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Is Fertilizing For Grain Quality Different From Fertilizing For Yield?

Illinois studies show that N rate needed to maximize grain protein is higher than that needed to optimize grain yield.

Summary: *Fertilizer recommendation systems for grain crops typically have been developed for maximum grain yield, without really knowing if these systems lead to optimal grain quality. Using corn as our example species we will review how fertilizer mineral nutrients might alter grain quality, and present some of our research results examining the nitrogen (N) levels needed to optimize grain protein concentration. Nitrogen-rate trials conducted at various sites across Illinois over the past few years invariably have shown that the amount of N fertilizer needed for optimal grain protein is higher than that needed to maximize grain yield. We also have demonstrated that genetics (i.e. hybrid makeup) plays a major role in our ability to modulate corn grain protein with N fertility, and we suspect this is also true for other quality components and other fertilizer nutrients. The inevitable improvement in grain quality using biotechnology could have important ramifications in future nutrient needs.*

Farmers usually apply fertilizers in hopes of obtaining maximum yield and profit, with little regard to their possible impact on grain quality. This view, however, could change in the future as more and more farmers grow specialty crops designed to contain a specific grain quality component. Grain quality itself is a fairly vague and encompassing term usually used to refer to the major seed storage products such as starch, protein, and oil. Grain quality, however, can also refer to a wide array of other grain factors such as the metabolites (i.e. sugars, amino acids, fatty acids), vitamins, or mineral nutrients found in crop seeds, many of which may have high economic values, depending on their end use.

Mineral nutrients

Because of the many components and/or definitions of grain quality, there are also multiple ways by which grain quality could be altered by mineral nutrient fertility. One obvious example is where an increase in the supply of a particular mineral nutrient leads to an increase in that nutrient in the seed. For this quality component, the inherent level (and range) of a particular nutrient in the seed largely determines its ability to be positively altered by increasing its availability through fertilization. An example of the variable levels and ranges of mineral nutrients found in corn grain is shown in Table 1.

By inference, grain nutrients present in low amounts, and with small ranges (i.e. Ca and Fe), would not be expected to be easily alterable through fertilization, while the opposite should be true for elements present in large amounts and with high ranges (i.e. N and phosphorus (P)). Using this approach, if the level of a particular seed nutrient is not at its maximum, then it can generally be increased with fertilizer additions.

Table 1. The average concentration and range in some mineral nutrient elements in corn grain.

Mineral	Mean%	Range%
N	1.29	1.02 - 1.50
P	0.38	0.22 - 0.54
K	0.48	0.31 - 0.62
S	0.10	0.09 - 0.14
Mg	0.14	0.09 - 0.22
Ca	0.03	0.01 - 0.04
Fe	0.003	0.001 - 0.09

Adapted from Heckman et al. 2003

Scientific literature is replete with examples showing where fertilizer additions positively increased the level of a particular quality component in the grain. Alternatively, we suspect there are even more unpublished studies where fertilizer additions had no effect on the concentration of a given grain quality component, presumably because the level of that component was already at its maximum range.

Further complicating this approach are instances where it is disadvantageous for a fertilizer to increase the mineral nutrient level in the grain. An example would be phytate (the major storage form for P in the seed), which can be high in the manures of corn-fed animals, leading to P runoff and degradation of water supplies. Thus, even though mineral nutrients themselves are important components of grain quality, positively altering their

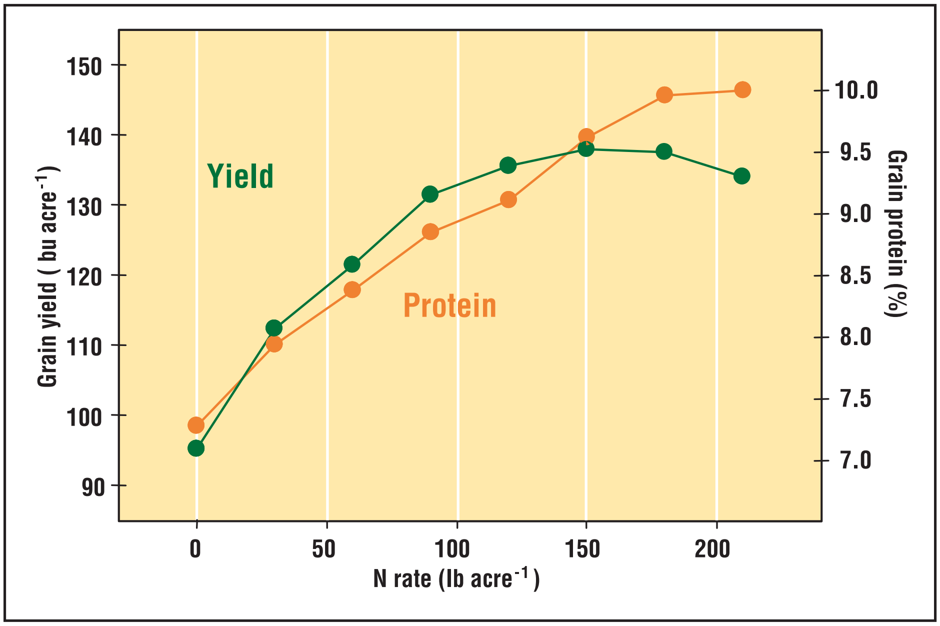

Figure 1. Generalized effect of fertilizer N rate on yield and protein percentage of corn grain, 2000-2003.

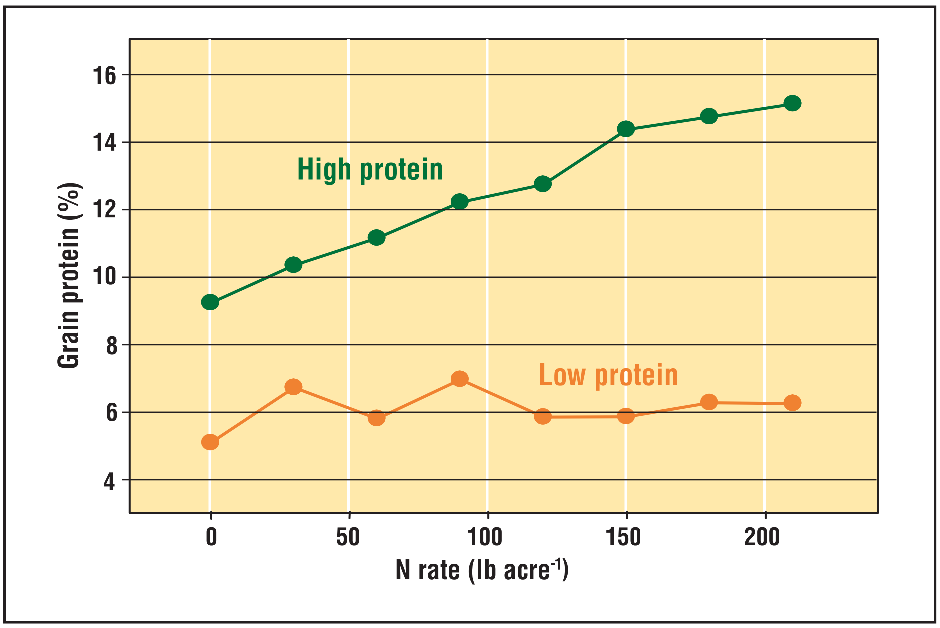

Figure 2. Response of an ultra-high grain protein hybrid and ultra-low grain protein hybrid to incremental increases of N supply, 2000-2003.

levels in the grain (by fertilizing) can be very difficult, requiring considerable knowledge of the specific nutrient's role in seed storage.

The nutrient elements in the grain that are most likely to be altered by fertilization are those that are elemental components of the major storage products: starch, protein, or oil. Of these three storage products, only protein contains mineral nutrients, including N (approximately 12%) and sulfur (S) (approximately 1%). As a result, N and S are the mineral nutrient elements in corn grain that are most likely to be modulated through fertilization. In addition to directly affecting the level of a grain quality component, fertilizer or mineral nutrients can also indirectly alter grain quality by changing the plant's metabolism or physiology. While the possibilities for enhancement in grain quality through altered plant metabolism are innumerable, it is very difficult to describe and predict physiological processes with certainty, which makes managing them with fertilizer nearly impossible. Thus, we will not discuss this concept further, even though we are well aware that optimizing plant growth through proper nutrition can improve many aspects of grain quality. What we will discuss are some of our program's research results evaluating fertilizer N rates needed to optimize grain yield and grain protein concentration in corn grain. We will also examine how genetic differences in grain protein level alter the N rate/protein percentage relationship.

N response

Yield vs. protein. Our N response trials were conducted in Illinois over the last four years. While the data produced showed that grain yield and grain protein increased simultaneously as the N rate went from deficient to sufficient, it also demonstrated that the N rate needed to maximize grain protein was higher than that needed to optimize grain yield. For this data, the response function of grain yield to fertilizer rate is clearly quadratic, with an optimal N rate of about 150 lbs/A of N. Conversely, the grain protein response function to increasing N supply was much more linear, with more than 150 lbs/A of N being needed to achieve maximum protein percentage (Figure 1). A similar generalized response in yield and protein to increasing N supply has also been noted for wheat and other small grains.

Hybrid effect. While grain yield response to N supply was basically similar for all the hybrids evaluated, the ability to modulate a hybrid's grain protein concentration with the N supply was highly genotype dependent. This dependency is illustrated in Figure 2 where grain protein concentration of an ultra-high protein hybrid responded linearly to increasing N supply, while protein concentration in the low-protein hybrids was not influenced by the N supply. While these data demonstrate the strong genetic control that is exerted over grain composition, they also show the interactive effects of N supply and genotype that can alter grain composition. This finding has important ramifications for N fertilizer usage, as high protein hybrids would require more fertilizer N than low protein hybrids to achieve their higher grain protein. Thus, large changes in grain protein percentage (or potentially other grain quality components) resulting from genetic selection of biotechnology would undoubtedly alter the relationship between grain productivity and N needs, thereby changing the absolute requirements for fertilizer nutrients.

Methodology

These trials included corn hybrids with wide variation in grain protein percentage and were conducted between 2000 and 2003 at the Crop Sciences Research and Education Center in Champaign, the Northern Illinois Agronomy Research Center in DeKalb, and the Joliet Junior College Demonstration and Research Center in Joliet.

Fifteen different hybrid/N rate combinations were used. All trials involved incremental increases in fertilizer N rate (usually 0 to 210 lbs/A in 30- or 40-lb increments) always supplied as ammonium sulfate.

All trials were part of statistically replicated and randomized experiments and all demonstrated significant N-induced increases in grain yield and grain protein concentration.

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