RESEARCH ON NITROGEN INDICES IN WISCONSIN AND THE MIDWEST

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Introduction

Development of reliable nitrogen (N) availability indices has long been an important goal of agricultural scientists. However, progress in this area has been slowed by problems with calibrating certain N indices with crop response and by the absence of strong incentives to develop and implement N tests. Nitrogen test development for humid regions of the Midwest and eastern U.S. is more difficult due to climatic conditions in these areas which can cause relatively rapid changes in the amounts of plant-available N in the crop root zone.

Recent interest in use of diagnostic tests for N in humid regions of the U.S. has been stimulated by economic and environmental pressures to predict crop nitrogen needs more accurately. Essentially all of the research on N indices has concentrated on predicting N needs for corn production, since this crop receives most of the fertilizer N used in the Midwest. Development of N indices for midwestern conditions has taken several directions, including modification of soil profile nitrate tests for humid regions, evaluation of early growing season (pre-sidedress) soil and plant nitrate tests, and investigation of late-season and post-season plant tests. Research on one or more of these N indices is underway at most agricultural experiment stations in the Midwest, and several states are recommending use of an N test on production acreage. The purpose of this paper is to provide a selective review of recent research on N tests in Wisconsin and humid regions of the Midwest.

Nitrogen Availability Indices

Preplant Soil Profile Nitrate Test

Soil profile nitrate tests are useful for measuring residual or carryover nitrate that can be recovered by subsequent crops. Early work in Iowa (White et al., 1958; White and Pesek, 1959) showed that yields of subsequent crops were influenced by soil residual nitrate levels, and other work in humid climates (Peterson and Attoe, 1965; Olsen et al., 1970) showed substantial accumulation of profile nitrate. Soil tests for residual nitrate were evaluated and subsequently implemented for routine use in semi-arid regions of the Midwest and Great Plains regions (Hergert, 1987). Recent work in Wisconsin (Bundy and Malone, 1988) showed that corn yield response to applied N was influenced by the amounts of nitrate-N in the top 2 to 3 ft of soil before

planting. On well drained silt loam soils, no response to applied N occurred where preplant soil nitrate-N levels exceeded 150 lb N/acre. Accumulation and overwinter retention of residual nitrate was markedly affected by soil and climatic conditions that influence water percolation through the soil profile. In general, spring preplant profile nitrate contents were inversely related to overwinter precipitation, and a wide annual variation in profile nitrate levels occurred during the Wisconsin research (1983 to present). In years with near-normal overwinter precipitation (October-April), 50 to 60% of the fall profile nitrate was retained overwinter, but the amounts of profile nitrate retained ranged from near 0 with high precipitation to 100% in dry years. Recent work (Roth and Fox, 1990) shows that overwinter retention of nitrate also occurs under humid climatic conditions in Pennsylvania soils.

Data from a long-term crop sequence experiment at Lancaster, Wisconsin, were used to estimate the frequency of significant pro-file nitrate carryover in Wisconsin soils (Vanotti and Bundy, 1990). In this experiment, several sequences include unfertilized oat grown after corn that received a range of N rates. These sequences provide an opportunity to detect oat yield responses to the residual effects of N applied to corn during the previous growing season. Data from this study during the 1967 through 1988 period show that oat yields were influenced by the residual effects of the previous year's N application in 17 of the 22 years. This finding suggests that significant profile nitrate carryover occurs in most years on well-drained silt loam soils in Wisconsin and that soil tests for profile nitrate are usually needed to adjust N recommendations for nitrate carryover.

A preplant profile nitrate test was implemented through the Wisconsin soil testing laboratories in 1989, and a summary of test results from the Madison laboratory during 1989 and 1990 is shown in Table 1. Climatic conditions preceding the 1989 and 1990 growing seasons favored accumulation of residual nitrate in soils, and this is reflected by the very high mean soil nitrate contents found in the soils tested. Growers were able to realize large savings in N fertilizer costs and avoid potential loss of excess N to the environment by using the nitrate test. While soil nitrate contents in years with average precipitation will be substantially lower than those shown in Table 1, the test should provide benefits to growers in most years.

Table 1. Nitrate-N in soil samples tested in Univ. of Wisconsin Lab., spring 1989-90*.

Depth	Mean nitrate-N 1989**	1990***
ft	-------- lb N/acre --------	
0-1	80	69
1-2	78	74
2-3	56	51
0-3	214	194

* Includes samples received by June 1.
** n=212. *** n=2013.

The utility of the preplant soil nitrate test for improving the accuracy of N fertilizer recommendations for corn is illustrated in Figure 1. Data plotted in Figure 1 indicate the economic optimum N rate for corn in a series of experiments on two silt loam soils where preplant soil nitrate contents were measured. The economic optimum N rates vary from 0 to approximately 180 lb N/acre, depending on soil nitrate content. The N recommendation for corn provided by Wisconsin's preplant profile nitrate test is indicated by the dashed line in Figure 1, and it closely follows the optimum N rates identified in individual experiments. These results show that the preplant soil nitrate test effectively improves the accuracy of N recommendations for corn through site-specific adjustments for soil nitrate content.

Pre-sidedress Soil Nitrate Test

A soil test for predicting N availability to corn that involves sampling the top foot of soil when corn plant are about 6 to 12 inches tall was initially proposed by Magdoff et al. (1984). This approach has been extensively evaluated in Iowa (Blackmer et al., 1989) and Pennsylvania (Fox et al., 1989), and tests based on this research are currently in use in Iowa, Pennsylvania, and several other northeastern states. In addition, research to evaluate this test is underway in several midwestern states, including Wisconsin. The pre-sidedress or late spring soil nitrate test is designed to allow sampling late enough to obtain estimates of N mineralization from non-fertilizer sources such as manure, legumes, crop residues, and soil organic matter, and to detect possible losses of available N due to leaching or denitrification early in the growing season. Yet, the test must be performed early enough to allow N additions according to the test results.

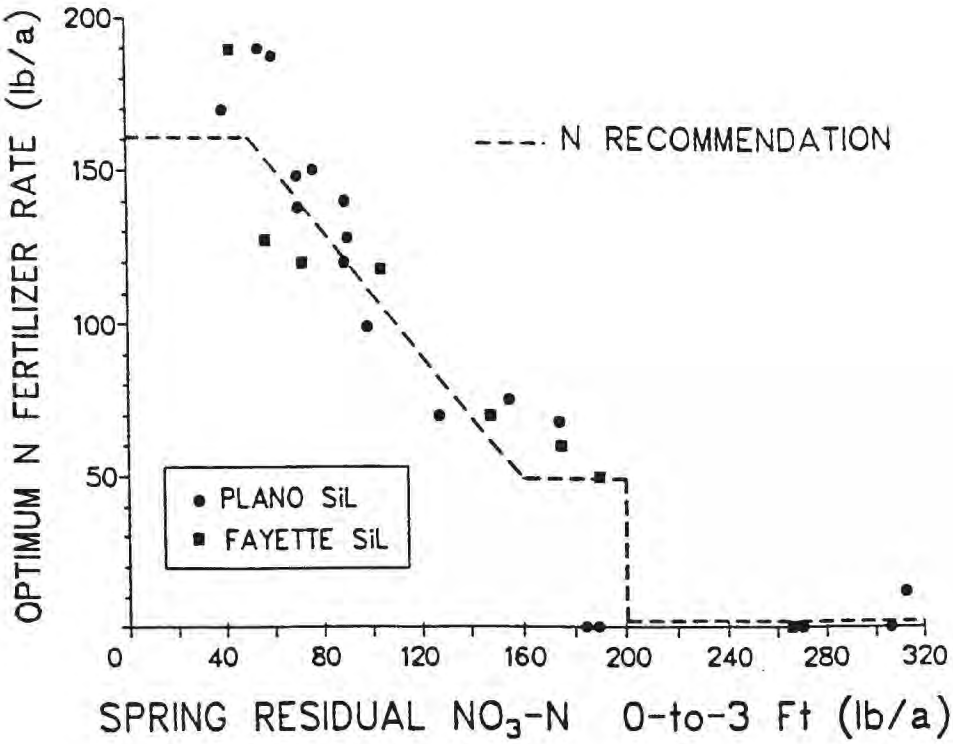

Figure 1. Optimum N rates for corn and spring soil nitrate contents on two Wisconsin soils (M.B. Vanotti, 1990).

Work to correlate pre-sidedress test results with corn yields has produced surprisingly consistent critical values across large geographic areas. Essentially all of the published work from the Midwest and the northeastern U.S. indicates that corn yield response to applied N is not likely if the pre-sidedress soil nitrate test value is in the 20 to 25 ppm nitrate-N range. Research to predict corn N recommendations at test values below the critical range is continuing in several states, and studies to evaluate alternative sampling times and depths are also in progress.

Use of a preplant sampling time in certain cropping systems such as corn following corn could improve the convenience of the soil nitrate test, and this possibility is being studied in Iowa and Wisconsin research. Table 2 contains Wisconsin results showing the relationship between preplant and pre-sidedress soil nitrate contents in two crop management systems. These results show a good correlation between top foot nitrate content in preplant and presidedress samples in the continuous corn management system. As expected, the correlation was poor in the corn following legume management system where most of the nitrate

release occurred after the preplant sampling (see Table 3). If the good relationship between preplant and pre-sidedress soil nitrate values can be confirmed in additional growing seasons where nitrate carryover from previous years is not as great as in 1989, preplant samples taken to a 1 ft depth may be suitable for predicting corn N fertilizer needs in some management systems.

Table 2. Correlation between preplant and pre-sidedress soil nitrate-N contents at various depths in two management systems, 1989.

Management system	Depth	No. of sites	Correlation
	ft		r
CC	0-1	7	0.91***
	0-2	7	0.87***
	0-3	7	0.80**
LC	0-1	6	0.25 NS
	0-2	6	0.59 NS
	0-3	6	0.76*

CC = continuous corn; LC = corn following a forage legume. *, **, *** Significant at the 0.10, 0.05, and 0.01 probability levels, respectively. NS = not significant.

Table 3. Nitrate-N in top foot of soil for corn following alfalfa, 1989.

County	Nitrate-N	
	April	June
	----- ppm N ------	
Columbia	12	43
Wood	15	27
Dane	9	21
Grant	2	20
Marathon	5	26

One of the major advantages of the pre-sidedress soil nitrate test is its ability to estimate the amounts of available N provided by non-fertilizer sources such as manure and legumes. Magdoff et al. (1984) and Fox et al. (1989) found that the pre-sidedress test adequately predicted corn N response on sites with histories of manure application, and El-Hout and Blackmer (1990) found that the test predicted the absence of response to added N where corn was grown following alfalfa. Data from several Wisconsin locations (Table 3) show that the pre-sidedress nitrate test performed in June detects the rapid mineralization

of available N following incorporation of the previous legume crop. June soil nitrate values at all locations in Table 3 are at or above the 20 to 25 ppm critical value, and yield data for these locations showed little if any response to applied N. Therefore, the early growing season soil nitrate test appears useful for identifying those fields where response to applied N will not occur or where grower uncertainty exists as to appropriate N contributions from manure and previous legume crops.

Pre-sidedress Plant Nitrate Test

A second procedure to predict sidedress N requirements for corn that involves determination of the nitrate concentration in the basal stem of young corn plants approximately 30 days after emergence was initially proposed by Iversen et al. (1985). McClenahan and Killorn (1988) also studied this method in Iowa, and found acceptable correlations between test results and corn yield at five of six locations. However, their results showed that relationships between stalk nitrate values and grain yield varied substantially among locations, and appeared to be related to soil characteristics. In Pennsylvania, Fox et al. (1989) compared the presidedress plant and soil nitrate tests in 87 N response exper-iments over a 4-year period and concluded that the stalk nitrate test was not an accurate predictor of corn N response, while the soil nitrate test provided good prediction of crop N response.

The pre-sidedress plant nitrate test appears to be influenced by light intensity, soil moisture status, and possibly, corn hybrid selection. It may have utility in localized areas where the influence of these factors is controlled or well known, but its application to state-wide use appears uncertain, since the soil nitrate test provides similar advantages without being subject to the environmental interferences that affect the plant test.

Post-season Plant Nitrate Test

Recent work in Iowa (Binford et al., 1990) indicates that measurement of nitrate concentrations in the lower portions of cornstalks at physiological maturity can be used to determine the degree of excess or deficiency in the supply of N available to the crop during the growing season. This study showed that stalk nitrate concentrations between 0.025 and 0.18% nitrate-N were optimum for corn production. Use of this test has potential for identifying production situations where changes in N management practices are needed to avoid excessive or inadequate supplies of N to the corn crop. It could also be useful for identifying years or locations where substantial amounts of nitrate-N remain in the soil at the end of the growing season. Soil nitrate tests could be used at these sites to predict crop N needs in the next

growing season.

Post-season stalk nitrate and soil profile nitrate measurements were made at five locations in Wisconsin at the end of the 1989 growing season (Table 4). Post-season stalk nitrate concentrations generally increased with increasing rates of applied N, and all stalk nitrate-N values were in or above the 0.025 to 0.18% N critical range established in the Iowa work. This result is consistent with the observed absence of yield response to applied N at all five sites during the 1989 growing season. Correlations between post-season soil profile nitrate and stalk nitrate measurements were significant at all sites (Table 4) and indicate that the post-season stalk test has potential for predicting post-season soil nitrate levels.

Table 4. Post-season stalk nitrate-N concentrations and correlation with soil profile nitrate-N at five Wisconsin locations, 1989.

County	N rate, lb/acre			Correlation with soil nitrate-N
	0	100	200	
	------- Nitrate-N, % ------			r
Clark	0.25	0.32	0.29	0.41*
Monroe	0.10	0.55	0.75	0.80***
Columbia	0.71	0.92	1.27	0.54**
Grant	0.57	0.72	0.95	0.84***
Dane	0.15	0.58	0.81	0.79***

*, **, *** Significant at the 0.10, 0.05, and 0.01 probability levels, respectively.

Summary

Nitrogen tests have potential for improving the accuracy of N recommendations for corn in humid regions of the Midwest through site-specific prediction of crop N needs. It seems likely that one or more of these N indices will be routinely used as the basis for N recommendations since they offer important economic and environmental benefits.

Two soil nitrate tests have potential for use in the Midwest. Preplant profile soil nitrate tests are useful for adjusting N recommendations for residual or carryover nitrate-N. This test is most useful where corn is grown following corn and where soil and climatic conditions favor residual nitrate accumulation. The pre-sidedress soil nitrate test also provides a reliable index of N availability to corn in humid regions. It is uniquely suited for predicting N availability from non-fertilizer sources such as previous legume crops and manures.

The pre-sidedress plant nitrate test is influenced by certain soil and climatic conditions, and currently appears to be less reliable than soil nitrate tests.

Results to date indicate that post-season cornstalk nitrate concentrations can identify situations where excess N was available to corn during the growing season, and the test should be useful for adjusting N management to provide more appropriate N levels. This test also has potential for indicating where soil nitrate tests should be used to adjust N recommendations for excess soil nitrate in the next growing season.

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