USING YIELD AND PROTEIN HISTORY FROM DRYLAND FIELDS TO IMPROVE NITROGEN FERTILIZER RECOMMENDATIONS[1]

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INTRODUCTION

Typical of dryland, where fallowed wheat yields range from 15 to 45 Bu/A, neither yield nor protein responses to nitrogen (N) fertilizer are consistent (2, 3, 4, 8). Workers at the Tetonia and Aberdeen Branch Stations in Intermountain Idaho began trials as early as the 1940's, but there were no unifying concepts that would allow projection of trial results to individual farm fields. Therefore, few reports have been published, although trials have continued to date (1, 5, 8, 9).

The purpose of this paper is to summarize and interpret the data collected over the entire period. We identified the two following goals:

1. The summary should be based on established agronomic relations, and

2. The results of the analysis should improve predictions of yield and protein responses to N fertilizer.

METHODS

All data used in this report were from replicated field experiments with either hard red winter or hard red spring wheat. The experiments were conducted on both on- and off- station locations, so that the range of eastern Idaho dryland conditions were represented. Usually farmer's plantings were used for off-station trials. Early trials indicated that there were no wheat varietal differences to N response (8), and so differences in farm varieties was not considered a variable. Therefore, yield and grain protein increases from N treatments were, respectively, converted to bushel and percent protein increase per pound N per acre applied. As final increments from high rates of N were expected to affect behavior differently than initial rates, etc., yield and protein changes from added N were analyzed separately for each treatment level with applied N. For example, where plots received 0, 30, 60, and 90 lb N/A, the 90 lb N/A plot was analyzed in comparison with the 60 lb N/A plot to determine the effect of the last 30 lb of N. Thus, if the

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90 lb N/A plot produced 3 Bu/A more than the 60 lb N/A treatment, the units recorded were

$$\Delta Y/\Delta N = 3(\text{Bu/A})/30\ (\text{lb N/A}) = 0.1$$

where ΔY is change in yield and ΔN indicates change in N rate.

We will show that this approach can be useful for any increment of N if the $\Delta Y/\Delta N$ value is compared with yield and protein content from the next lower N rate, or, in field situations with the "historic" yield and protein content.

INTERPRETATION OF RESULTS

Spring and winter wheat were initially considered and analyzed as different crops. However, regression trends indicated they were similar. Figure 1 shows that the yield:protein content relation is continuous, except that spring wheat is at the low yield:high protein content end of the scatter diagram.

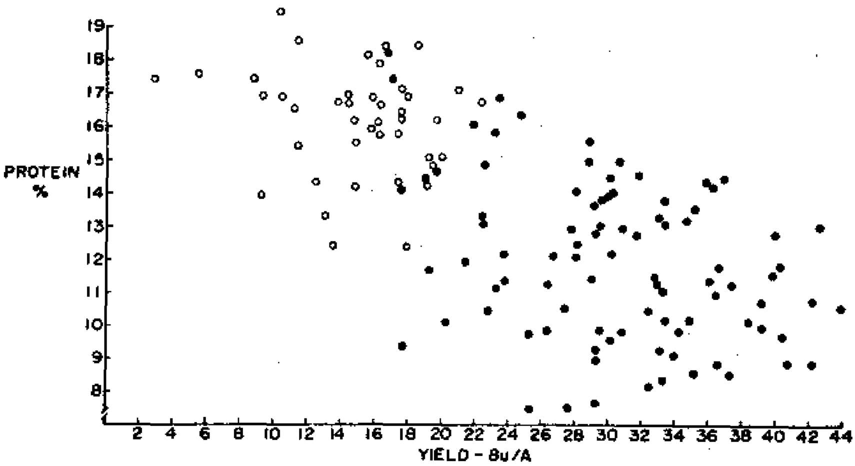

Fig. 1. Protein content vs. yield from plots show a continuous trend. Open circles are spring wheat and solid circles are winter wheat.

Another similarity (Fig. 2) comes from graphing yield increases caused by N, i.e. $(\Delta Y/\Delta N)$, versus protein content (in this paper, always from next lower N increment or "historic") where data for the spring wheat extends the distribution. Thus, spring and winter were analyzed and presented together.

Figure 2 illustrates that the best response to additional N is on low protein wheat fields. This same phenomena has been reported previously for Oregon and Washington (2, 3, 4, 6, 7). Agronomically, protein quantity reflects N availability. The more abundant wheat kernel carbohydrate content is quite dependent on moisture supply. Thus, the percent protein essentially compares protein to carbohydrate amounts and is a growing season integration of the nitrogen-to-moisture status. A "best fit" line for this relationship (Fig. 2) with the formula

$$(\Delta\hat{Y}/\Delta N) = -0.09 + 19.3\ (1/\%\ \text{protein})^2$$

indicates the (1/% protein) term should be used in any further multiple regression approach.

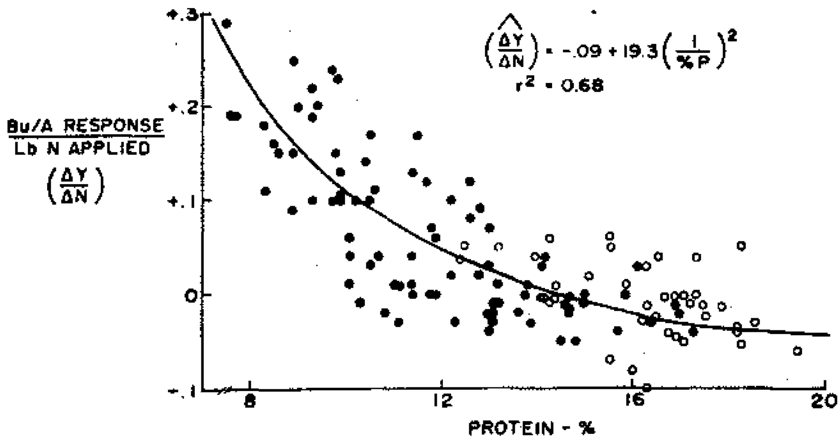

Fig. 2. Comparison of $\Delta Y/\Delta N$ vs. percent protein, indicating that winter wheat (solid circles) and spring wheat (open circles) individually and collectively show a trend. Highest $\Delta Y/\Delta N$ values were from plots where grain protein content was low.

Better estimates of yield responses to N can be made by considering both yield and protein content of wheat. It was obvious from Fig. 1, where highest yields were from plots having the lowest protein, together with Fig. 2 where low protein plots responded to N best, that the higher yielding plots should respond to N best (see also reference #6). The following equations might appear to depict just the opposite, and so an explanation is given. If Fig. 1 had included the value of $\Delta Y/\Delta N$ for each point plotted, a trend would have developed showing similar $\Delta Y/\Delta N$ values occurring in bands (Fig. 3). These bands indicate that there is a relationship between yield and protein content which governed $\Delta Y/\Delta N$. At a given protein content, the largest $\Delta Y/\Delta N$ values are found with the lowest yields. The statistical analysis method used to study this aspect was to relate yields vs. protein contents as a function which separated the positive from the negative $\Delta Y/\Delta N$ values. This line or function may be called the "line of zero return" (Fig. 4) because it represents the protein content - yield relation where no yield response can be expected from added N. Subtracting a protein level found from the "line of zero return" is done by the expression:

$$[17.5 - 0.125\ (\text{Bu/A}) - \text{observed}\ \%\ \text{protein}]$$

where both the Bu/A and observed % protein figures are inserted from

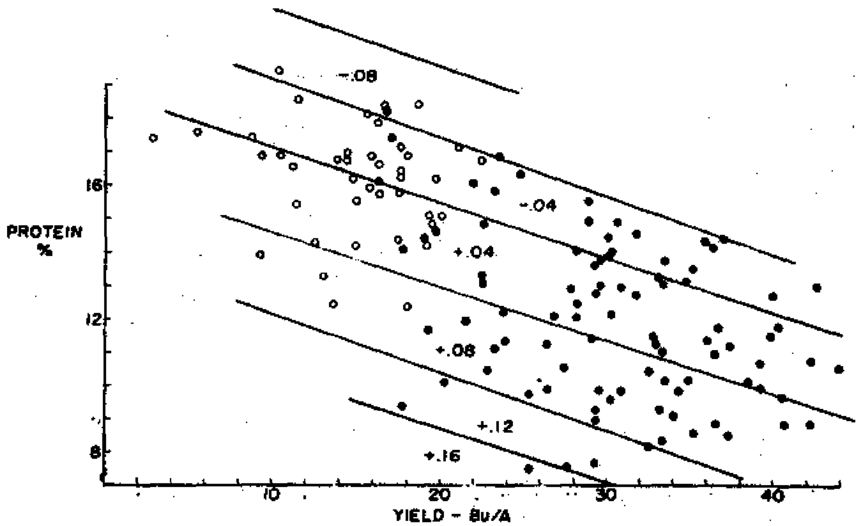

Fig. 3. Protein content vs. yield of wheat where lines group together similar $\Delta Y/\Delta N$ values. The approximate mean value is indicated between the lines.

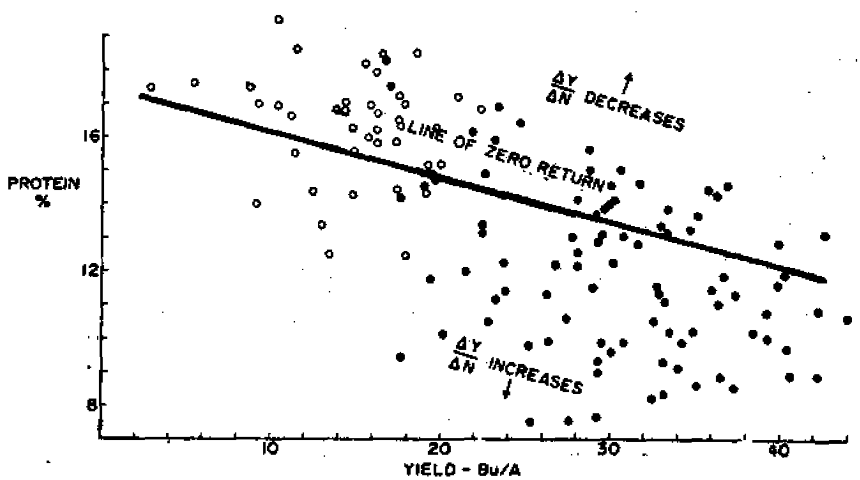

Fig. 4. A "line of zero return", having protein content as a function of [17.5 - 0.125 (Bu/A)] indicates the yield and protein where no changes in yields were found from added N.

field data. Regressing $\Delta Y/\Delta N$ on this expression indicates:

$$(\hat{\Delta Y}/\Delta N) = 0.013 + 0.027\ [17.5 - 0.125\ (\text{Bu/A}) - \text{observed \% protein}]$$

$$= 0.49 - 0.003\ (\text{Bu/A}) - 0.027\ (\text{observed \% protein})$$

$$r^2 = 0.66$$

This regression did not have as high a correlation coefficient as where $(1/\%\ \text{protein})^2$ was used previously. Thus, incorporating $(1/\%\ \text{protein})^2$ by multiple regression shows:

$$(\hat{\Delta Y}/\Delta N) = 0.155 - 0.00147\ (\text{Bu/A}) - 0.01176\ (\%\ \text{protein}) + 11.86\ (1/\%\ \text{protein})^2$$

$$R^2 = 0.71$$

which was the best estimate found while adhering to the goals of this paper.

Changes in protein content from N fertilizer were also related to yield and protein content. Dividing yield by $(\%\ \text{protein})^2$ gave terms that were negatively related to the change in percent protein per lb N applied per acre, i.e. to $\Delta P/\Delta N$. As a second term for use in multiple regression, % protein was also negatively related. Thus:

$$(\hat{\Delta P}/\Delta N) = 0.14 - 0.069\ \left[\frac{\text{Bu/A}}{(\%\ \text{protein})^2}\right] - 0.0072\ (\%\ \text{protein})$$

$$R^2 = 0.64$$

This relation indicated that plots having low protein wheat responded best to N for producing a total protein (% protein x Bu/A) change, but only after the potential yield increases from N were first acquired. The average $\Delta P/\Delta N$ for all plots was 0.037, or a 1.3% increase with a conservative 35 lbs N/A rate.

SUMMARY AND FIELD USE

Yield and protein changes from N fertilizer were estimated using historic yield and protein content. It made little difference whether spring or winter wheat was being analyzed, because their inherent differences in yield and protein content accounted for associated differences in N response (spring wheat had less response than winter). Using a conservative 35 lb N/A, from final equations shown, gave the calculated responses shown in Table 1.

The interpretation in this report was derived from evaluating the effects of individual increments of fertilizer N. These averaged near 35 lb N/A. The corresponding yields and protein contents were taken ahead of the increment in question. However, the equations given here can also be used correctly to estimate responses from using higher N rates. Doing this merely requires that the response to each increment of up to 35 lbs N/A be computed as separate steps until the rate in question is reached. That is, the change in yield and protein content from the initial 35 lb N/A application should be added to the base amounts before calculating the effect of a second N increment, etc. Usually it will be found that the effects of N become less and less pronounced with additional N increments.

Table 1. Expected increases in wheat yield (Bu/A) and protein (%) (in parenthesis) from adding 35 lb N/A.

	Historic Protein Content - %			
Historic Yield	7	10	13	16
Bu/A	Bu/A and % protein			
15	10 (2.4)	5 (2.0)	2 (1.4)	0 (0.7)
30	9 (1.6)	4 (1.6)	1 (1.1)	-1 (0.6)
45	9 (0.9)	3 (1.3)	0 (1.0)	-2 (0.5)

Where stored soil moisture, date of planting, etc. are expected to change the yield and protein from a "historic" value, this information should be used initially rather than a "historic" average.

Thus, it has been shown that the wheat plant itself has expressed an integration of growth factors by its final yield and protein content, which also expresses how it would have responded differently had the nitrogen nutrition been different.

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