NITROGEN RECOMMENDATIONS AND OPTIMUM NITROGEN RATES: HOW DO THEY COMPARE? [1]

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The goals of University N recommendations for corn are to suggest adequate amounts of N to maximize economic return to the grower and simultaneously avoid excess N additions that can contribute to water quality problems. With increasing concerns about the contributions of agricultural N to groundwater nitrate and to hypoxia in the Gulf of Mexico, the appropriateness of N recommendations and their research basis are increasingly questioned. In addition, University N recommendations are often being used as the technical criteria for nutrient management regulatory policy. These policies often view the University recommendations as an environmental maximum rate, while the basis for developing the recommendations is usually economic. This conversion of recommendations into regulations results in a loss of flexibility for growers and again emphasizes the need for reliable N recommendations.

The purpose of this paper is to examine: 1) The basis used to develop N recommendations; 2) The effectiveness of N credits and soil nitrate tests for adjusting N recommendations; 3) A comparison of N recommendations developed by several methods with observed optimum N rates; 4) Environmental implications of excess N use; and 5) Economic consequences of using the PSNT and N credits to adjust N recommendations.

The Basis for Nitrogen Recommendations

Historically, a mass balance approach considering crop N use and available N contributions from various sources was used as the basis for corn N recommendations (Stanford, 1973). This led to development and widespread adoption of corn N recommendations based on yield expectations (goals). Concerns about potential excess N fertilization due to unrealistic yield goal selection (Schepers et al., 1986), and poor relationships between yield and optimum N rates (Vanotti and Bundy, 1994a; Fox and Piekielek, 1995.) stimulated development of an alternative approach to corn N recommendations in Wisconsin. Results from numerous N response experiments on the major soil groups used for corn production were used to develop a soil-specific N recommendation approach in Wisconsin (Vanotti and Bundy, 1994a, 1994b). This approach recognizes that efficiency of N use varies substantially from year to year, and that optimum N rates are not greatly influenced by annual yield fluctuations. While many reports of poor relationships between corn yield and optimum N rates have appeared, an example is provided by results from a relatively large group of N response experiments conducted in Wisconsin between 1989 and 1999 (Fig. 1).

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This data shows the yield-optimum N rate relationship at 101 sites with a wide range of soils and crop and management histories. The trend lines show no relationship between yield and observed optimum N rate, but do show lower average optimum N rates for medium than for high yield potential soils. This supports one aspect of the current corn recommendation system that separates medium and fine textured soils according to their yield potential. It also confirms that yield estimates are not an appropriate basis for corn N recommendations on Wisconsin soils.

Site-Specific Adjustments to N Recommendations and Comparison with Observed Optimum N Rates

Site-specific adjustments of N recommendations for organic N inputs and soil inorganic N are essential for accurate identification of optimum N rates. Nitrogen contributions from organic sources such as legumes and manure can be assessed using "book value" credits based on research to identify the amounts of N likely to be provided by organic sources during the growing season. A second method for adjusting N recommendations for organic N inputs and soil inorganic N is the use of diagnostic tests such as the presidedress soil nitrate test (PSNT). Research in individual states and in the North Central Region, indicates that preplant and presidedress soil nitrate tests have potential for greatly reducing the frequency of excess N additions, thus improving the accuracy of N recommendations (Bundy and Sturgul, 1994; Bundy and Andraski, 1995; Bundy et al., 1999).

For example, Bundy and Andraski (1995) found that use of preplant and PSNT tests reduced the frequency of excess N applications for corn on soils with histories of N additions from organic sources or from fertilizer N. Specifically, where N was supplied from commercial fertilizers, 89 and 67% of the sites received correct N rates when the preplant and PSNT tests were used, respectively, compared with only 22 % when the unadjusted standard N recommendation was followed. Results from this study indicated that the most reliable prediction of optimum N rates was with the preplant nitrate test on sites with inorganic N inputs and with the PSNT where most N was provided from organic sources.

Regional research on the performance of soil nitrate tests also showed that these tests have substantial potential for improving N management. While the overall failure rates for identifying N responsive and non-responsive sites ranged from 30 to 36% for the preplant test and from 23 to 27% for the PSNT, most of these failures were due to identification of non-responsive sites as responsive, resulting in over application of N. Test failures that would have resulted in inadequate N applications ranged from 1 to 7% of the sites for the preplant test and from 2 to 5% of the sites for the PSNT.

Slow mineralization of N from organic sources due to below normal spring temperatures has been identified as one of the factors contributing to over application of N where the PSNT is used (Magdoff, 1991). An evaluation of N recommendations based on the PSNT in numerous Wisconsin N response experiments confirmed this possibility (Fig. 2). These results show a marked increase in excess N applications when average May and

June air temperatures were 1°F or more below the long-term average. Apparently, the lower temperatures slowed N mineralization from organic sources and caused an under estimate of available N by the PSNT. This resulted in N recommendations that were higher than the observed optimum rate. Based on this information, the accuracy of the PSNT could probably be increased by reference to temperature information for the period prior to performing the test.

Although the potential for substantial improvements in optimum N rate identification are feasible through use of soil nitrate tests, their use in most regions is very low (Fox et al., 1999). For example, a survey of 13 states in the North Central Region showed that use of the PSNT ranged from 0 to less than 5 % of the corn acreage. Similar low use values were found for the preplant test in states with humid climates.

Environmental Effects of Excess N Use

Comparisons of various approaches for making N recommendations indicate that excess N additions are common. While the environmental concerns with excess N are well understood, there is relatively little information showing the relationship between excess N application and nitrate leaching. Andraski et al. (2000) measured soil water nitrate concentrations and estimated nitrate leaching at various levels of excess N additions in several crop management systems. Soil water nitrate-N concentrations and end-of-season soil nitrate-N contents were directly related to the amount of N applied in excess of the observed optimum N rate for the crop management system under study. Average nitrate-N concentrations were <10 ppm where fertilizer N rates were >45 lb N/acre below the EONR, 10 to 20 ppm at EONR, and >20 ppm where fertilizer N rates were >45 lb N/acre above the EONR. These results are nearly identical to the findings of Jemison and Fox (1994) in a similar study in Pennsylvania.

Estimated nitrate leaching based on a calculated soil water budget and measured soil water nitrate concentrations showed that 3 to 80 lb N/acre was lost during the 18-month monitoring period, depending on the crop management system. These nitrate leaching estimates are within the range of nitrate leaching measurements from N fertilized corn using equilibrium-tension pan lysimeters (Brye et al., 2000). During a 3-year period on soils similar to those used by Andraski et al. (2000), annual nitrate-N leaching measured at the 4.5 ft depth ranged from 29 to 92 lb N/acre.

Effects of N Management Decisions on Economic Returns

Although verified management recommendations and diagnostic tests for improving N application rate decisions are available, and the environmental effects of excess N use are well known, surveys of farmer practices show substantial evidence of excess N applications. While there are many factors contributing to excess N use, the most apparent is inadequate accounting for legume and manure N contributions. The frequently stated reason for inadequate N crediting is that farmers fear economic loss due to N deficiencies if recommended optimum N rates are used. Data from over 100 N response experiments conducted in Wisconsin during 1989-1999 were used to evaluate economic returns associated with using "book value" N credits and adjustments based on the PSNT compared with ignoring these adjustments. Results showed that making appropriate adjustments for organic N inputs was consistently more profitable with an increase in gross returns of $8 to $17/acre for the entire database (Fig. 3) and about $30/acre under the most favorable production conditions (30% of the database) (Fig. 4).

Summary

Use of verified techniques to identify optimum N rates and site-specific adjustments for organic N inputs and soil nitrate are critical to achieving the economic and environmental advantages improved N management. Avoiding the inappropriate connection between yield and optimum N rates can help avoid excess N use and ensures a sound conceptual basis for educational efforts on N management. The performance of the PSNT appears to be related to May and June temperatures, and excess N is often recommended when temperatures are below normal. Estimates of nitrate losses from various crop management systems show a direct relationship between nitrate leaching and excess N applications. Gross economic returns are enhanced when appropriate "book value" or PSNT adjustments are made for legume and manure N compared with ignoring these adjustments. This finding is in contrast to the common perception that complete crediting for organic N sources increases economic risk.

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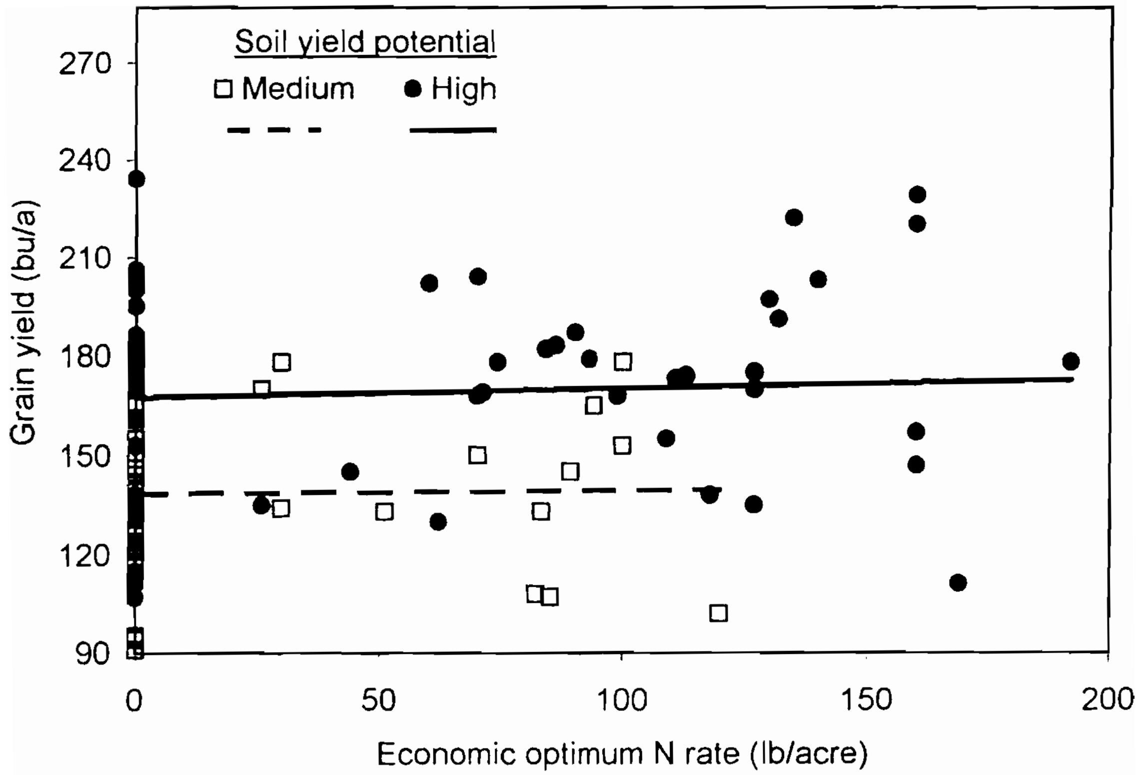

Fig. 1. Relationship between corn grain yield and economic optimum N rate, 101 sites, 1989-1999.

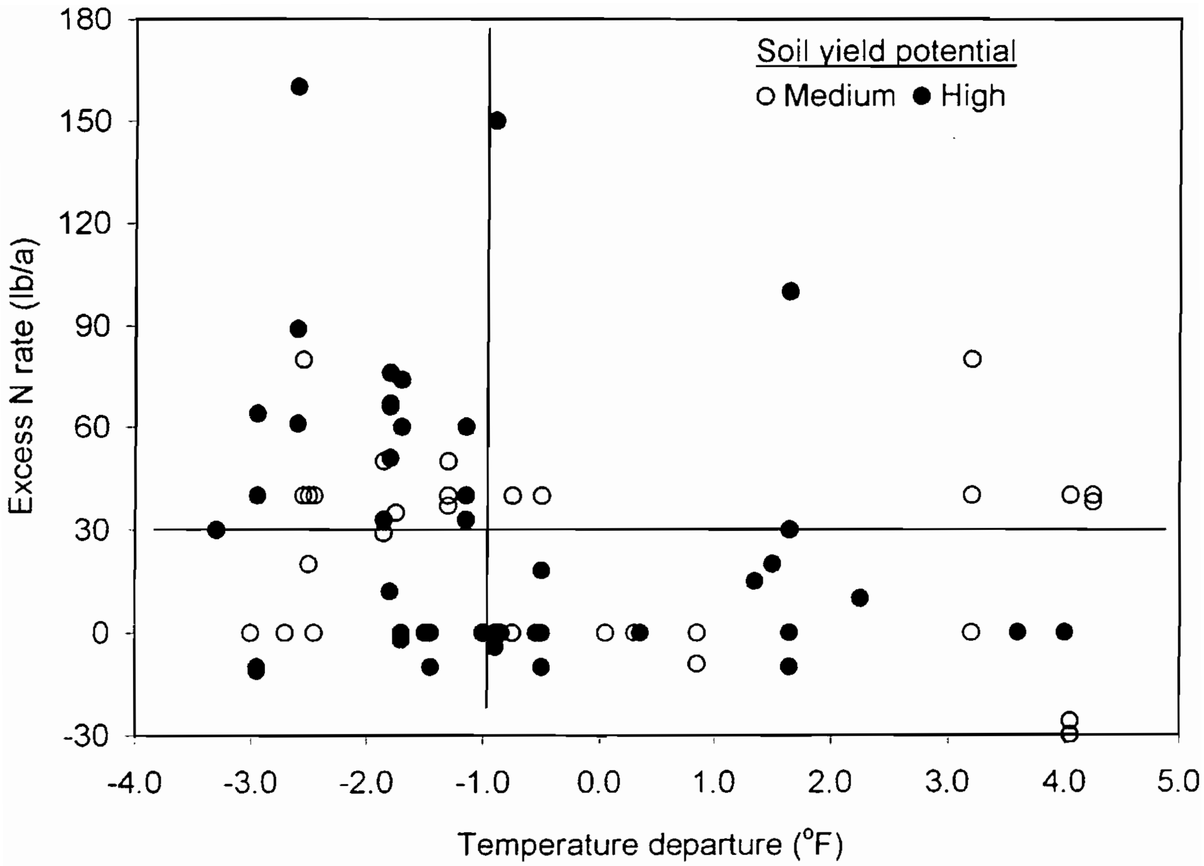

Fig. 2. Relationship between departure from long-term average May-June air temperature and excess N fertilizer recommended by PSNT for medium (n = 45) and high (n = 56) yield potential soils, 1989 to 1999.

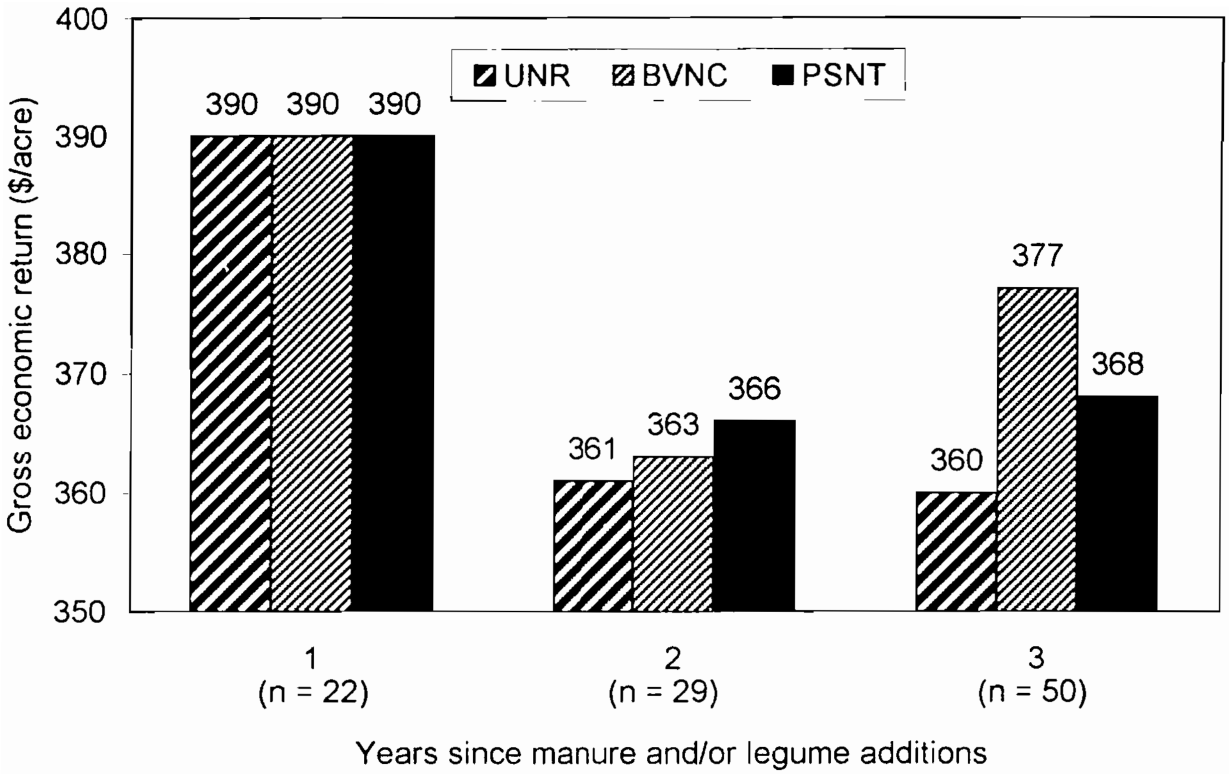

Fig. 3. Comparison of gross economic return from N recommendation methods in three crop management history categories from 101 sites, 1989 to 1999. UNR, unadjusted; BVNC, UNR minus book value N credits; PSNT, pre-sidedress nitrate test.

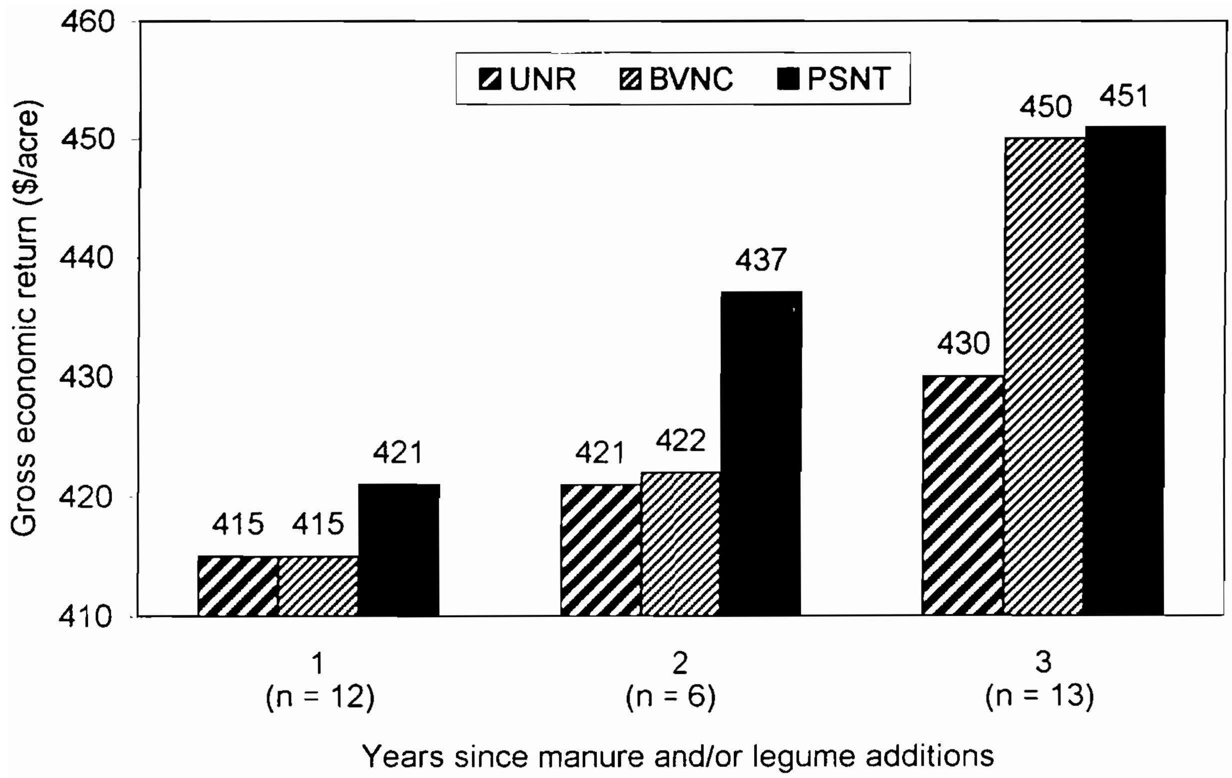

Fig. 4. Comparison of gross economic return from N recommendation methods in three crop management history categories from 31 sites with high yield potential soils where May-June average air temperatures were average to above average, 1989 to 1999. UNR, unadjusted; BVNC, UNR minus book value N credits; PSNT, pre-sidedress nitrate test.

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