COMPARING THE PERFORMANCE OF PREPLANT AND PRESIDEDRESS SOIL NITRATE TESTS FOR THE NORTH-CENTRAL REGION

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INTRODUCTION

Soil nitrate (NO_3-N) testing is a recommended best management practice (BMP) for adjusting corn N fertilization rates across the North-Central region. Several approaches to soil NO_3-N testing are used and vary in both recommended time and depth of sampling (Hergert, 1987). Nitrate is very mobile in soil and is subject to either loss from leaching and denitrification or gain from net mineralization of crop residue and manure. The processes that govern nitrate accumulation in soils are most active in the spring when fresh residues are incorporated and soil water and temperature are at an optimum for N mineralization. Soil NO_3-N samples may be collected in the spring prior to planting (PPNT) or just prior to sidedress N application time (PSNT). Magdoff et al. (1984) introduced the presidedress nitrate test (PSNT) which delays soil sampling until the factors that influence nitrate accumulation are allowed to operate as long as possible before a sidedress N application is made (Magdoff, 1991). The decision to apply fertilizer N following soil NO_3-N sampling is based on the value of a critical soil nitrate level (CSNL). The CSNL represents the concentration of soil NO3-N above which no crop response to the application of fertilizer N is expected. Research conducted in the Midwest and Eastern states suggests that the CSNL for soil NO_3-N is relatively uniform across a wide geographic area. However, criteria used in the selection of the statistical models used to derive the CSNL are not clearly defined and rarely provide a means of evaluating the relative impact of the chosen CSNL on the environment or farm economics (Cerrato and Blackmer, 1990; Sander et al., 1994). In 1988, a North Central Regional Committee (NC-201)[2], initiated a long-term study to provide a regional evaluation of soil NO_3-N tests. Variables such as time and depth of sampling and previous management practices were evaluated with respect to their effect on the prediction of corn response to N fertilizer application.

METHODS

__Field Experiments__: Corn yield and soil NO3-N data were collected from 301 sites across the North Central region over a five year period from 1988-92 (Fig. 1). Sites included a variety of previous cropping and manure management practices (Table 2). Nitrogen treatments included a zero N check plot and a non-N limiting treatment based on site determined N response functions, or local university N recommendations. N treatments were replicated at least 4 times. Spring preplant soil samples (PPNT) were taken in 1-ft depth increments to a depth of 2 ft from each replication of the check plot. Presidedress soil samples (PSNT) were taken in the same depth increments and the same check plots when corn plants were approximately 1 ft tall. Non-N limiting plots were fertilized after PSNT sampling time. Grain yield was harvested from each replication and yields reported at 15.5% moisture. Percent relative yield (RY) was calculated as the ratio of:

[yield (unfertilized) / yield (non-N limiting)]

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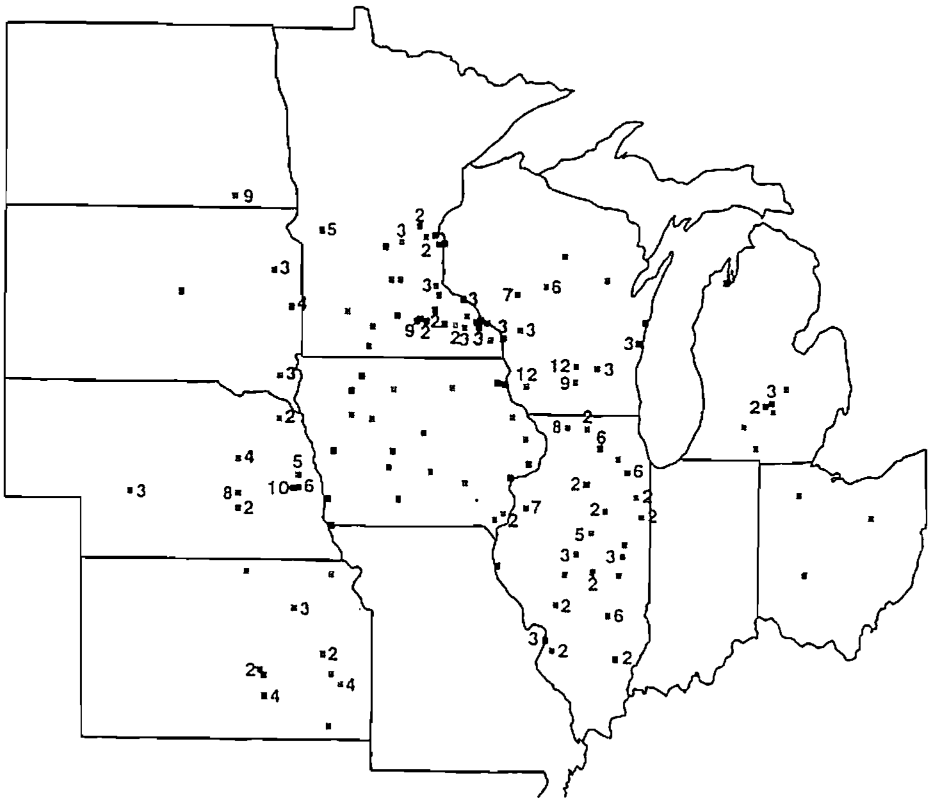

Figure 1. Map of site location and number of sites for the NC-201 project.

<u>CSNL Determination:</u> The relationship between soil NO_3-N concentration and RY was determined with either a linear response plateau (LRP) or quadratic response plateau (QRP) model (Proc NLIN, SAS Institute, 1990). These segmented model techniques allowed an estimate of the CSNL for different sampling times, sampling depths and previous management. The adequacy of the LRP or QRP model fit was assessed by calculating the R^2 and testing normality of residuals using the Shapiro-Wilk test.

<u>Soil Test Failure Rate</u>: A separate statistic, the *failure rate,* was also developed to provide a more practical decision tool for choosing the adequacy of a given model-determined CSNL for different time and depth of soil sampling (Fig. 2). Each site was ranked as either responsive or non-responsive to N fertilization by considering a RY > 90% as a non-N responsive site. A sampling strategy was considered a failure if:

a.) soil **[NO3-N] > CSNL and RY ≤ 90%** (i.e. predicting a non-N responsive site that was responsive to N fertilization), a **TYPE A FAILURE**, or

b.) Soil **[NO3-N] < CSNL and RY > 90%** (i.e. predicting an N-responsive site that was non-N responsive), a **TYPE B FAILURE.**

A RY > 90% was chosen as non-N responsive to increase the power of interpretation of the failure rate statistic. Choosing a RY closer to 100% generally lowered the calculated failure rate and reduced the discriminating power of this statistic. Type A failures would represent an economic loss to the producer from lost production whereas a Type B failure would result in both an economic loss from over fertilization and an increased risk of groundwater contamination with NO_3-N.

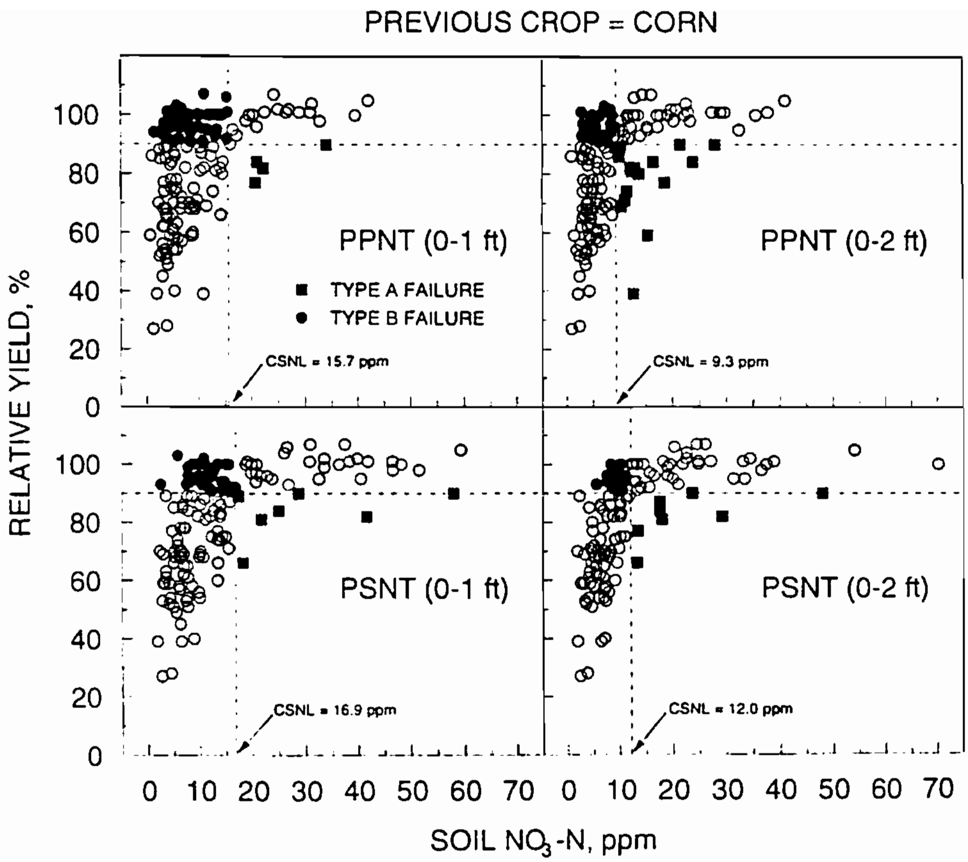

Figure 2. Relative corn grain yield vs. soil NO_3-N concentration for sites with corn as the previous crop. Preplant (PPNT) and Presidedress (PSNT) sampling time.
Type A Failure = Soil NO_3-N > CSNL and Relative Yield ≤ 90%
Type B Failure = Soil NO3-N < CSNL and Relative Yield > 90%.

RESULTS

Choosing a CSNL: Table 1 lists a comparison of test statistics and failure rates for the LRP and QRP models applied to an analysis of all observations. The CSNL values determined from fitting the QRP model to the PSNT 0-1 ft depth are very close to the 20 to 25 ppm range reported by others (Bundy and Meisinger, 1994). The CSNL values were approximately 7 ppm lower, however, for the LRP model. Calculation of the coefficient of determination (R^2) and the test of normality of residuals (Shapiro-Wilk test) did not provide sufficient criteria for choosing a CSNL. However, total failure rate for the LRP model averaged 3.1% (PPNT 0-1 ft) to 7.8% (PPNT, 0-2 ft) *lower* than the QRP. The lower failure rate for the LRP model came primarily from a substantial reduction in TYPE B failure rate. ***Choosing the lower CSNL associated with the LRP would result in less risk of environmental contamination from over fertilization, but would also result in a modest increase in TYPE A failures. In situations where regulation of N rates are considered, using the LRP CSNL to decide N fertilization rate may offer less profit risk than mandating a ceiling on N rate.***

Table 1. Comparison of Linear Plateau and Quadratic Plateau model performance (all observations).

Time of Soil Sampling[1]	depth	Model[2]	R^2	Shapiro-Wilk[3] Test	CSNL[4]	n	Relative Grain Yield Mean	Max.	Min.	Probability of RY>90%	Failed soil test[5] TOTAL	TYPE A	TYPE B
	ft			Prob < W	ppm		--------------%		-------------		------------% of sites		--------------
PPNT	0 - 1	LRP	0.21	0.0001	>15.7	30	98	107	77	0.9	36.3	1.0	35.3
					<15.7	262	81	108	27	0.39			
		QRP	0.22	0.0001	>22.3	15	101	107	90	1.0	39.4	0	39.4
					<22.3	277	81	108	27	0.42			
PPNT	0 - 2	LRP	0.24	0.0001	> 9.3	90	93	108	39	0.68	29.5	6.8	22.6
					< 9.3	202	78	105	27	0.32			
		QRP	0.24	0.0001	>16.7	27	98	107	77	0.85	37.0	0.7	36.3
					<16.7	265	81	108	27	0.38			
PSNT	0 - 1	LRP	0.41	0.0006	>16.9	66	98	107	66	0.84	27.6	2.3	25.2
					<16.9	235	79	108	27	0.31			
		QRP	0.41	0.0004	>24.0	39	99	107	82	0.87	33.2	0.7	32.7
					<24.0	262	80	108	27	0.36			
PSNT	0 -2	LRP	0.50	0.0072	>12.0	77	96	107	66	0.82	22.6	4.6	18.0
					<12.0	162	76	105	27	0.26			
		QRP	0.50	0.0340	>17.9	44	99	107	81	0.89	28.8	0.8	28.0
					<17.9	195	79	105	27	0.34			

[1] **PPNT** = PREPLANT sampling time; **PSNT** = PRESIDEDRESS sampling time.
[2] **LRP**=Linear-Response Plateau, **QRP**=Quadratic Response Plateau.
[3]The Shapiro-Wilk test statisticfor the null hypothesis that the residual values (relative yields observed minus relative yields predicted by the model) are a random sample from a normal distribution, with a Prob value < 0.10 leading to rejection of the null hypothesis.
[4]**CSNL** = Critical soil nitrate-N level.
[5]**TYPE A** failure = Soil NO3-N > CSNL and RY ≤90%; **TYPE B** failure = Soil NO3-N <CSNL and RY > 90%.

Effect of Sampling Depth: Increasing sampling depth from 1 to 2 ft did not vastly improve the fit of either LRP or QRP models but CSNL values did decrease with depth of sampling (Table 1). The reduction in failure rate associated with greater sampling depth resulted from the detection of sites with appreciable accumulation of NO3-N in the second ft. Sites exhibiting TYPE B failures at the 1-ft sampling depth which were successfully predicted as non-N responsive with a 2-ft sample (76 sites for PPNT and 43 sites for PSNT) had soil [NO3-N] in the 1-2 ft depth which averaged 14 ppm. ***Nitrate-N in the 1-2 ft depth is an important source of N for corn and accounting for this N in calibrating either the PPNT or PSNT should result in less failure in predicting N-responsive sites and in reducing the risk of groundwater N contamination.***

Effect of Sampling Time, Previous Crop and Manure : With the exception of soybean and small grain as previous crops, the risk of failure in predicting an N response was reduced by sampling later in the season (Table 2.). When corn was the previous crop, a 2-ft PSNT reduced the failure rate to half that of a 1-ft PPNT sample. The change in [NO3-N] between PPNT and PSNT were lowest for soybean and small grain as previous crops reflecting earlier crop residue decomposition for these crops. Although N recommendations for corn following soybean usually receive some legume N credit, PSNT sampling did not improve prediction of N responsive sites. Substantial net N mineralization occurred between PPNT and PSNT where alfalfa was the previous crop (+13.2 ppm) and manure had been applied in the study year (+8.9 ppm) (Table 2). TYPE B failures were reduced from >75% to < 40% (alfalfa as previous crop) by delaying sampling time until PSNT. ***Sites with the greatest change in soil [NO3-N] from PPNT to PSNT were also the sites where PSNT 0-2 ft sampling resulted in the most significant reduction in failure rate.***

Table 2. Soil test failure rate and soil [NO_3-N] for various previous crops and manure addition

Previous Crop or cropping system	Time of Sampling[1]	depth	n	Failed Soil Test[2] TOTAL	TYPE A	TYPE B	Mean NO_3-N concentration	Mean change in [NO_3-N] from PPNT to PSNT 0-1'	0-2'
		ft		------------% of sites------------			----------------------ppm----------------------		
All Observations	PPNT	0-1	292	36.3	1.0	35.3	8.5	4.7	3.2
		0-2	292	29.5	6.8	22.6	8.1		
	PSNT	0-1	301	27.6	2.3	25.2	13.4		
		0-2	239	22.6	4.6	18.0	11.7		
Corn (with and without manure)	PPNT	0-1	146	31.5	2.1	29.5	9.8	5.1	2.9
		0-2	145	25.5	10.3	15.2	9.6		
	PSNT	0-1	144	24.8	3.2	21.6	14.8		
		0-2	132	15.9	4.6	11.4	12.6		
Corn (without manure in study year)	PPNT	0-1	127	28.4	1.6	26.8	9.2	3.8	1.8
		0-2	126	25.4	11.1	14.3	8.8		
	PSNT	0-1	125	24.8	3.2	21.6	12.9		
		0-2	115	14.7	3.5	11.3	10.7		
Continuous Corn (no manure for 3+ years)	PPNT	0-1	74	24.3	2.7	21.6	8.1	3.0	1.5
		0-2	73	20.6	9.6	11.0	7.9		
	PSNT	0-1	72	19.4	2.8	16.6	9.6		
		0-2	67	10.5	4.5	5.6	9.6		
Second-year corn following alfalfa	PPNT	0-1	23	34.8	0	34.8	12.6	7.1	3.5
		0-2	23	21.7	8.7	13.0	12.1		
	PSNT	0-1	23	34.8	8.7	26.1	19.7		
		0-2	23	17.4	4.4	13.0	15.7		
Soybean	PPNT	0-1	80	33.8	0	33.8	6.3	3.1	2.0
		0-2	80	30.1	6.3	23.8	5.8		
	PSNT	0-1	86	31.4	1.2	30.2	10.1		
		0-2	56	30.4	7.1	23.2	7.7		
Small grain	PPNT	0-1	25	24.0	0	24.0	8.7	0.8	0.3
		0-2	25	12.0	0	12.0	7.8		
	PSNT	0-1	25	28.0	4.0	24.0	9.6		
		0-2	13	30.8	7.7	23.1	10.6		
Alfalfa	PPNT	0-1	27	92.6	0	92.6	7.8	13.2	9.4
		0-2	27	77.8	0	77.8	6.2		
	PSNT	0-1	28	39.3	0	39.3	21.3		
		0-2	26	38.4	0	38.4	16.1		
All sites with manure applied in study year	PPNT	0-1	28	46.4	3.6	42.9	14.6	8.9	7.1
		0-2	28	17.9	3.6	14.3	14.9		
	PSNT	0-1	29	27.5	3.5	24.1	24.6		
		0-2	24	25.0	8.3	16.7	23.3		

[1] **PPNT** = PREPLANT sampling time; **PSNT** = PRESIDEDRESS sampling time.

[2] **TYPE A** failure = Soil NO_3-N > CSNL and RY $\leq$ 90%; **TYPE B** failure = Soil NO_3-N < CSNL and RY > 90%.
CSNL derived from fitting LRP model to all observations.

Consistency of Failure Rate: Although the reduction in soil test failure rate was consistent for greater sampling depth and later sampling time, the relative magnitude of failure rate was not consistent among years. There appeared to be a relationship between the magnitude of N-response and failure rate each year. (Fig.3). TYPE A failure rates were highest in 1989 and TYPE B failure rates were highest in 1991. PSNT sampling time was most successful where yield level exceeded 200 bu/acre (Table 3). Of the sites with >200 bu/acre yield level, 60% were in 1992, a year with a low failure rate. Conversely, of the sites with <100 bu/acre yield level, 52% were in 1991, the year with the highest total failure rate. ***The success of soil NO_3-N sampling strategies are subject to variation in growing season that influence both soil N mineralization dynamics and crop N demand.***

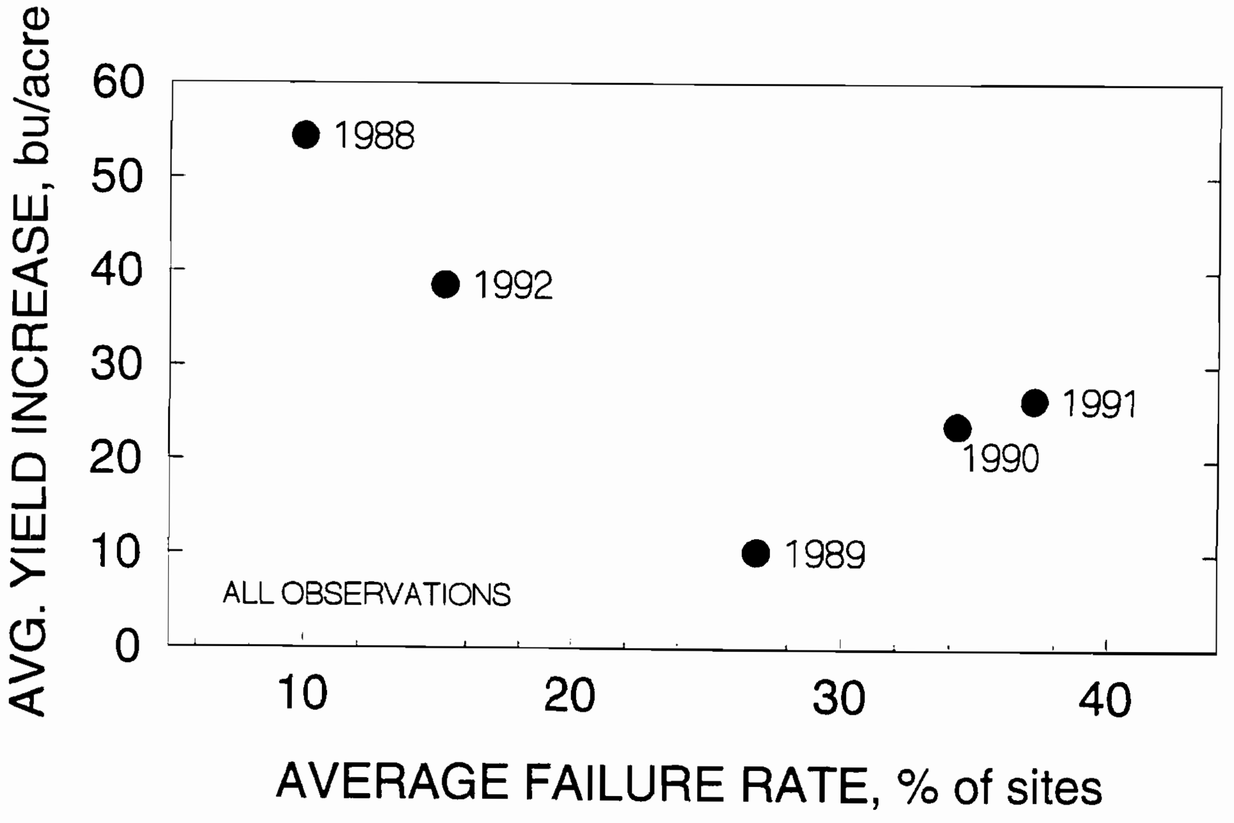

Figure 3. Relationship between average total soil test failure rate and average yield increase for the years 1988-1992.

Table 3. Effect of yield level, and sampling time and depth on the percent of sites where soil NO_3-N failed to predict N response.

Time of Sampling	Depth	Yield Level	n	Failed Soil Test[1] TOTAL	TYPE A	TYPE B
	ft	bu/ac		------------% of sites---------------		
PPNT	0 - 1	<100	18	27.8	0	27.8
		100-150	102	44.1	2.0	42.1
		150-200	139	33.8	0.7	33.1
		>200	33	27.3	0	27.3
PPNT	0 - 2	<100	18	22.2	0	22.2
		100-150	102	36.3	3.9	32.4
		150-200	139	25.2	9.4	15.8
		>200	33	30.3	9.1	21.2
PSNT	0 - 1	<100	23	34.8	0	34.8
		100-150	106	29.3	1.9	27.4
		150-200	139	28.1	3.6	24.5
		>200	33	15.2	0	15.2
PSNT	0 - 2	<100	15	33.3	0	33.3
		100-150	78	28.2	5.1	23.1
		150-200	115	20.0	6.1	13.9
		>200	31	12.9	0	12.9

[1]**Type A** failure = Soil NO_3-N>CSNL and RY≤90%; **TYPE** B failure = Soil NO_3-N<CSNL and RY>90%. CSNL derived from fitting *linear*-plateau model to all observations.

CONCLUSIONS

Soil nitrate-N testing is a proven best management strategy for estimating corn N needs. Pre-sidedress sampling and increasing depth of sampling improve the precision of these soil tests. A significant number of situations still exist where soil nitrate-N sampling fails to adequately predict N need. Much of the variability in both PPNT and PSNT can be attributed to the fact that these tests only measure available soil N status at one time prior to or early in the growth of the crop. Although N supply may be deemed deficient or adequate from a statistical standpoint with soil testing, soil nitrate-N sampling is a poor predictor of potentially mineralizable soil N. Soil nitrate-N status in itself gives no measure of plant N demand which will be a function of the conditions of the current growing season and other edaphic factors that influence yield potential. The conditions that influence crop N demand may not be the same conditions that influence soil N supply.

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