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Post-harvest evaluation of nitrogen management—a new approach for "selling" soil testing to wheat farmers[1]

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ABSTRACT

Nitrogen deficiencies are becoming more common in traditional wheat/fallow areas of the Great Plains as yield potentials have increased, while native soil fertility declines. Adequate calibration data exists for preventing these deficiencies through nitrate soil testing and N fertilizer application, but the problem is in "selling" this program to growers who have never used soil testing. The proposed education approach utilizes two principles: 1) wheat farmers generally have astute memories of the past protein levels in their grain, and 2) grain protein content is a reliable indicator of past nitrogen deficiency. This approach links the necessity of soil testing to 1) the grain protein content or 2) the percent hard and vitreous kernels (for durum wheat producers). Guidelines for eastern Colorado and western North Dakota have been developed. It would not be difficult for extension agronomists to take existing response data and develop guidelines proper for their locale.

Additional index words: **Nitrogen fertilization, Extension education, Durum wheat fertilization, Grain quality.**

TRADITIONALLY, summer-fallowing has been performed in the Great Plains for several reasons: moisture conservation, nitrate accumulation, and weed control. Nitrogen fertilization experiments conducted 20 to 30 years ago showed little response of wheat (*Triticum aestivum*) to N fertilization in eastern Colorado (Brengle and Greb, 1963) or western North Dakota (Bauer et al., 1970). Apparently nitrate release during the summer fallow period was adequate to meet production potentials at that time. Today, however, N deficiencies after summer fallow are becoming more common, as production potentials are increasing (due to improved varieties, better equipment, more timely field operations, etc.), and native soil N reserves are decreasing (due to crop removal and soil erosion). For example, Goos (1980) demonstrated that roughly 50% of the

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wheat fields in eastern Colorado would respond profitably to added N. Dahnke et al. (1982), in summarizing North Dakota soil test data over the years 1972–1981, showed that 55% of the summer-fallowed fields in western North Dakota had inadequate nitrate reserves for a 2350 kg/ha (35 bu/A) yield goal. Present use of N fertilizer in both of these production areas, from this author's observation, is far below the indicated agronomic need.

The answer to this problem is education, not research. Adequate nitrate soil test calibration data has been compiled for accurate N recommendations, if only increased participation could be achieved. The traditional extension approach has been to promote soil testing on its own merits, which are many. However, after speaking at over 40 farmer field days in Colorado and North Dakota, an alternative approach to presenting the need of soil testing and N fertilization has been developed. This approach ties together the relatively unfamiliar technology of soil testing to the extremely familiar concept of wheat protein content, a grain marketing criteria. The purpose of this paper is to show how the protein/soil testing guidelines have been developed and how they are being successfully used in extension programs.

PROCEDURE

Thirty replicated N rate experiments with hard red winter wheat in eastern Colorado were performed over the 1977–1980 growing seasons. Fifteen replicated nitrogen rate experiments with hard red spring wheat were performed in western North Dakota over the 1981–1982 growing seasons. Four replicated N rate experiments in North Dakota with durum wheat (*Triticum durum*) were performed by Dahnke et al. (1981) and grain quality data obtained by this author. Details of these experiments can be found in Dahnke et al. (1981); Goos (1980); Goos et al. (1981a); and Goos et al. (1982a). Grain yields, protein contents, and other quality parameters were performed by standard methods. Rates of N employed varied by experiment, but typically were 0, 28, 56, 84 kg N/ha or 0, 34, 68, 101 kg N/ha.

The following steps were used to determine rule of thumb grain protein guidelines.

1. The experimental yield and protein data were averaged across replication.
2. The experimental data were averaged across other experimental factors (except N rate) where appropriate. For example, if the experiment had a N rate × N source factorial design, and no significant differences existed between N sources, the data were averaged across N source and replication. Alternatively, treatments for analysis were selected which gave a N response curve which was unconfounded by other factors. For example, if the experiment was a N rate × P rate factorial design, and a significant phosphorus response was obtained, the data were selected from those treatments where P was not limiting yield. Or, if a particular N source (e.g., urea) gave a poorer N response than other sources (e.g., anhydrous ammonia or ammonium nitrate), then observations from the inferior source were not used.
3. The data for each experiment were thus reduced to a series of N rates and the resulting yields and protein contents. The yield data were then recalculated on a relative basis. Each yield was divided by the highest N fertilized yield for that experiment and multiplied by 100. The data for each experiment were thus reduced to a series of relative yields and grain protein contents as a function of N rate. If, at unreasonably high N rates, there was a yield reduction due to over fertilization of N, those observations were deleted. If N rates applied were inadequate to provide a yield maximum (yields still increasing at the highest N rate), the relative yields were calculated as described above, but the data from the highest N rate were deleted from subsequent graphical analysis. This was done because of the uncertainty of whether enough N had been applied to maximize yield.
4. Plots were made of the relative yield observations (Y-axis) as a function of the protein content observed at that relative yield (X-axis). The plotted data were visually inspected for a "break" between the N deficient observations and the N sufficient observations. The author has always found visual inspection of the data to be adequate, however, if data scatter precludes a simple visual determination of the protein critical level, then the graphical Cate-Nelson Method (Nelson and Anderson, 1977) should be employed. If data scatter precludes the use of the Cate-Nelson procedure, then the interaction chi-square approach (Keisling and Mullinix, 1979; Goos et al., 1982c) should be used.

RESULTS AND DISCUSSION

Protein vs. relative yield plots obtained for winter wheat in Colorado, and hard red spring wheat in North Dakota are displayed in Fig. 1 and 2, respectively. It does not take an involved statistical analysis to discern the protein critical levels for each of these graphs. For hard red winter wheat in Colorado, a critical level of 12% protein is apparent in Fig. 1. In other words, grain protein contents less than 12% are associated with substantial yield loss from N deficiency. Many cultivars ('Scout 66', 'Vona', 'Centurk', and 'Baca') are included in this data set. The "12% rule" in eastern Colorado has been widely publicized (Goos and Ludwick, 1980;

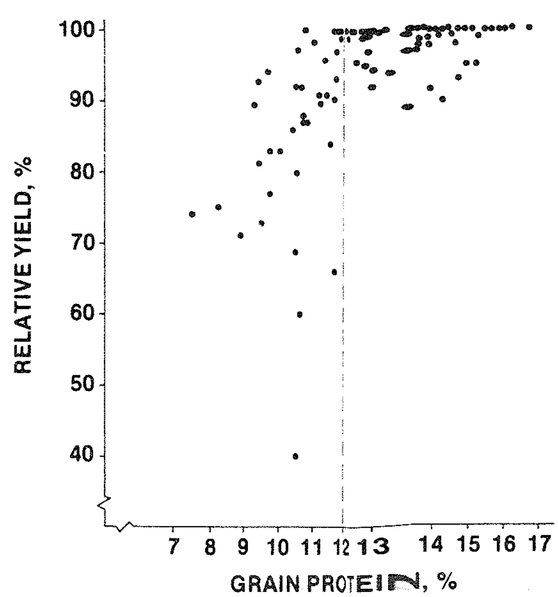

Fig. 1. Relative yields of four hard red winter wheat varieties as related to grain protein content. Colorado, 1977–1980.

Goos et al., 1981b; Goos et al., 1981c; Goos et al., 1982b; and Westfall et al., 1981) and has been received enthusiastically by extension agents and fertilizer dealers as a scientifically accurate, yet easily understood tool for the promotion of improved N management. The author has found that wheat producers, in general, have astute memories of the past protein contents produced on their fields, as the price received per bushel is determined in part by the protein content. Relating yield losses from N deficiency to the grain protein content has proven to be an effective concept association in the promotion of soil testing and advanced fertilization methods.

For hard red spring wheat in western North Dakota ('Len') a critical level of 14% protein is apparent (Fig. 2). This rule of thumb is presently receiving wide exposure in extension meetings in North Dakota (Carl Fanning, Extension Soils Specialist, NDSU, personal communication), and in grower-orientated publications (Goos et al., 1981a; Goos, 1983). Again, these results are easily understood and appreciated by wheat farmers, as grain protein determinations are a routine part of the marketing process. It must be cautioned that there is more varietal variability in the commonly grown hard red spring wheats than in the commonly grown hard red winter wheats, and protein guidelines must be interpreted accordingly.

Grain protein content, per se', is not a commonly determined parameter in the marketing of durum wheat. Instead, the percentage of hard and vitreous kernels is a major determinant of grain grade. Grain protein content is inversely correlated with the percentage of "yellowberry" kernels (Robinson et al., 1977). Since yellowberry kernels are graded as non-hard and vitreous, grain protein content and the percentage hard and vitreous kernels are directly correlated. The relative yield vs. vitreous kernel plot ('Cando') is shown in Fig. 3. Even though the number of sites included is limited for this analysis, a critical level of around 80% hard and vitreous kernels is indicated. This can be further related to grain grade. Durum wheat must have greater than 75% hard and vitreous kernels to make hard amber grade. This finding has also led to another useful extension education tool, that if a grower's durum will not make hard amber grade because of yellowberry, then yield loss from N deficiency was likely. Again, a strong case for improved N management in durum wheat can be made by relating the well-understood concept of grain grade to profit lost from N deficiency.

The protein critical levels derived have been remarkably constant for a wide range of yield levels. For example, the 12% rule for winter wheat was derived from maximum yield observations of 1240–3830 kg/ha (Goos et al., 1982c). In years of moisture stress, yields will be depressed and protein contents will generally be high (Terman et al., 1969). However, in such years the N requirement for maximum yield will also be lower. Thus, the grain protein critical levels have been found to be applicable in both good and poor years.

There have been instances in this author's experience where these simple protein critical levels have been shown not to be valid, however. For example, if the field has a nitrate distribution such that an early season N deficiency occurs, and later in the season the roots take up a deeper supply of nitrate, then high protein grain will result on a field that suffered a yield loss from N deficiency. Such cases have been unusual.

CONCLUSION

The post-harvest evaluation of past N management through grain protein critical level analysis has been a very successful extension education tool in Colorado

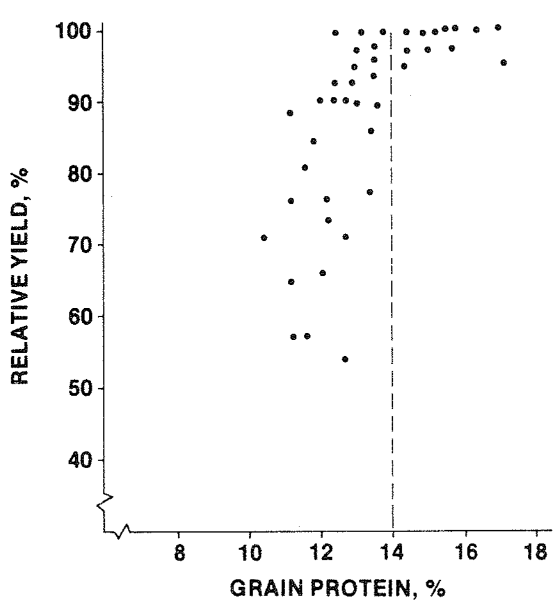

Fig. 2. Relative yields of 'Len' hard red spring wheat as related to grain protein content. North Dakota, 1981–1982.

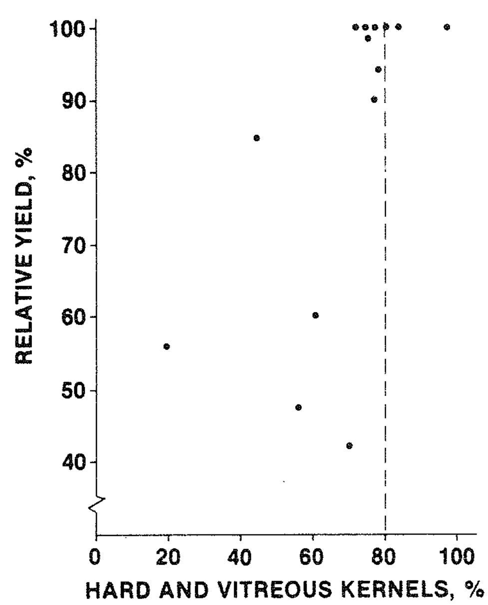

Fig. 3. Relative yields of 'Cando' durum wheat as a function of hard and vitreous kernel percentage. North Dakota, 1981.

and North Dakota. Arranging existing research data to discern the "critical level" is not difficult, and provides growers, extension personnel, and fertilizer dealers with easy to interpret guidelines for evaluating past N fertilization practices. This approach should hold promise for extension use on other crops where protein information is commonly determined, such as malting barley. This approach should also prove to be useful in other wheat production areas.

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