HOW MUCH NITROGEN DO SOYBEANS LEAVE FOR CORN?

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Many studies in Iowa have shown that the optimal rates of N fertilization for corn following soybean tend to be less than the optimal rates for corn following corn. This conclusion is supported by data presented in Figure 1, which summarizes the results of 35 pairs of N-response trials having 10 rates of fertilizer N applied. Quadratic-plateau yield response curves were fit to the data from each site and analyzed to determine economic optimum rates of fertilization. The mean economic optimum rates of fertilization were 103 lb N/acre for corn following soybean and 163 lb N/acre for corn following corn.

Data presented in Figure 1 show that maximum yields of corn following soybean were 11% higher than those for corn following corn. This yield difference is due to effects of rotation on insect damage, disease problems, moisture availability, and other yield-limiting factors not related to N availability. Although such effects increase the overall benefits of alternating corn and soybean crops, they complicate efforts to quantify the amounts of N that seem to be carried over from soybean to corn.

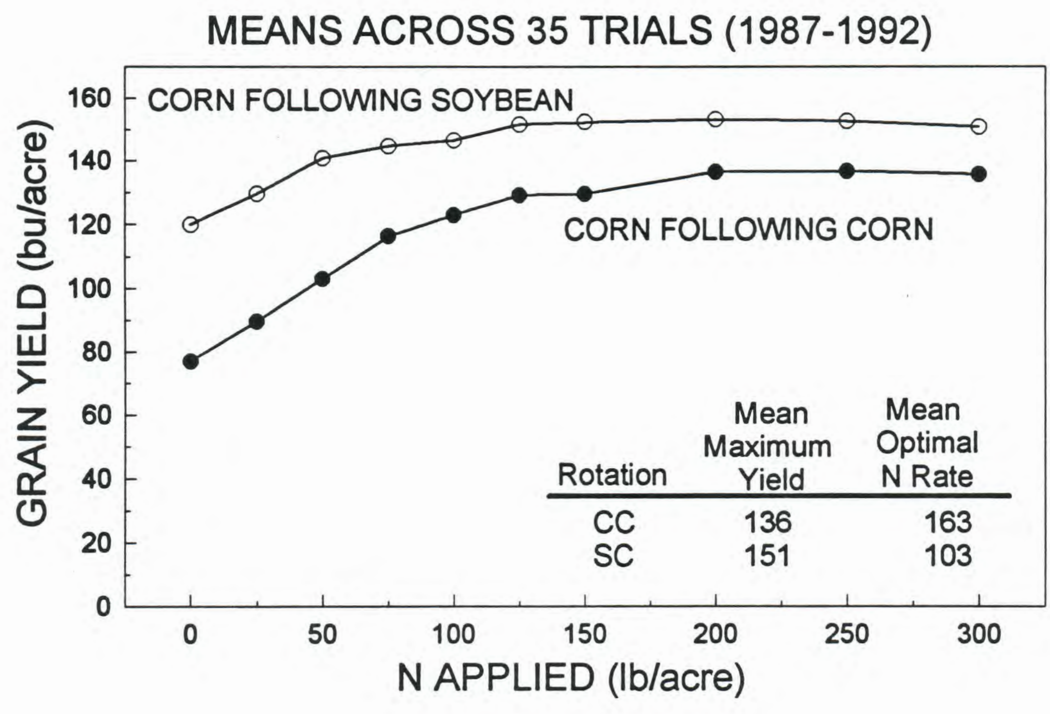

Figure 1. Summary of results of 35 pairs of trials comparing the responses of corn following corn and corn following soybean to N fertilizer broadcast and incorporated shortly before planting (from Meese, 1993). The analyses are based on a fertilizer price of $0.10 /lb N and a grain price of $2.50/bu.

Data presented in Figure 2 show that the difference in fertilizer requirement between the two rotations differed greatly among the 35 pairs of trials. The variability is great enough that the mean difference in fertilizer requirement provides little information that is useful for selecting rates of fertilization at individual sites. The variability cannot be explained by merely considering differences in soybean yields.

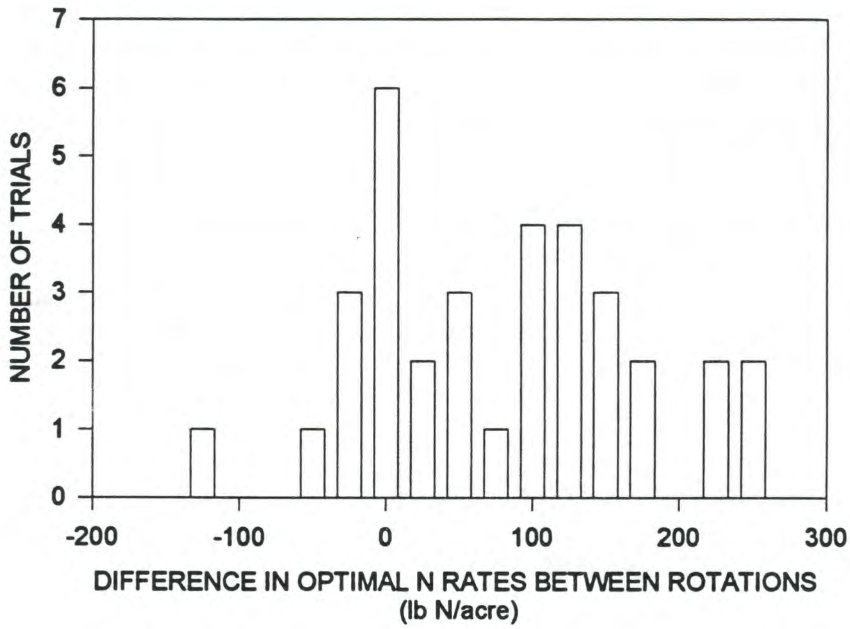

Figure 2. Frequency distribution for differences in optimal rates of N fertilization between corn following corn and corn following soybean in response trials at 35 sites.

Mechanism of N "carryover"

It is commonly assumed that the difference in optimal rates of N fertilization can be explained by carryover of biologically fixed N from soybean to corn. This explanation, however, is inadequate because the best-available estimates indicate that the amounts of N exported from fields during soybean harvest greatly exceed the amounts fixed during growth of this crop (Heichel and Barnes, 1984). The amounts of N harvested can exceed the amounts fixed because soybean crops also take up nitrate and ammonium from the soil.

Studies of the concentrations of N remaining in the organic fraction of soils in long-term rotation-fertility trials in Iowa show that soybeans place a drain on supplies of soil N. Pottker (1987) found that organic matter concentrations decreased more rapidly under corn-soybean cropping sequences than under corn-corn cropping sequences if adequate N fertilizer is applied to avoid yield-limiting deficiencies of N in both rotations. These observations suggest that the lower fertilizer requirement for corn following soybean must be attributed, at least in part, to a greater net mineralization of soil organic matter after soybean.

Recent laboratory studies explain why net mineralization of N tends to be greater following soybean than following corn (Green and Blackmer, 1996). The results (see Figure 3) reveal a difference in amounts of plant-available N consumed (i.e., immobilized) by soil microorganisms decomposing corn and soybean residues in soils. Plant-available N is consumed during decomposition of both residues, but more is consumed during the decomposition of corn residues because there is more residue to decompose. The difference in amounts of plant-available N consumed is approximately equal to the amount of "N credits" usually recommended for corn after soybean.

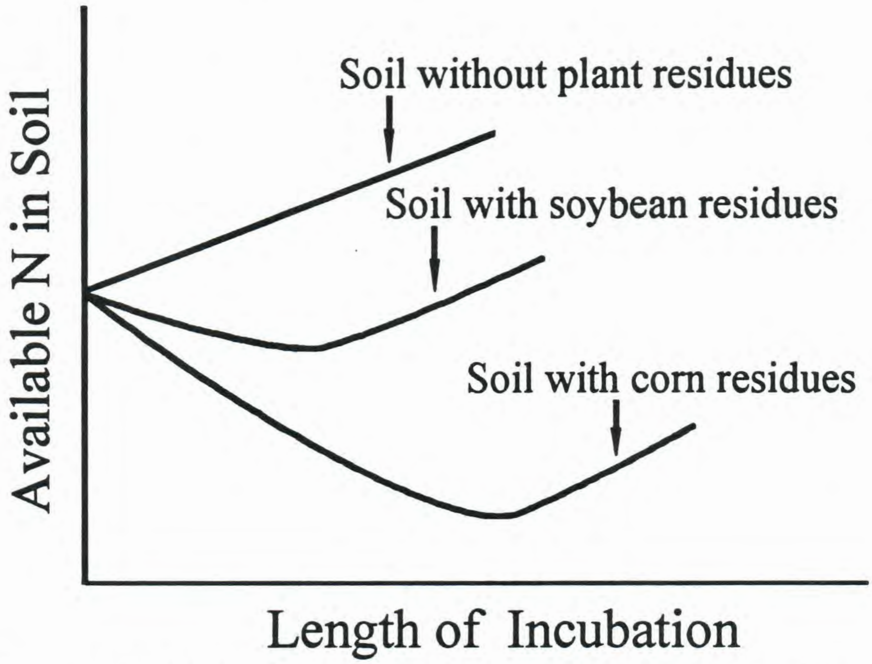

Figure 3. Effects of decomposing corn and soybean residues on concentrations of plant-available N (nitrate-N and exchangeable ammonium-N) in soils incubated under conditions where losses of N are negligible.

Much of the extra N consumed by soil microorganisms during corn residue decomposition is incorporated into the organic fraction of soil. This freshly formed organic N replaces at least part of the organic N that was mineralized during growth of the crop; it therefore decreases the *net* amounts of N mineralized. The *gross* amounts of N mineralized from soil organic matter each year are greater than the net amounts mineralized, a fact that explains why N-15-tracer studies show that most of the N in corn plants is derived from the soil even when adequate amounts of fertilizer N are applied (Sanchez and Blackmer, 1988; Cerrato and Blackmer, 1990). Failure to recognize the sequential nature of immobilization and mineralization during plant residue decomposition under field conditions may have caused errors in interpretation of N-15 tracer studies (Blackmer and Green, 1995). These errors probably have contributed to confusion concerning the mechanism by which soybean crops seem to leave extra N for corn.

The amounts of new soil organic matter formed each year largely depends on the amounts of mature plant residues returned to the soil. Because less residue is returned after soybean, a smaller portion of the organic matter mineralized during the growth of soybeans is replaced. This results in a net loss of organic matter and a net mineralization of plant-available N. Adding extra N after soybean will not prevent the net loss of soil organic matter (Green et al., 1995).

Another important observation in the laboratory studies is that soybean residues decompose more rapidly than do corn residues. Because soybean crops usually mature earlier than do corn crops, consumption of plant-available N usually occurs much earlier when soybean residues are decomposing than when corn residues are decomposing. Although the time of residue decomposition varies from year to year, soybean residue decomposition tends to consume plant-available N in the fall whereas corn residue decomposition tends to consume plant-available N in the spring. This difference in time of residue decomposition should be expected to have great impact on N fertilizer requirement on years where rainfall in late fall, winter, or early spring leaches all plant-available N from the soils. Under such conditions, N consumed during residue decomposition in the fall does not increase N fertilizer requirements for the next crop whereas N consumed during residue decomposition in the spring does. Year-to-year variability in time of crop maturity, time of residue decomposition, and amounts of plant-available N lost during the fall-to-spring period could easily explain the observed variability in differences in N fertilizer requirement between the two rotations. This better understanding of the primary factors causing variability in N fertilizer requirement gives reason to hope that it may soon be possible to predict much of the variability before fertilizers are applied.

Implications for N management

The practice of calculating "N credits" for N carried over from soybeans to corn conveys incorrect ideas about the processes actually occurring in soils. These incorrect ideas make it difficult to identify ways to improve N management in corn-soybean cropping systems.

An alternative approach is to consider corn following soybean to be a totally different crop than corn following corn when making N fertilizer recommendations. In absence of better information, a reasonable recommendation is to apply the rates that would have maximized net returns to fertilization when applied across all trials (see Figure 4). These rates, of course, vary with prices for corn and fertilizer. A serious limitation of these recommendations, however, is that they fail to address important year-to-year and site-to-site variability in N fertilizer requirement.

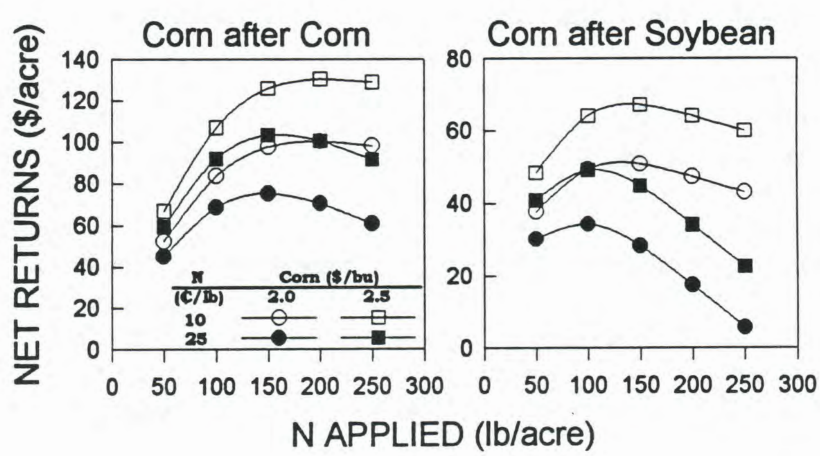

Figure 4. Relationships between various rates of N fertilization and mean net returns to fertilization in price scenarios utilizing yield-response data from 35 pairs of trials in Iowa. The fertilizer was broadcast and incorporated shortly before planting.

Recommendations that address year-to-year and site-to-site variability in N fertilizer requirement can be attained by using the existing guidelines for the late-spring test for soil nitrate in Iowa. A project funded by the Iowa Soybean Promotion Board is exploring the possibility of developing such recommendations based on detailed information about the previous crop and weather conditions up to the time of fertilization.

References Cited

Blackmer, A.M., and C.J. Green. 1995. Nitrogen turnover by sequential immobilization and mineralization during residue decomposition in soils. Soil Sci. Soc. Am. J. 59:1052-1058.

Cerrato, M.E., and A. M. Blackmer. 1990. Effects of nitrapyrin on corn yields and recovery of ammonium-N at 18 site-years in Iowa. J. Prod. Agric. 3:513-521.

Green, C.J., and A.M. Blackmer. 1995. Residue decomposition effects on nitrogen availability to corn following corn-fertilizer or soybean. Soil Sci. Soc. Am J. 59:1065-1070.

Green, C.J., A. M. Blackmer, and R. Horton. 1995. Nitrogen effects on conservation of carbon during corn residue decomposition in soils. Soil Sci. Soc. Am. J. 59:453-459.

Heichel, G.H., and D.K. Barns. 1984. Opportunities for meeting crop nitrogen needs from symbiotic nitrogen fixation. p. 49-59. *In* D. F. Bezdicek (ed.) Organic Farming: Current technology and its role in asustainable agriculture. Spec. Pub. No. 46. American Society of Agronomy, Madison, WI.

Meese, B.G. 1993. Nitrogen management for corn after corn and corn after soybean. Ph.D. Dissertation. Iowa State University, Ames.

Pottker, D. 1987. Effects of fertilizer nitrogen and cropping systems on the availability of nitrogen for corn production in Iowa. Ph.D. Dissertation. Iowa State University, Ames.

Sanchez, C. A., and A.M. Blackmer. Recovery of anhydrous ammonia-derived nitrogen-15 during three years ofcorn production in Iowa. Agron. J. 80:102-108.