. Development of these tables can no doubt be accomplished with current data, but is beyond the scope of this independent investigation. The validity and usefulness of NIR technology will no doubt play an increasingly vital role to assist farm managers in the decision making process for the economically feasible application of additional nitrogen for yield and/or protein level increases.

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Figure 1. Nitrogen concentration in leaves, stems, and heads of Alex-Olaf spring wheat in relation to growth stage, 1981-1982. Bauer et. al. [2].

Nitrogen concentration in leaves (○), stems (◊), and heads (●) of Alex-Olaf spring wheat in relation to growth stage, 1981-1982. Values are from all combinations of 3 fertilizer N and 3 water levels.

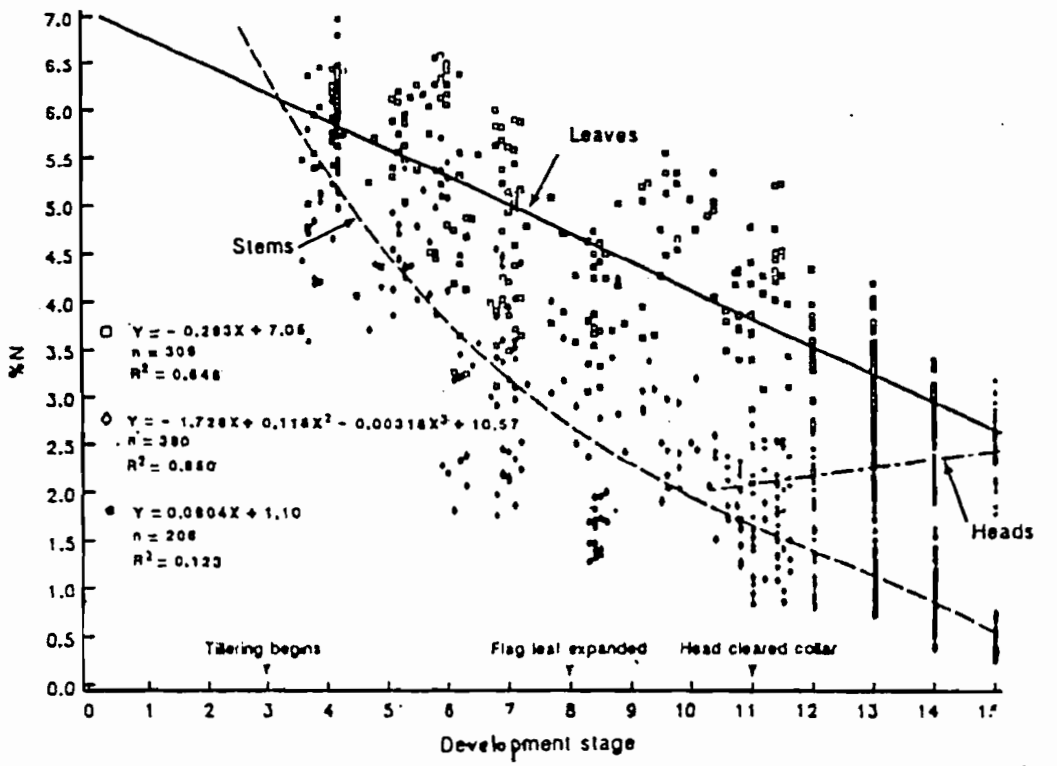


Figure 2. Regression with 95% confidence limits of days after anthesis and N concentration in grain of HRSW. Bauer et. al. [3].

Regression with 95% confidence limits of days after anthesis and N concentration in grain of hard red spring wheat, trials 79F, 81F, 82F,81NF, and 82NF. (Regression of kernel dry matter assimilation from Bauer et al., 1985 is included.)

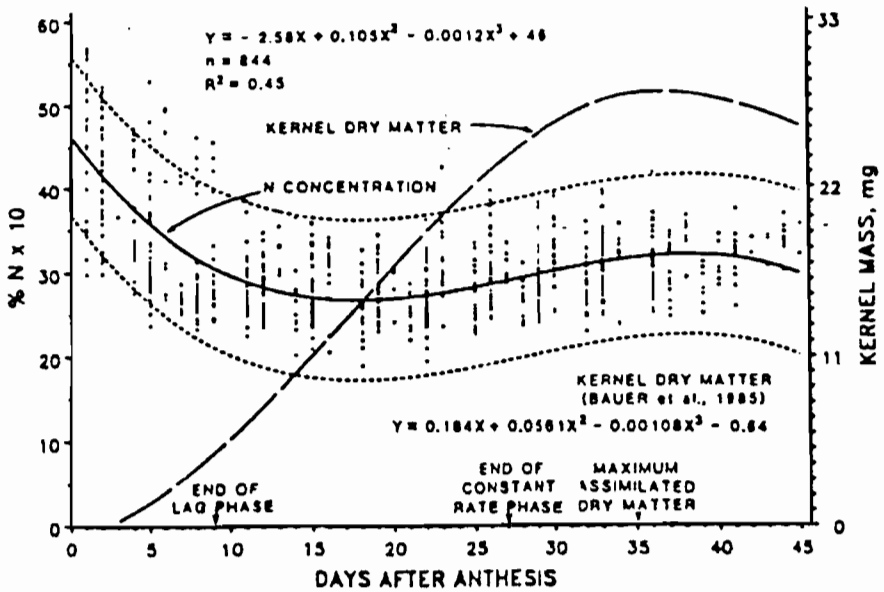
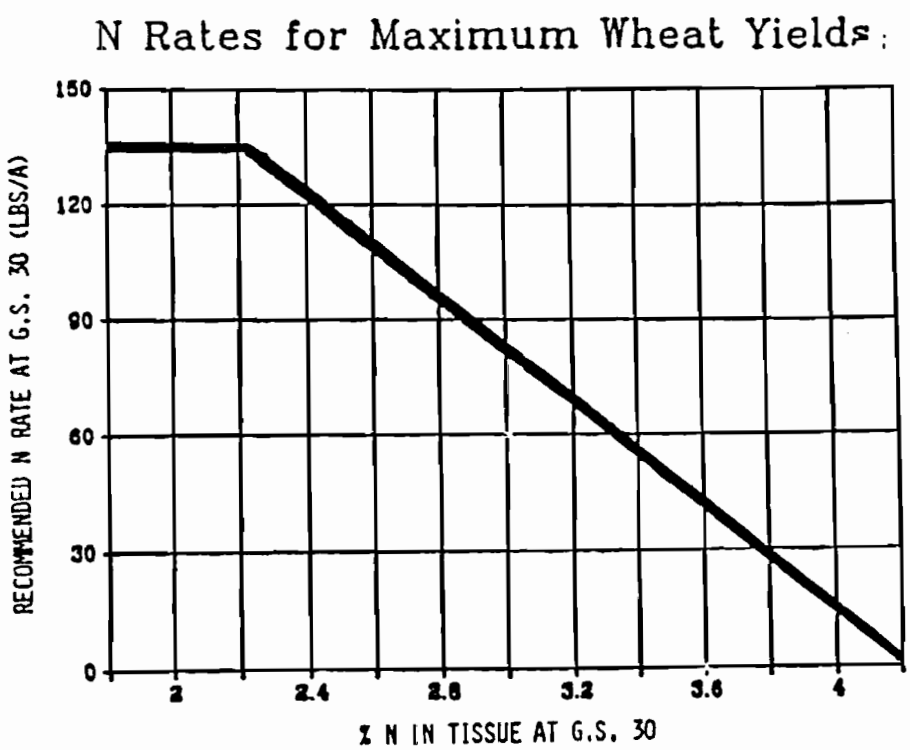


Figure 3. N Rates for Maximum Wheat Yields. Alley et. al. [1].



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