North Central Regional Research Publication No. 342

Evaluation of Soil Nitrate Tests for Predicting Corn Nitrogen Response in the North Central Region

L.G. Bundy, D.T. Walters, and A.E. Olness

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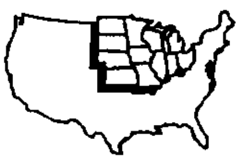

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March 1999

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Also available at:
www.soils.wisc.edu/extension/soilnitrate.pdf

Sponsored by the agricultural experiment stations of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin and the U.S. Department of Agriculture, Agricultural Research Service.

This publication was prepared by the North Central Regional Committee NC-201, Nutrient Management to Sustain Productivity While Protecting Surface and Groundwater Quality. Members of the committee are listed on the inside front cover.

The research was funded by the North Central Regional Association (NCRA) of Agricultural Experiment Station Directors. The NCRA is one of four regional associations with responsibility for facilitating cooperation of regional and national research. The research is supported in part by the Regional Research Fund (RRF), which is a federal appropriation authorized by the Hatch Act. Additional support comes from other federal programs as well as state and private sources. The research program focuses on regional priorities that are identified and developed jointly by State Agricultural Experiment Station (SAES) Directors, Departmental Chairs and participating scientists. More information on the NCRA is available at http://www.wisc.edu/ncra.

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EVALUATION OF SOIL NITRATE TESTS FOR PREDICTING CORN NITROGEN RESPONSE IN THE NORTH CENTRAL REGION

L.G. Bundy, D.T. Walters, and A.E. Olness

INTRODUCTION

Although soil nitrate (NO_3) tests are widely used in low rainfall areas of the North Central Region, development and implementation of effective soil NO_3 tests throughout the Great Plains and Midwest could improve agronomic efficiency of nitrogen (N) and reduce potential water quality problems associated with N use on cropland. Consequently, a North Central Regional Research Committee (NC-201 Nutrient Management to Sustain Productivity while Protecting Surface and Ground Water Quality) initiated a core experiment to provide a regional evaluation of soil NO_3 tests. Soil NO_3 tests have potential for more accurately predicting corn response to applied N than yield-based or soil-specific N recommendation procedures alone, because they can account for plant-available N that is not included in most N recommendation methods. Specifically, preplant soil NO_3 tests measure residual or carryover NO_3-N from N use in previous years. Other sampling approaches, such as the presidedress soil NO_3 test (PSNT) can estimate the amounts of organic N that will become available to the crop during the growing season from sources such as soil organic matter, manure, and legume crop residues.

One of the objectives of the NC-201 Regional Committee was to determine the applicability of various times and depths of soil sampling for NO_3-N testing, including the PSNT, and to develop complementary means for predicting crop N needs which will protect surface and ground water quality. This regional publication on use of soil NO_3 tests in the North Central Region reports the results of the committee's research on this subject. The goal of the regional project was to evaluate soil NO_3 tests for identifying N responsive or non-responsive sites, but not to calibrate the soil NO_3 tests for making N fertilizer recommendations.

SUMMARY OF PREVIOUS WORK AND JUSTIFICATION

Although preplant soil NO_3 tests have a long history of successful use in semi-arid regions of the Western and Great Plains region of the United States (Hergert, 1987), effective soil NO_3-N tests are also needed in humid regions of the USA (Bock and Kelley, 1992). One of the most promising approaches to NO_3 testing in the higher rainfall areas of the Midwest and Eastern states is use of the presidedress soil NO_3 test (PSNT) (Magdoff et al., 1984). Research conducted in the humid regions of the United States (Magdoff et al., 1984; 1990; Magdoff, 1991; Blackmer et al.,1989; Fox et al., 1989) suggests that the PSNT is effective for predicting corn response to applied N and that the critical value for the test (20 to 25 ppm N) is relatively uniform across a wide geographical area (Table 1). In addition, several recent studies in humid regions (Bundy and Malone, 1988; Roth and Fox, 1990; Liang et al., 1991) have confirmed earlier work showing that residual NO_3 can remain in the profiles of medium- to fine-textured soils during the overwinter period and may contribute available N to subsequent crops. Therefore, preplant soil NO_3 tests (PPNT) have also been developed and implemented for use in predicting crop N response and need for applied N in humid regions (Bundy et al., 1992; Schmitt and Randall, 1994; Bundy and Andraski, 1995). Methods for using soil NO_3 tests to predict corn N needs have been summarized by Bundy and Meisinger (1994), and N recommendations based on the results of these tests are provided in extension publications in states where NO_3 tests are used.

Research to improve N management for corn in the North Central Region is justified by the importance of the region in national and world corn production and by the substantial usage of fertilizer N in the region. Most fertilizer N used in the United States is applied to corn which receives an average of about 128 lb of N per acre (Daberkow and Taylor, 1993). From 1990 through 1992, about 74.1 million acres of corn were grown and about 7.64 billion bushels of grain were produced annually in the North Central United States (Table 2; USDA, 1992). The 12 states in this area produced 87% of the total corn grain on 83% of the total acreage devoted to corn production (USDA, 1992; Fig. 1). Thus, we estimate that at least 4 million tons of N fertilizer are applied each year at a cost of between \$600 to \$800 million for corn production within the 12-state area. The estimates exclude manure applications and N fixed by legumes used in crop rotations; so, the estimate of 128 lb N applied per acre of corn is a conservative value. Other sources (Keeney and Follett, 1991) provide somewhat higher estimates of N use in the North Central Region (6.0 million tons of N). The trend in N fertilizer use for corn production has been one of increasing intensity since about 1945. The corresponding trend in grain yield in the North Central Region has been also increasing by about 1.1% per year over the last 20 yr (USDA, 1974 and 1992; Table 2).

MATERIALS AND METHODS

Corn yield and soil NO_3-N data were collected from 307 sites across the North Central Region over a 5-yr period from 1988-92 (Fig. 1). Numerical values in Fig. 1 indicate the number of site-years of data collected at the same general geographic location, but experiments were never located on the same plots for more than 1 yr. The complete database for the project is shown in Appendix Table 1. Sites included a variety of soil and climatic characteristics and previous cropping and manure management practices (Table 3). Variables associated with the research sites as well as parameters such as time and depth of sampling were evaluated with respect to their effect on the prediction of corn response to N fertilizer application. A common research protocol described below was used by all cooperators in the regional project.

Treatment Specifications

An adapted corn hybrid was grown using recommended production practices except for N fertilization. Treatments included a no-N check plot and a "non-N limiting" treatment to assure an adequate N supply for the crop. The non-N limiting treatment was based on N response functions determined at the site or local university N recommendations. The check and non-N limiting treatments were replicated at least four times. Where starter fertilizer N or manure was applied, the same amount of N from these sources was applied to both the check and non-N limiting treatments. Starter fertilizer N additions were limited to 15 lb N/acre. Sites were selected to minimize the effects of previous site management by using only those locations where both the check and non-N limiting plots received the same N management for at least 1 yr before use in this study.

Table 1. Summary of PSNT calibration studies and test performance in the USA.

Location	Critical value	% correct†	Low PV‡ in RR	Reference
	ppm NO_3-N			
Delaware	17	70	--	Sims et al. (1995)
Iowa	20-25	--	--	Blackmer et al. (1989)
Maryland	22	--	Yes	Meisinger et al. (1992)
New York	21	84	Yes	Klausner et al. (1993)
Northeast USA	18	--	--	Magdoff et al. (1990)
Pennsylvania	21	89	Yes	Fox et al. (1989)
Wisconsin	21	73	--	Bundy and Andraski (1995)

† Correct identification of N responsive sites (%).
‡ Locations reporting low predictive value (PV) in the PSNT responsive range (RR).

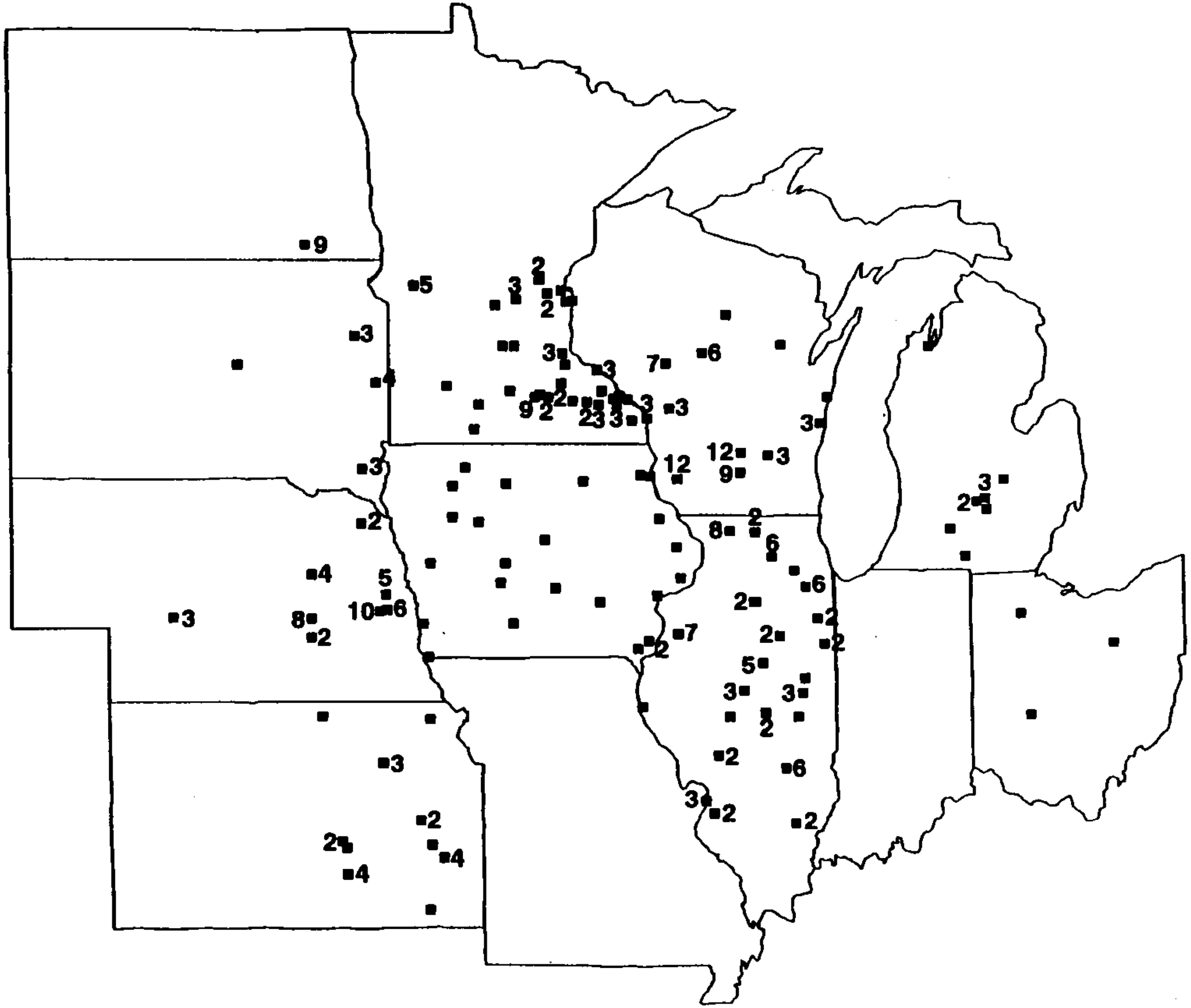

Figure 1. Locations of experimental sites in the North Central Region, 1988-1992. (Numerical values indicate multiple site-years of data from one location.)

Soil Sampling and Analysis

Spring preplant soil samples were taken in 1-ft depth increments to a depth of 2 ft from the check treatment. Each soil sample consisted of a composite of at least eight cores per plot. Presidedress soil samples were taken from the same plots using identical procedures when corn plants were about 1 ft tall, measured to the top of the crop canopy. Samples were rapidly air-dried or frozen before analysis to avoid changes in inorganic N content. Nitrate-N and exchangeable ammonium-N (optional) in the samples were determined using accepted analytical procedures (Keeney and Nelson, 1982). Routine soil tests for extractable K, available P (Bray and Kurtz-1), water pH, and soil organic matter content were performed on surface soil samples (0 to 6- to 0- to 8-inch depth) from each site (Dahnke, 1988).

Site Characteristics

A 3-yr site history including previous crops, rate and source of applied N, N application method during the previous year, manure application rate, method of incorporation, and estimated available N content, and tillage method and timing was compiled for each site. Soil characteristics including series name, surface texture, drainage class and use of tile drainage, parent material, topographic position, limitations to root growth or water movement within 6 ft of the surface, depth to water table, routine soil tests and soil organic matter or organic C content were recorded. Weekly total precipitation was measured during the period between preplant and preside-dress soil sample collection, and daily minimum and maximum temperatures were obtained from the nearest weather station.

Plant Data

Planting date, plant density, and corn hybrid were recorded for each location. Grain yields were determined in at least four replications of the check (no N) and non-N limiting treatments by harvesting a minimum of 20 ft of row from each plot. Grain moisture at harvest was determined, and yields were reported at 15.5% moisture.

Relative Yield Calculation

Relative yield (RY) in the control treatment at each site was calculated by dividing the mean check plot yield by the mean yield obtained in the non-N limiting treatment and expressing the result as a percent of the non-N limiting treatment yield. Therefore, a high RY indicates little or no response to N, while a low RY reflects a N responsive site.

Data Analysis

Data from all cooperators were compiled and summarized for each year. The relationships between relative yield and soil NO_3-N content were determined with Proc NLIN techniques (SAS Institute Inc., 1985) using the linear-response plateau (LRP) and quadratic-response plateau (QRP) models. These segmented model techniques allowed an estimate of the critical soil NO_3 level (CSNL) for different sampling times, sampling depths and previous management. The CSNL represents the concentration of soil NO_3-N above which no crop yield response to additional N is expected. 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 (DeLong and Yuan, 1988).

Table 2. Three-year average corn production in the North Central United States. †

Year	Total acreage‡	Grain production	Average yield§	% of USA	
				Acreage	Production
	million acres	billion bushels	bushels/acre		
1971 to 1973	70.9	5.62	110	80	87
1990 to 1992	74.1	7.64	134	83	87

† Source: USDA Agricultural Statistics (1974 and 1993).

‡ Including corn grown for silage.

§ Excluding corn grown for silage.

Table 3. Regression equations (LRP and QRP) and critical soil NO_3-N levels for corn grown following several cropping systems, 1988 through 1992.

Previous crop or cropping system	Time of sampling	Soil depth	n	Linear-response plateau (LRP): Equation†	LRP: Critical soil NO_3-N level	LRP: Plateau yield	Quadratic-response plateau (QRP): Equation	QRP: Critical soil NO_3-N level	QRP: Plateau yield
		ft			ppm	%		ppm	%
All observations	PPNT	0-1	292	$RY = 68.2 + 1.89N$	15.7	97.9	$RY = 64.8 + 2.98N - 0.067N^2$	22.3	98.0
		0-2	292	$RY = 62.8 + 3.28N$	9.3	93.3	$RY = 61.9 + 4.10N - 0.120N^2$	16.7	96.1
	PSNT	0-1	301	$RY = 57.9 + 2.34N$	16.9	97.4	$RY = 52.3 + 3.81N - 0.079N^2$	24.0	98.1
		0-2	239	$RY = 48.0 + 4.02N$	12.0	96.2	$RY = 41.9 + 62.6N - 0.170N^2$	17.9	97.9
Corn (with and without manure)	PPNT	0-1	146	$RY = 65.8 + 1.77N$	17.8	97.3	$RY = 63.8 + 2.42N - 0.041N^2$	29.4	99.4
		0-2	145	$RY = 63.7 + 2.12N$	15.8	97.2	$RY = 58.6 + 3.68N - 0.088N^2$	20.8	97.0
	PSNT	0-1	144	$RY = 55.5 + 2.22N$	19.0	97.7	$RY = 42.2 + 3.68N - 0.070N^2$	26.4	97.9
		0-2	132	$RY = 48.8 + 3.40N$	14.3	97.4	$RY = 43.3 + 5.19N - 0.120N^2$	21.3	98.5
Corn (without manure in study year)	PPNT	0-1	127	$RY = 64.8 = 1.71N$	19.2	97.0	$RY = 62.8 + 2.30N - 0.037N^2$	31.4	99.0
		0-2	126	$RY = 62.0 + 2.17N$	16.1	96.9	$RY = 55.4 + 4.11N - 0.106N^2$	19.3	95.1
	PSNT	0-1	125	$RY = 54.7 + 2.22N$	18.9	96.7	$RY = 48.8 + 3.66N - 0.069N^2$	26.3	96.9
		0-2	115	$RY = 48.2 + 3.40N$	14.2	96.5	$RY = 42.2 + 5.33N - 0.128N^2$	20.8	97.7
Continuous corn (no manure for 3+ years)	PPNT	0-1	74	$RY = 61.9 + 1.83N$	18.0	94.8	$RY = 60.6 + 2.30N - 0.033N^2$	34.9	100.7
		0-2	73	$RY = 57.5 + 2.68N$	13.5	93.7	$RY = 52.3 + 4.50N - 0.120N^2$	18.4	93.8
	PSNT	0-1	72	$RY = 54.8 + 2.16N$	18.9	95.6	$RY = 48.9 + 3.64N - 0.072N^2$	25.4	95.0
		0-2	67	$RY = 43.8 + 3.93N$	12.6	93.3	$RY = 38.0 + 6.00N - 0.160N^2$	19.3	95.9
Second-year corn following alfalfa	PPNT	0-1	23	$RY = 73.1 + 1.46N$	19.3	101.3	$RY = 69.5 + 2.35N - 0.044N^2$	26.8	100.9
		0-2	23	$RY = 69.8 + 1.99N$	15.2	100.0	$RY = 66.4 + 3.11N - 0.071N^2$	21.7	100.2
	PSNT	0-1	23	$RY = 58.1 + 2.067N$	19.3	98.0	$RY = 57.7 + 2.54N - 0.037N^2$	33.9	100.9
		0-2	23	$RY = 64.7 + 1.84N$	19.8	101.1	$RY = 47.3 + 4.73N - 0.110N^2$	22.3	100.2
Soybean	PPNT	0-1	80	---------- Lacking high soil NO_3-N/nonresponsive sites ----------					
		0-2	80	---------- Lacking high soil NO_3-N/nonresponsive sites ----------					
	PSNT	0-1	86	$RY = 64.1 + 1.93N$	17.0	96.9	$RY = 59.1 + 3.19N - 0.067N^2$	23.7	96.9
		0-2	56	---------- Lacking high soil NO_3-N/nonresponsive sites ----------					

— continued —

Table 3. (continued).

Previous crop or cropping system	Time of sampling	Soil depth	n	Linear-response plateau (LRP): Equation†	LRP: Critical soil NO_3-N level	LRP: Plateau yield	Quadratic-response plateau (QRP): Equation	QRP: Critical soil NO_3-N level	QRP: Plateau yield
		ft			ppm	%		ppm	%
All sites with manure in the study year	PPNT	0-1	28	$RY = 71.4 + 2.52N$	11.0	99.1	$RY = 60.0 + 6.04N - 0.233N^2$	13.0	99.2
		0-2	28	$RY = 75.6 + 2.02N$	12.2	100.2	$RY = 70.0 + 3.93N - 0.129N^2$	15.2	99.9
	PSNT	0-1	29	$RY = 69.7 + 1.82N$	16.6	99.9	$RY = 45.1 + 8.03N - 0.304N^2$	13.2	98.1
		0-2	24	$RY = 82.5 + 0.83N$	22.4	101.1	$RY = 78.4 + 1.59N - 0.028N^2$	28.3	100.9
Small grain	PPNT	0-1	25	$RY = 56.4 + 2.90N$	16.0	102.8	$RY = 54.6 + 3.80N - 0.069N^2$	27.7	107.2
		0-2	25	$RY = 56.9 + 3.39N$	13.0	101.0	$RY = 55.1 + 4.50N - 0.105N^2$	21.4	103.1
	PSNT	0-1	25	$RY = 53.0 + 3.32N$	12.8	95.5	$RY = 50.1 + 4.60N - 0.115N^2$	20.1	96.3
		0-2	13	$RY = 56.6 + 3.43N$	11.2	95.0	$RY = 55.8 + 4.20N - 0.105N^2$	19.9	97.6

† RY = relative grain yield; N = soil NO_3-N concentration.

Soil Test Failure Rate

Criteria for selecting 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). Frequently, the superiority of one response model could not be established using R^2 values or the results of the Shapiro-Wilk test. A separate approach, the soil NO_3 test failure rate, was developed to evaluate the effects of sampling time, sampling depth, and the appropriateness of CSNL determined by the LRP and QRP models. In this approach, each site was classified as either responsive or nonresponsive based on RY levels in the unfertilized treatment. If RY was greater than 90%, the site was considered nonresponsive. Choosing a RY closer to 100% generally lowered the failure rate but reduced the discriminating power of this statistic. For example, a higher RY value would result in more sites being identified as responsive, thus more sites would receive a recommendation for N fertilization. A soil NO_3 testing strategy was considered a failure if: (i) the soil NO_3 test $\geq$ CSNL and RY $\leq$ 90% (i.e., the test predicted a non-N-responsive site, but the site actually responded to N fertilization), a TYPE A failure; or (ii) the soil NO_3 test < CSNL and RY > 90% (i.e., the test predicted a N-responsive site, but the site did not respond to N fertilization), a TYPE B failure.

Assessing the failure rate of each soil NO_3 testing approach evaluated provided a practical tool for selecting the most useful soil NO_3 sampling strategies. TYPE A failures represent an economic loss to producers caused by reduced yields, while a TYPE B failure results in economic loss from excess fertilizer application and increases the risk of groundwater and surface water contamination with NO_3. The failure rate statistic allowed evaluation of soil NO_3 test performance in specific crop and soil management situations.

CHARACTERIZATION OF THE REGION AND DATABASE

Climatic Characterization of the Region

The 12 states in the North Central Region represent a broad range of climatic conditions that affect crop production and the behavior and management of N. Normal annual total precipitation ranges from more than 44 inches in the southeastern part of the region to less than 16 inches on the western border of the region (NOAA, 1983). Consequently, average annual potential percolation below the root zone in well-drained soils planted to corn (Stewart et al., 1975) ranges from 7 inches in the eastern part of the region to 1 inch in the western (Great Plains) portion of the region. Normal daily average temperatures in July range from less than 65°F in the extreme northern part of the region to more than 82°F in south central Kansas. Similarly, normal daily average temperatures in January range from less than 5°F in northern North Dakota and Minnesota to about 35°F along the southern border of the region (NOAA, 1983).

Characterization of the Database

Locations and data for the individual research sites in the region that comprised the database used in this study are shown in Fig. 1 and Appendix Table 1. Characteristics of the experimental sites are summarized in Fig. 2, which shows the frequency of soil test values for extractable K, available P (Bray and Kurtz-1), water pH, and soil organic matter content. Frequencies of surface soil texture and drainage classes as well as tillage and manure history are also illustrated in Fig. 2. The parameters in Fig. 2 were provided for most sites, but data from a few sites were incomplete with regard to one or more of the characteristics shown in Fig. 2.

Distributions of soil test P and K values were strongly skewed toward values approximating those usually considered optimum for corn production. Cooperators were encouraged to use sites with adequate soil P and K levels for corn, and this criteria was usually met. Median values for soil test K and P were about 195 and 42 ppm, respectively, while the corresponding average values for these tests were about 238 and 51 ppm. The soil test P distribution excludes 10 values obtained using the sodium bicarbonate extraction test (Olsen) on sites with pH values of at least 7.5 in North Dakota and Minnesota. The interpretation of these tests usually indicated a low relative P availability.

Most experimental sites had medium-textured surface soils in the loam or silt loam textural classes (Fig. 2). Since most of the corn acreage in the region is located on medium-textured soils, the textural makeup of the database is typical of the production situation. The data-base also includes a substantial number of sites on coarse-textured soils (sands, loamy sands, and sandy loams) and on fine-textured soils (clay loams, silty clay loams, and clays).

Drainage characteristics of the experimental sites were separated into five classes, ranging from excessively to poorly drained. Only seven sites on coarse-textured soils in Minnesota and Kansas were classified as excessively drained. The distribution of the remaining sites among the drainage classes indicates that most were located on well-drained to

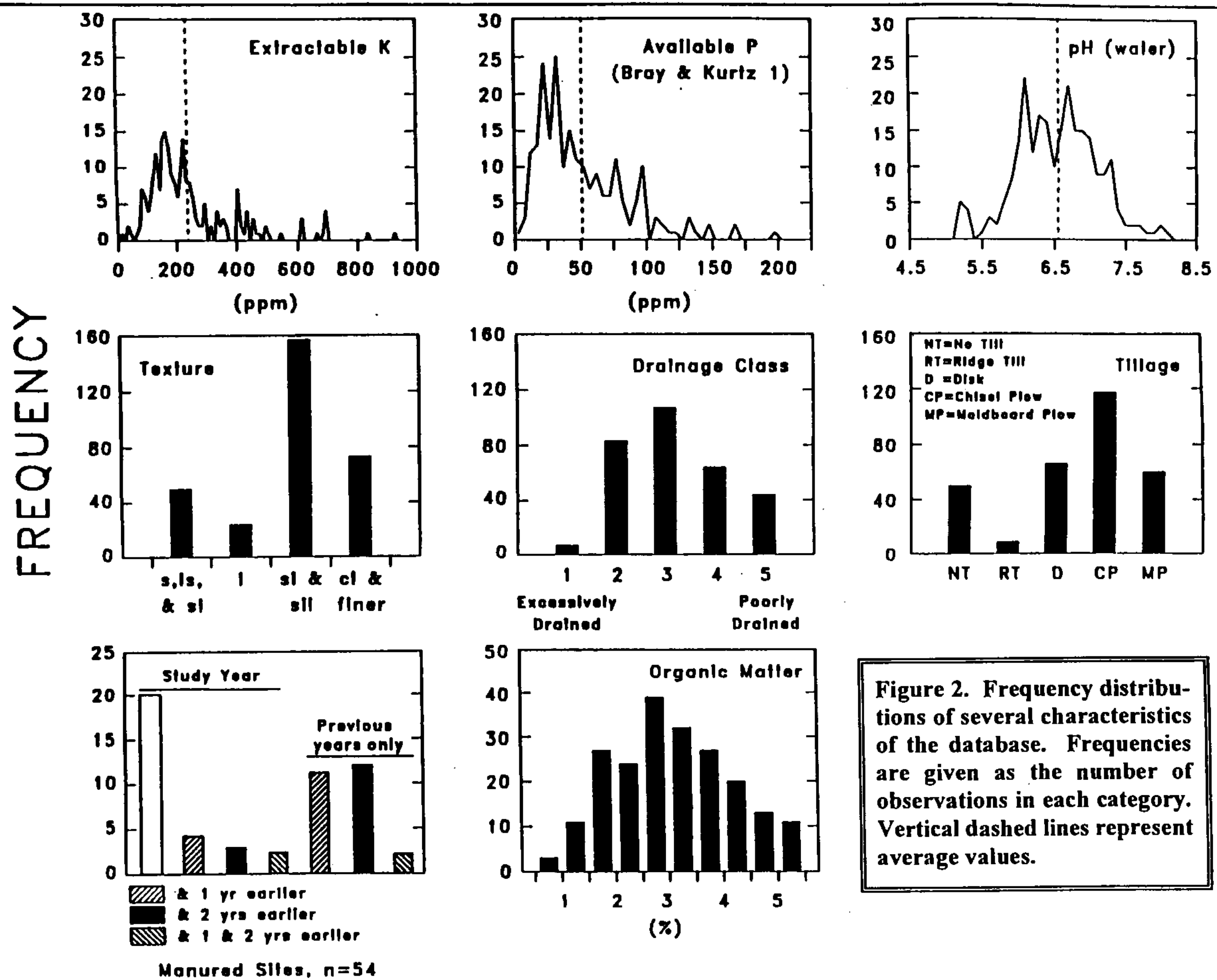

Figure 2. Frequency distributions of several characteristics of the database. Frequencies are given as the number of observations in each category. Vertical dashed lines represent average values.

moderately well-drained soils which is a reasonable approximation of the drainage characteristics of land used for corn production in the 12-state region.

Five tillage systems were used at the experimental sites (Fig. 2). Chisel plowing, moldboard plowing, and disking were the predominant tillage methods. Disking was often the primary tillage where corn followed soybean (about 2/3 of the disking observations). No-till corn was grown on 50 sites with 26 of these having silt- or silt loam-textured soils, and 10 additional sites were following soybean. No-till production on medium-textured soils or where the previous crop was soybean is considered more likely to be successful than on sites with fine-textured soils with large amounts of residue.

Manure was applied in the study year or within the previous 2 yr at 54 sites (Fig. 2). Of the sites with manure histories, 29 received manure in the study year and nine of these sites also had histories of manure additions during the previous 2 yr. Other sites had histories of manure additions only during the 2 yr preceding the study year.

RESULTS AND DISCUSSION

Of the 307 sites included in the database, 56% had relative yield (RY) values ≤ 90%, and were considered responsive to N fertilization. The frequency of N responsive sites varied with previous crop and manure application history (Tables 4 and 5). Where corn was the previous crop, 59% of the sites had RY values ≤ 90%, while sites with a previous soybean or small grain crop were 67 and 71% N responsive, respectively. None of the sites having a previous crop of alfalfa responded to N fertilization. The N responsiveness of sites usually increased with time since the most recent manure application (Table 5).

Regression equations using LRP and QRP models and the corresponding CSNL for preplant and presidedress soil NO_3 tests are shown in Table 3 for the previous crop categories included in the core experiment database. Most of the studies were done where the previous crop was corn, alfalfa, or soybean with a smaller number of locations following small grains.

Model Selection and CSNL Determination

Table 6 lists a comparison of test statistics and failure rates for the LRP and QRP models applied to all observations. The relationships between CSNL and TYPE A and TYPE B failures for the LRP model are illustrated in Fig. 3 for the PPNT and PSNT at two sampling depths. Soil NO_3-N critical levels were approximately 7 ppm lower for the LRP model.

However, R^2 and Shapiro-Wilk statistics did not provide sufficient criteria for choosing an overall critical level of all observations. Total failure rate was 3 to almost 8% lower for the LRP model, which resulted primarily from a reduction in TYPE B failures. Choosing the lower CSNL associated with the LRP would result in less risk of environmental contamination from excess NO_3-N; however, it would

Table 4. Effect of previous crop on the frequency of N-responsive sites with ≤ 90% relative yield in the control treatment, 1988-1992.

Previous crop	Relative yield ≤ 90%	Relative yield >90%	% Responsive sites
	------ no. of observations ------		
Corn	88	61	59
Soybean	58	28	67
Small grains	17	7	71
Alfalfa	0	28	0
Other	7	7	50
Total	170	131	56

Table 5. Effect of manure history on the percentage of sites with ≤90% relative yield (RY) in the control treatment for all observations and where previous crop was corn, 1988-1992.

Manure history	Previous crop: Corn	All observations
	------ % of sites ≤ 90% RY ------	
No manure for at least 3 yr	69	62
Applied 2 yr prior to study year	40	50
Applied 1 yr prior to study year	36	31
Applied study year	26	31

Table 6 . Comparison of linear-plateau (LRP) and quadratic-plateau (QRP) model performance (all observations), 1988-1992.

Time of sampling	Soil depth	Model	R^2	Shapiro-Wilk† test	CSNL	Relative grain yield n	Mean	Max.	Min.	S.D.	Probability of RY>90%	Failed soil test‡ 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	7.1	0.9	36.3	1.0	35.3
					<15.7	262	81	108	27	17.9	0.39			
		QRP	0.22	0.0001	>22.3	15	101	107	90	3.9	1.0	39.4	0	39.4
					<22.3	277	81	108	27	17.8	0.42			
PPNT	0 - 2	LRP	0.24	0.0001	> 9.3	90	93	108	39	11.9	0.68	29.5	6.8	22.6
					< 9.3	202	78	105	27	18.2	0.32			
		QRP	0.24	0.0001	>16.7	27	98	107	77	7.3	0.85	37.0	0.7	36.3
					<16.7	265	81	108	27	17.9	0.38			
PSNT	0 - 1	LRP	0.41	0.0006	>16.9	66	98	107	66	6.9	0.84	27.6	2.3	25.2
					<16.9	235	79	108	27	17.6	0.31			
		QRP	0.41	0.0004	>24.0	39	99	107	82	5.7	0.87	33.2	0.7	32.7
					<24.0	262	80	108	27	17.6	0.36			
PSNT	0 -2	LRP	0.50	0.0072	>12.0	77	96	107	66	7.9	0.82	22.6	4.6	18.0
					<12.0	162	76	105	27	17.8	0.26			
		QRP	0.50	0.0340	>17.9	44	99	107	81	7.9	0.89	28.8	0.8	28.0
					<17.9	195	79	105	27	17.8	0.34			

†The Shapiro-Wilk test statistic for 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.

‡ **TYPE A** failure = Soil NO_3-N ≥ CSNL and RY ≤ 90%; **TYPE B** failure = Soil NO_3-N <CSNL and RY > 90%.

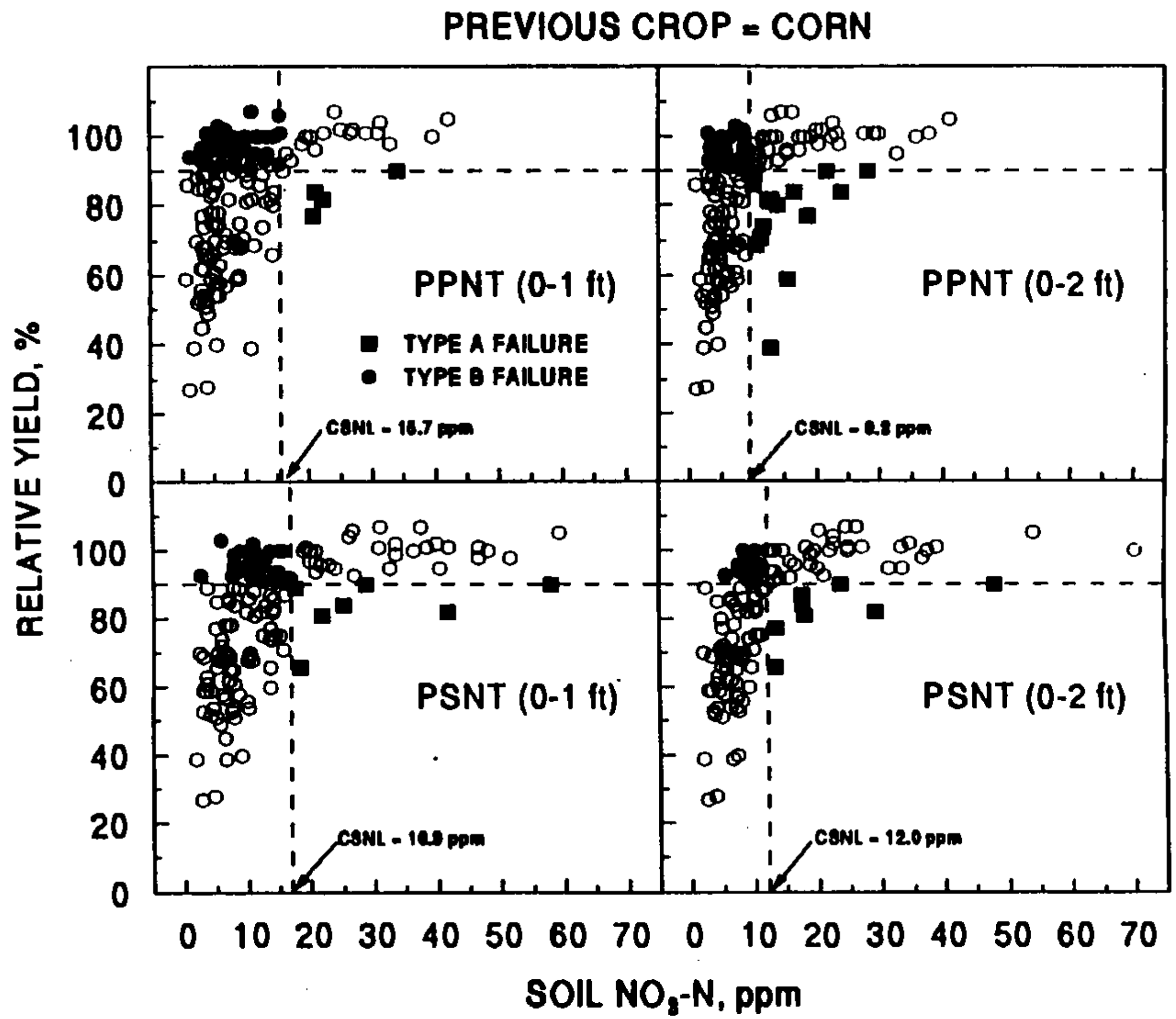

Figure 3. Relationships between the critical soil NO_3 level (CSNL) and TYPE A and TYPE B test failures using the linear-response plateau model with the preplant (PPNT) and presidedress (PSNT) NO_3 tests at two sampling depths. TYPE A failure = Soil $NO_3 \geq$ CSNL and RY $\leq$ 90%; TYPE B failure = Soil NO_3-N < CSNL and RY > 90%.

also result in a modest increase in TYPE A failures. This is also reflected in a lower probability of non-responsive sites above the LRP model CSNL. The CSNL values associated with the LRP and QRP models for the PSNT sampling time (Table 6) are similar to the range of CSNL values reported by others (Table 1). Based on the lower overall failure rate with the LRP CSNL, the LRP model was selected for all subsequent evaluations of NO_3 test performance.

Effect of Sample Depth

Increasing sampling depth from 1 to 2 ft did not improve the fit of either the LRP or QRP model, but the CSNL values were lower at the 2-ft depth (Table 6). This finding is consistent with results from other studies showing lower critical soil NO_3-N concentrations when sampling depth was increased from 1 to 2 ft (Binford et al., 1992; Bundy and Andraski, 1995). Increasing sampling depth from 1 to 2 ft resulted in a slight increase in TYPE A failures with an increase from 3 to 20 sites for preplant sampling (PPNT) and from 7 to 11 sites for presidedress sampling (PSNT). In contrast, TYPE B failures were substantially reduced with the 2-ft sampling depth. The reduction in failure rate associated with deeper sampling depth resulted from the detection of sites with appreciable accumulation of NO_3-N in the second foot. Sites exhibiting TYPE B failures at the 1-ft sample depth, which were successfully predicted as non-responsive with a 2-ft sample depth (76 sites for PPNT and 43 sites for PSNT), had a soil NO_3-N concentration in the 1- to 2-ft depth, which averaged 12 and 14 ppm NO_3-N for PPNT and PSNT sampling times, respectively. Soil NO_3-N in the 1- to 2-ft depth is a readily available source of N for the corn plant. Previous studies of sampling depth effects on PSNT performance have shown little or no advantage to sampling the 1- to 2-ft depth (Binford et al., 1992; Bundy and Andraski, 1995; Sims et al., 1995). However, these evaluations of performance were based on sampling depth effects on the R^2 value of statistical models rather than on a test failure rate statistic. For the PSNT, overall failure rates were generally lower for medium-textured soils than for fine- or coarse-textured soils (Table 7).

Preplant sampling to 2 ft on soils with organic matter < 2%, on fine-textured soils, and on soils with pH levels > 7.0, however, resulted in an increase in total failure rate (Table 7). For the low organic matter soils, average soil NO_3-N concentrations were lower, and there was little change in NO_3-N in the second-foot increment from PPNT to PSNT (Table 8). This indicates a low potential for mineralization of N as the season progressed and low capacity for immobilization and remineralization of residual mineral N. Where pH was > 7.0, soil NO_3-N in the second foot decreased between PPNT and PSNT sampling times soils (Table 11), and the second-foot NO_3-N change between sampling times was small on fine-textured soils (Table 12). These observations also suggest that second-foot NO_3-N was not a major source of N in these two soil categories.

Effect of Sampling Time

With the exception of sites with soybean or small grain as a previous crop (Table 9) and coarse-textured soils (Table 7), the risk of failure in predicting an N response was reduced by sampling later (PSNT timing) in the growing season. When corn was the previous crop, the 2-ft PSNT reduced the overall failure rate to one-half that realized with a 1-ft PPNT sampling (Table 9). Preplant (PPNT) sampling when alfalfa was the previous crop resulted in a > 75% failure rate, all of which were TYPE B. This finding is consistent with other work showing that preplant soil NO_3 values in corn following alfalfa were low due to inadequate time for organic N mineralization and that preplant tests were of limited value in separating N responsive and nonresponsive sites (Bundy and Andraski, 1993). None of the corn following alfalfa sites responded to N, and no individual CSNL was derived for the alfalfa data subset; however, TYPE B failures were reduced to < 40% of sites by delaying sampling until PSNT and using the overall CSNL. Predictions of N response for second-year corn after alfalfa were also reduced to a 17% failure rate with a 2-ft PSNT sample (Table 9). Use of the PSNT to determine corn N needs following alfalfa has been investigated in several studies (El-Hout and Blackmer, 1990; Roth et al., 1992; Bundy and Andraski, 1993; Morris et al., 1993). These studies showed that corn following alfalfa usually did not respond to N fertilization, and that yields were maximized by low rates (30 to 50 lb N/acre) when response occurred. Roth et al. (1992) and Bundy and Andraski (1993) reported that about 50% of the sites studied had PSNT (0 to 1 ft) results < 21 ppm NO_3-N. Morris et al. (1993) concluded that the PSNT for corn after alfalfa was most effective when used with a critical value of 14 ppm NO_3-N.

The change in soil NO_3-N concentration between PPNT and PSNT sampling times averaged +13.2 and +9.4 ppm for the 0- to 1- and 0- to 2-ft depths, respectively, for first-year corn following alfalfa (Table 10). It is apparent that substantial net N mineralization occurs after corn planting in soils

Table 7. Percent of sites where soil NO_3-N test failed to predict N response as influenced by soil properties, and sampling time and depth, 1988-1992.

				Failed soil test †					
				Overall ‡ CSNL			Soil specific § CSNL		
Soil property	Time of soil sampling	Depth	n	TOTAL	TYPE A	TYPE B	TOTAL	TYPE A	TYPE B
		ft		% of sites					
Soil pH									
< 6.0	PPNT	0-1	26	CSNL beyond range of data			23.1	0	23.1
		0-2	26	23.1	0	23.1	15.4	0	15.4
	PSNT	0-1	26	34.6	0	34.6	26.9	7.7	19.2
		0-2	15	CSNL beyond range of data			Model failed to fit		
6.0 - 6.5	PPNT	0-1	87	27.6	0	27.6	26.4	0	26.4
		0-2	86	19.7	2.3	17.4	19.7	2.3	17.4
	PSNT	0-1	87	21.8	1.2	20.6	19.5	2.3	17.2
		0-2	58	17.2	2.5	13.8	15.5	5.2	10.3
6.6 - 7.0	PPNT	0-1	70	50.0	0	50.0	41.4	2.9	38.5
		0-2	70	37.1	2.9	34.3	37.1	2.9	34.3
	PSNT	0-1	70	38.6	1.4	37.2	41.4	0	41.4
		0-2	58	35.0	5.2	29.3	37.9	0	37.9
> 7.0	PPNT	0-1	40	27.5	0	27.5	32.5	0	32.5
		0-2	40	35.0	20.0	15.0	25.0	2.5	22.5
	PSNT	0-1	40	30.0	7.5	22.5	22.5	15.0	7.5
		0-2	34	23.5	8.8	14.7	23.5	11.8	11.8
Soil Organic Matter									
<2 %	PPNT	0-1	26	23.1	0	23.1	23.1	0	23.1
		0-2	26	34.6	19.2	15.4	30.8	19.2	11.6
	PSNT	0-1	22	31.8	0	31.8	27.7	0	27.3
		0-2	26	26.9	0	26.9	26.9	0	26.9
2 - 4 %	PPNT	0-1	134	41.0	2.2	38.8	38.8	2.2	36.6
		0-2	134	31.3	6.7	24.6	36.6	4.5	32.1
	PSNT	0-1	135	26.7	4.4	22.2	25.9	3.7	22.2
		0-2	124	24.2	7.3	16.9	26.6	7.3	19.4
> 4 %	PPNT	0-1	47	42.6	0	42.6	53.2	0	53.2
		0-2	47	31.9	6.4	25.5	46.8	0	46.8
	PSNT	0-1	50	30.0	0	30.0	28.0	6.0	22.0
		0-2	41	22.0	0	22.0	19.5	0	19.5
Soil Texture¶									
Coarse	PPNT	0-1	49	34.7	0	34.7	32.7	0	32.7
		0-2	49	28.6	8.2	20.4	30.6	4.1	26.5
	PSNT	0-1	45	33.3	0	33.3	17.8	0	17.8
		0-2	46	30.4	0	30.4	10.9	4.4	6.5
Medium	PPNT	0-1	174	38.5	1.2	37.4	37.4	1.2	36.2
		0-2	174	28.2	5.2	23.0	28.2	5.2	23.0
	PSNT	0-1	185	23.8	2.7	29.6	27.6	1.1	26.5
		0-2	139	20.1	6.5	13.7	23.7	2.2	21.5
Fine	PPNT	0-1	66	31.8	1.5	30.3	31.8	1.5	30.3
		0-2	66	33.3	10.6	22.7	31.8	0	31.8
	PSNT	0-1	68	33.8	2.9	30.9	29.4	4.4	25.0
		0-2	54	22.2	3.7	18.5	20.4	7.4	13.0

† **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-response plateau model to all observations.
§ CSNL derived from fitting linear-response plateau model to specific data subsets based on soil properties.
¶ Coarse includes LS, SL, FSL, CS; Medium includes L, Si, SiL, SCL; Fine includes C, CL, SiCL.

Table 8. Mean soil [NO_3-N] as a function of organic matter content, sampling time and depth, with the change in soil [NO_3-N] between sampling time, 1988-1992.

Soil property	Soil depth	Time of soil sampling	n	Soil test [NO_3-N] Mean	Max.	Min.	S.E.	Mean change in [NO_3-N] from PPNT to PSNT n	0-1'	0-2'	(1-2')	T	Prob>T †
				ppm					ppm				
Soil Organic Matter													
< 2 %	0-1	PPNT	26	9.1	29	1	1.6	22	2.3			1.6	0.1226
		PSNT	22	11.1	40	2	1.1						
	0-2	PPNT	26	8.2	22	1	1.2	26		-0.1	(0.9) ‡	0.3	0.9753
		PSNT	26	8.1	34	2	1.5						
2 - 4 %	0-1	PPNT	134	9.1	42	0	0.6	134	6.0			8.3	0.0001
		PSNT	135	15.2	59	3	1.0						
	0-2	PPNT	134	8.8	41	0	0.6	123		4.2	(2.1)	6.2	0.0001
		PSNT	124	13.1	70	3	0.9						
> 4 %	0-1	PPNT	47	9.1	31	1	0.8	47	4.4			3.8	0.0004
		PSNT	50	13.7	37	4	1.2						
	0-2	PPNT	47	8.5	23	2	0.7	38		2.8	(0.6)	3.4	0.0017
		PSNT	41	11.5	27	4	1.0						

† Probability that the change in [NO_3-N] from PPNT to PSNT =0.

‡T value is for change in [NO_3-N] over the 0- to 2-ft depth.

Table 9. Percent of sites where soil NO_3-N test failed to predict N response, 1988-1992.

Previous crop or cropping system	Time of soil sampling	Depth	n	Failed soil test † Overall ‡ CSNL TOTAL	TYPE A	TYPE B	Crop specific § CSNL TOTAL	TYPE A	TYPE B
		ft		% of sites					
All observations	PPNT	0-1	292	36.3	1.0	35.3	na		
		0-2	292	29.5	6.8	22.6	na		
	PSNT	0-1	301	27.6	2.3	25.2	na		
		0-2	239	22.6	4.6	18.0	na		
Corn (with and without manure)	PPNT	0-1	146	31.5	2.1	29.5	33.6	2.1	31.5
		0-2	145	25.5	10.3	15.2	30.3	2.1	28.3
	PSNT	0-1	144	24.8	3.2	21.6	23.6	2.1	21.5
		0-2	132	15.9	4.6	11.4	21.2	3.0	18.2
Corn (without manure in study year)	PPNT	0-1	127	28.4	1.6	26.8	29.9	1.6	28.4
		0-2	126	25.4	11.1	14.3	27.8	1.6	26.2
	PSNT	0-1	125	24.8	3.2	21.6	23.2	1.6	22.4
		0-2	115	14.7	3.5	11.3	20.9	1.7	19.2
Continuous corn (no manure for 3+ years)	PPNT	0-1	74	24.3	2.7	21.6	27.0	2.7	24.3
		0-2	73	20.6	9.6	11.0	19.2	2.7	16.4
	PSNT	0-1	72	19.4	2.8	16.6	19.4	1.4	18.1
		0-2	67	10.5	4.5	5.6	10.4	4.4	6.0
Second-year corn following alfalfa	PPNT	0-1	23	34.8	0	34.8	39.1	0	39.1
		0-2	23	21.7	8.7	13.0	34.8	0	34.8
	PSNT	0-1	23	34.8	8.7	26.1	30.4	4.3	26.1
		0-2	23	17.4	4.4	13.0	30.4	0	30.4
Soybean	PPNT	0-1	80	33.8	0	33.8	-------- Model failed to fit --------		
		0-2	80	30.1	6.3	23.8	-------- Model failed to fit --------		
	PSNT	0-1	86	31.4	1.2	30.2	31.4	1.2	30.2
		0-2	56	30.4	7.1	23.2	-------- Model failed to fit --------		
Small grain	PPNT	0-1	25	24.0	0	24.0	28.0	0	28.0
		0-2	25	12.0	0	12.0	28.0	0	28.0
	PSNT	0-1	25	28.0	4.0	24.0	24.0	4.0	20.0
		0-2	13	30.8	7.7	23.1	23.1	0	23.1
Alfalfa	PPNT	0-1	27	92.6	0	92.6	-------- Model failed to fit --------		
		0-2	27	77.8	0	77.8	-------- Model failed to fit --------		
	PSNT	0-1	28	39.3	0	39.3	-------- Model failed to fit --------		
		0-2	26	38.4	0	38.4	-------- Model failed to fit --------		
All sites w/manure in study year	PPNT	0-1	28	46.4	3.6	42.9	17.9	3.6	14.3
		0-2	28	17.9	3.6	14.3	28.6	3.6	25.0
	PSNT	0-1	29	27.5	3.5	24.1	27.6	3.5	24.1
		0-2	24	25.0	8.3	16.7	33.3	0	33.3

† **TYPE A** failure = Soil NO_3-N $\geq$ CSNL and RY $\leq$ 90%; **TYPE B** failure = Soil NO_3-N < CSNL and RY > 90%.

‡ CSNL derived from fitting linear-response plateau model to all observations.

§ CSNL derived from fitting linear-response plateau model to specific crop or cropping system observations.

Table 10. Mean soil [NO_3-N] as a function of sampling time, depth, and previous crop or cropping system with the change in soil [NO_3-N] between sampling time, 1988-1992.

Previous crop or cropping system	Depth	Time of soil sampling	n	Soil test [NO_3-N] Mean	Max.	Min.	S.E.	n	Mean change in [NO_3-N] from PPNT to PSNT 0-1'	0-2'	(1-2')	T	Prob>T †
	ft			ppm					ppm				
All observations	0-1	PPNT	292	8.5	50	0	0.4						
		PSNT	301	13.4	59	2	0.6	288	4.7			10.7	0.0001
	0-2	PPNT	292	8.1	45	0	0.4						
		PSNT	239	11.7	70	2	0.6	223		3.2	(1.5)	3.1	0.002
Corn (with and without manure	0-1	PPNT	146	9.8	42	1	0.6						
		PSNT	144	14.8	59	2	1.0	142	5.1			7.9	0.0001
	0-2	PPNT	145	9.6	41	1	0.7						
		PSNT	132	12.6	70	1	0.9	130		2.9	(1.3)	4.6	0.0001
Corn (without manure in study year)	0-1	PPNT	127	9.2	40	1	0.7						
		PSNT	125	12.9	58	2	0.9	123	3.8			6.7	0.0001
	0-2	PPNT	126	8.8	38	1	0.6						
		PSNT	115	10.7	48	2	0.7	113		1.8	(0.6)	3.8	0.0002
Continuous corn (no manure for 3+ yr)	0-1	PPNT	74	8.1	31	1	0.7						
		PSNT	72	11.2	42	2	1.0	72	3.0				
	0-2	PPNT	73	7.9	38	1	0.7						
		PSNT	67	9.6	33	2	0.8	67		1.5	(0.6)	2.5	0.015
Second-year corn following alfalfa	0-1	PPNT	23	12.6	40	3	2.0						
		PSNT	23	19.7	41	7	2.4	23	7.1			4.4	0.0002
	0-2	PPNT	23	12.1	36	3	1.9						
		PSNT	23	15.7	37	6	2.0	23		3.5	(-0.1)	3.8	0.001

— continued —

Table 10, (continued).

Previous crop or cropping system	Depth	Time of soil sampling	n	Soil test [NO_3-N] Mean	Max.	Min.	S.E.	Mean change in [NO_3-N] from PPNT to PSNT n	0-1'	0-2'	(1-2')	T	Prob>T †
	ft			ppm					ppm				
Soybean	0-1	PPNT	80	6.3	14	0	0.4						
		PSNT	86	10.1	55	2	0.7	80	3.1			7.4	0.0001
	0-2	PPNT	80	5.8	14	0	0.3						
		PSNT	56	7.7	19	2	0.4	52		2.0	(1.1) ‡	5.3	0.0001
Small grain	0-1	PPNT	25	8.7	50	1	2.0						
		PSNT	25	9.6	41	2	1.7	25	0.8			0.8	0.426
	0-2	PPNT	25	7.8	45	1	1.9						
		PSNT	13	10.6	35	3	2.6	13		0.3	(0.5)	0.3	0.761
Alfalfa	0-1	PPNT	27	7.8	19	2	0.9						
		PSNT	28	21.3	43	7	1.8	27	13.2			7.1	0.0001
	0-2	PPNT	27	6.2	16	2	0.7						
		PSNT	26	16.1	27	8	1.2	25		9.4	(5.0)	8.5	0.0001
All sites with manure applied in study year	0-1	PPNT	28	14.6	50	3	2.1						
		PSNT	29	24.6	59	2	3.1	28	8.9			4.1	0.0003
	0-2	PPNT	28	14.9	45	3	2.2						
		PSNT	24	23.3	70	5	3.2	24		7.1	(4.1)	2.7	0.012

† Probability that the change in [NO_3 -N] from PPNT to PSNT = 0.

‡ T value is for change in [NO_3 -N] over the 0- to 2-ft depth.

where alfalfa was the previous crop. Where corn followed soybean, the change in soil NO_3-N concentration between sampling times was not nearly as large as following alfalfa, and failure rate was not substantially reduced by delaying soil sampling until PSNT (Tables 9 and 10). Apparently, the influence of a previous soybean crop on soil NO_3-N concentration is reflected at the preplant soil sampling time.

Overall CSNL vs. Previous Crop/Soil Specific CSNL

The CSNL generated from fitting the entire data set (all observations at the 0- to 1-ft sampling depth in Table 3) to the LRP or QRP models ranged from 16.9 to 24.0 ppm NO_3-N, which are very similar to the CSNL values published by others for the PSNT (Table 1). The NC-201 database was divided into smaller groups of site data based upon common previous crop, manure addition or soil pH, organic matter, and texture. Critical soil NO_3-N levels for each of these data subsets were generated from fitting the LRP and QRP models (Table 3). In general, selecting previous crop or soil specific CSNL values did not result in a reduction of failure rate compared to using the CSNL based on the entire dataset (Table 9). In several cases, model fit was improved by subsetting the data; however, this did not always result in a reduction in failure rate. Using the soil-specific data for coarse-textured soils, the model fit was improved and the failure rate reduced for the PSNT sampling time with either the 1- or 2-ft sample depth (Table 7). Overall failure rate was increased using a crop-specific CSNL, but with an overall reduction in TYPE A failure rate (Table 9).

Change in Soil NO_3-N Concentration Between Sampling Times

The average change in soil NO_3 concentration ([NO_3-N]) from PPNT to PSNT sampling times was usually positive regardless of previous crop or soil property (Tables 8 and 10 to 13). On average, about 75% of sites exhibited an increase in [NO_3-N] from PPNT to PSNT (Table 13). An exception to this statistic were those sites following alfalfa where nearly 100% were positive, and those sites with yield level exceeding 200 bu/acre corn yield. Average soil [NO_3-N] at the 1-ft depth ranged from a high of 24.6 ppm (manured sites, PSNT) to a low of 6.3 ppm (previous crop soybean, PPNT) (Table 10). Given the lack of corn N response when alfalfa was the previous crop, it is interesting to note that PPNT soil [NO_3-N] were very low, but a large increase in soil [NO_3-N] occurred by the PSNT sampling time. The change in soil [NO_3-N] at either the 1- or 2-ft depth ranked on the basis of previous crop or cropping system was alfalfa >> manured > second-year corn after alfalfa > corn > soybean > small grain. The change in soil [NO_3-N] from PPNT to PSNT was lowest for soils with organic matter < 2%, coarse and fine texture, or a pH <6.0 (Tables 8, 11, 12). This is consistent with our knowledge of factors affecting a soil's potential for mineralization (pH, organic matter), storage (immobilization) of N (organic matter and texture), denitrification of NO_3-N (fine texture), and leaching of NO_3-N (coarse texture).

Effect of Year

Although the reduction in soil test failure rate was consistent for greater sampling depth and later sampling time across the 5 yr of data collection, the relative magnitude of failure rate was not consistent among years (Table 14). Failure rates in 1991 were highest, averaging 37.2% and in 1992 were lowest, averaging 15.2%. TYPE A failure rates were highest in 1989 and Type B failure rates highest in 1991. Of the sites with >200 bu/acre yield level, 60% were in 1992, the year with the lowest failure rate (Table 15). Of the sites with <100 bu/acre yield level, 52% were in 1991, the year with the highest total failure rate. These statistics indicate the vulnerability of soil NO_3-N sampling strategies to annual climatic variation as this effects the potential for NO_3-N losses, soil N mineralization, and crop N demand. The results also suggest that soil NO_3-N test performance was best in high-yielding years when climatic factors favored NO_3-N retention in the corn root zone and efficient N utilization by the crop. This finding is similar to results indicating better soil NO_3-N test performance on high-yield potential soils than on medium- or low-yield potential soils (Bundy and Andraski, 1995). High crop N demand in good years may also make residual soil NO_3-N a more important source of N for corn.

CONCLUSIONS

1. Neither the R^2 nor the Shapiro-Wilk test provided clear statistical criteria for selecting a CSNL derived from the LRP or QRP models. Calculation of a failure rate based on non-N-responsive sites and CSNL gave a more practical decision tool for assessing the economic or environmental consequence of selecting a given CSNL. Although an improved model R^2 generally resulted in a lower failure rate, there were cases where an improved R^2 did not always insure the lowest failure rate.
2. Sampling to 2 ft improved the success of predicting non-responsive sites for both PPNT

Table 11. Mean soil [NO_3-N] as a function of soil pH, sampling time, and depth with the change in soil [NO_3-N] between sampling time, 1988-1992.

Previous crop or cropping system	Depth	Time of soil sampling	n	Soil test [NO_3-N] Mean	Max.	Min.	S.E.	Mean change in [NO_3-N] from PPNT to PSNT n	0-1'	0-2'	(1-2')	T	Prob>T †
	ft			---------- ppm	----------	----------	----------		---------- ppm	----------	----------		
Soil pH													
< 6.0	0-1	PPNT	26	5.8	13	2	0.6						
		PSNT	26	8.7	34	2	1.3	26	2.9			2.8	0.0095
	0-2	PPNT	26	5.3	12	2	0.6						
		PSNT	15	6.3	11	2	0.7	15		1.3	(1.2) ‡	1.8	0.0905
6.0 - 6.5	0-1	PPNT	87	7.8	50	1	0.8						
		PSNT	87	11.5	58	2	1.1	87	3.7			4.9	0.0001
	0-2	PPNT	86	7.4	45	1	0.7						
		PSNT	58	11.5	70	2	1.8	58		3.2	(2.3)	2.7	0.0097
6.5 - 7.0	0-1	PPNT	70	7.6	29	0	0.6						
		PSNT	70	12.3	39	2	0.9	70	4.7			6.1	0.0001
	0-2	PPNT	70	7.0	27	0	0.6						
		PSNT	58	10.7	32	4	0.8	58		3.5	(1.6)	6.1	0.0001
> 7.0	0-1	PPNT	40	8.8	31	1	1.0						
		PSNT	40	12.1	37	2	1.4	40	3.3			2.7	0.0108
	0-2	PPNT	40	8.7	24	1	1.0						
		PSNT	34	10.2	26	2	1.2	34		1.7	(-0.2)	1.9	0.0633

† Probability that the change in [NO_3-N] from PPNT to PSNT =0.

‡ T value is for change in [NO_3-N] over the 0- to 2-ft depth.

Table 12. Mean soil [NO_3-N] as a function of soil texture, sampling time, and depth with the change in soil [NO_3-N] between sampling time, 1988-1992.

Previous crop or cropping system	Depth	Time of soil sampling	n	Soil test [NO_3-N] Mean	Max.	Min.	S.E.	n	Mean change in [NO_3-N] from PPNT to PSNT 0-1'	0-2'	(1-2')	T	Prob>T †
	ft			ppm					ppm				
Soil Texture ‡													
Coarse	0-1	PPNT	49	8.0	34	1	1.1						
		PSNT	45	10.7	58	2	1.6	45	2.4			2.7	0.0087
	0-2	PPNT	49	7.9	28	1	1.0						
		PSNT	46	9.1	48	2	1.3	46		0.9	(0.6) §	0.9	0.3612
Medium	0-1	PPNT	174	9.1	50	1	0.6						
		PSNT	185	15.5	59	2	0.8	174	6.4			10.6	0.0001
	0-2	PPNT	174	8.5	45	1	0.6						
		PSNT	139	13.9	70	2	0.8	128		4.9	(2.4)	7.8	0.0001
Fine	0-1	PPNT	66	7.6	22	0	0.6						
		PSNT	68	9.7	55	2	1.0	66	1.5			2.6	0.0108
	0-2	PPNT	66	7.0	20	0	0.5						
		PSNT	54	8.2	29	2	0.6	54		0.9	(0.3)	1.8	0.0808

† Probability that the change in [NO_3-N] from PPNT to PSNT =0.

‡ Coarse includes LS, SL, FSL, LFS, CS; Medium includes L, SiL, SCL; Fine includes C, CL, SiCL.

§ T value is for change in [NO_3-N] over the 0- to 2-ft depth.

Table 13. Percent of sites where change in soil [NO_3-N] between preplant (PPNT) and presidedress (PSNT) time was >0, 1988-1992.

Category	Δ[NO_3-N] PPNT to PSNT > 0 †		
	0-1 ft	0-2 ft	1-2 ft
	% of sites		
All observations	80 (288)	76 (228)	70 (223)
Soil Organic Matter	77 (203)	75 (187)	71 (182)
<2%	68 (22)	62 (26)	73 (22)
2-4%	81 (134)	78 (123)	71 (122)
>4%	70 (47)	76 (38)	71 (38)
Soil pH			
< 6.0	85 (26)	67 (15)	80 (15)
6.0-6.5	81 (87)	76 (58)	64 (58)
6.6-7.0	84 (70)	83 (58)	74 (58)
>7.0	63 (40)	68 (34)	56 (34)
Manure			
None	82 (235)	77 (179)	74 (174)
Applied in study year	82 (28)	79 (24)	63 (24)
Applied prior to study year	76 (25)	72 (25)	48 (25)
Relative Yield			
> 90%	82 (130)	77 (105)	69 (104)
< 90%	78 (158)	76 (123)	71 (119)
Previous Crop/Cropping System			
Alfalfa	93 (27)	100 (25)	96 (25)
Corn	78 (142)	75 (130)	68 (128)
Soybean	86 (80)	81 (52)	69 (52)
Small grain	60 (25)	54 (13)	62 (13)
Yield Level (bu/acre)			
0 - 100	78 (14)	60 (6)	50 (5)
100 - 150	83 (84)	84 (62)	71 (52)
150 - 200	75 (102)	71 (80)	72 (79)
>200	91 (30)	84 (26)	65 (20)
Texture			
Coarse	71 (45)	61 (46)	57 (42)
Medium	87 (174)	87 (128)	80 (127)
Fine	68 (66)	65 (54)	57 (54)
Year			
1988	60 (5)	80 (5)	100 (5)
1989	76 (38)	79 (38)	66 (38)
1990	69 (88)	65 (62)	64 (58)
1991	84 (82)	75 (52)	73 (51)
1992	91 (75)	86 (71)	73 (71)

† Number in parentheses = total number of sites.

Table 14. Effect of year on the percent of sites where soil [NO_3-N] failed to predict N response, 1988-1992.

Time of sampling	Soil depth	Year	n	Failed soil test † TOTAL	TYPE A	TYPE B
				---- % of sites ----		
PPNT	0-1	1988	5	20.0	0	20.0
		1989	38	39.5	5.3	34.2
		1990	92	42.4	1.1	41.3
		1991	82	47.6	0	47.6
		1992	75	16.0	0	16.0
PPNT	0-2	1988	5	0	0	0
		1989	38	29.0	10.5	18.5
		1990	92	34.1	13.2	20.9
		1991	83	37.4	1.2	36.3
		1992	75	17.3	4.0	13.3
PSNT	0-1	1988	5	20.0	0	20.0
		1989	38	26.3	5.3	21.1
		1990	92	32.6	2.2	30.4
		1991	91	34.1	1.1	33.0
		1992	75	14.7	2.7	12.0
PSNT	0-2	1988	5	0	0	0
		1989	38	23.7	10.5	13.2
		1990	64	28.1	4.7	23.4
		1991	61	29.5	1.6	27.9
		1992	71	12.7	4.2	8.5

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

Table 15. Effect of yield level on the percent of sites where soil [NO_3-N] failed to predict N response, 1988-1992.

Time of sampling	Soil depth	Yield level	n	Failed soil test † TOTAL	TYPE A	TYPE B
	ft	bu/acre		---- % 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

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

and PSNT. Nitrate-N in the 1- to 2-ft depth is readily available to corn, and accounting for this N in calibrating soil NO_3 tests and making fertilizer N recommendations should result in improved fertilizer N efficiency and reduce the risk of groundwater contamination with NO_3-N.

3. Although model fit was generally improved for data subsets based on soil pH, organic matter and texture, the failure rate was generally higher when these soil specific CSNL were used. An exception to this was a significant reduction in TYPE B failures on coarse-textured soils sampled at PSNT. Using the crop-specific CSNL, however, reduced TYPE A failure rate.
4. Overall failure rates for the PPNT and PSNT with a 2-ft sampling depth were 30 and 23%, respectively. However, the respective TYPE A failure rates were 7 and 5% for the PPNT and PSNT. These results suggest that most of the test failures would have resulted in over-application of N rather than inadequate N additions.
5. Presidedress soil sampling (PSNT) to 2 ft reduced the overall failure rate in predicting N response to between 10 and 17% of all sites when corn was the previous crop. This is a reduction from 20 to 26% failure rate for the preplant (PPNT) sampling time.
6. Soil NO_3-N concentrations below the PPNT critical level resulted in > 75% failure rate when alfalfa was the previous crop. Presidedress sampling (PSNT) of these sites, however, captured substantial net mineralization of N and failure rate was reduced to < 39% of these sites. Although N recommendations for corn following soybean usually receives some legume N adjustment, PSNT sampling did not reduce the failure rate of predicting N responsive or non-responsive sites.
7. The change in soil NO_3-N concentrations from PPNT to PSNT was greatest for soils that had received manure (+8.9 ppm) or where alfalfa was the previous crop (+13.2 ppm). These were also the sites with the most significant decline in failure rate from PSNT sampling. Soils with low organic matter, high denitrification or leaching potential and pH <6.0 exhibited the lowest change in NO_3-N concentrations.
8. Failure rate reduction with increased sampling depth and later sampling time was consistent from year-to-year; however, the frequency of soil test failure was not. Total soil test failure rates varied from 37.2 to 15.2% across years with differences in both TYPE A and TYPE B failure rates as well. The relative success of soil NO_3 test strategies is subject to variations in growing season that influence the potential for NO_3-N loss, soil N mineralization dynamics, and crop N demand.

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Appendix Table 1. NC-201 data base.

												CROP GROWN									JULIAN DAY		SOIL NO_3-N				YIELD		
Ref	Yr	State	I.D.	Lat	Long	Txt	Drn	pH	OM	P	K	86	87	88	89	90	91	92	M	Till	PPNT	PSNT	PP1	PP2	PS1	PS2	Ylo	Yhi	RY
1	88	NE	CH1	41	100	sil	2	6.5	2.1	99	357	C	C	C					0	CP	105	157	14.2	8.7	13.5	9.5	112	170	66
2	88	NE	CH3	41	100	sl	2	6.5	2			C	C	C					0	CP	95	157	5.9	4.6	3.5	4.2	120	190	63
3	88	NE	CH4	41	100	sil	2	6.9	2.7			C	C	C					0	CP	95	157	8.4	4.9	9.9	6.1	117	172	68
4	88	NE	CH5	41	100	l	3	6.3	1.2			C	C	C					0	CP	95	158	8.9	5.8	13.4	9.1	116	193	60
5	88	NE	CH6	41	100	sil	2	7.0	2.3	30	430	C	C	C					0	CP	96	157	15.4	11.8	16.3	15.6	140	152	92
6	89	MN	NAUX	46	94	cl	5	6.7	6	25	135		C	S	C				0	D	111	170	8.5	7.2	10.9	8.7	146	166	88
7	89	MN	B	46	94	sil	2	6.6	M	34	165		C	S	C				0	CP	110	166	7.5	6.6	15.3	12.4	163	187	87
8	89	MN	F	46	94	cl	5	6.3	5.9	17	139		C	S	C				0	CP	111	172	12.3	11.3	10.5	9.1	138	148	93
9	89	MN	G	46	94	cl	5	6.0	M	19	89		A	C	C				0	CP	112	170	13.5	11.6	15.1	14.5	178	178	100
10	89	MN	I	46	94	sil	2	7.3	2.4	78	170		A	C	C				0	CP	109	171	13.3	12.5	21.7	18	137	169	81
11	89	MN	O	46	94	cl	5	7.3	6	32	139		C	C	C				0	MP	111	170	19.6	19.2	13.4	13.3	182	182	100
12	89	MN	A	46	94	cl	5	7.2	4.5	26	140		S	C	C				0	MP	111	170	11.5	10.4	7	7	108	157	69
13	89	MN	Miller	46	94	sil	2		3.9				C	C	C				0	MP	109	170	20.3	22.4	13.4	13.2	186	186	100
14	89	MN	Rodrigues	46	94	fsl	4		2.4				C	C	C				0	CP	110	172	8.1	13.6	19.8	21.9	132	132	100
15	89	MN	Arnold	46	94	sil	5		3.5				A	C	C				2	MP	109	177	39.5	35.6	36.3	37.4	175	175	100
16	89	MN	Lockwood	46	94	ls	1		1.5				C	S	C				0	NT	110	167	2.1	2	2.4	2.1	64	88	73
17	89	MN	Olson	46	94	l	2		2.5				C	C	C				0	CP	125	184	2.4	3.5	10.9	11.3	99	112	88
18	89	NE	CH1	41	100	sil	2	6.5	2.1				C	C	C				0	CP	116	166	5.2	4.1	6.6	5.8	85	121	70
19	89	NE	CH3	41	100	lfs	3	6.8	0.7				C	C	C				0	RT	116	174	3.7	3.5	2.8	3.3	46	87	53
20	89	NE	CH4	41	100	sil	2	6.9	2.7				C	C	C				0	CP	114	173	6.5	4.6	6.1	5.3	94	138	68
21	89	NE	CH5	41	100	l	3	6.5	2				C	C	C				0	CP	114	173	8.2	5.6	10.2	8.3	94	134	70
22	89	NE	CH6	41	100	sil	2	7.0	2.3				C	C	C				0	CP	119	173	20.7	18.6	13.4	13.4	115	149	77
23	89	WI	HUM-CC	45	90	sl	2		1.9				A	C	C				0	CP	114	179	25.0	19.8	33.5	22.5	114	112	102
24	89	WI	HUM-CMC	45	90	sl	2		1.4				A	C	C				1	CP	114	179	27.0	20.8	39.8	34.4	130	127	102
25	89	WI	HUM-AC	45	90	sl	2		2.2				A	A	C				1	CP	114	179	17.0	9.8	13	11.3	134	133	101
26	89	WI	MAR-CC	45	90	sil	4		2.3				A	C	C				2	MP	114	180	29.0	27.5	38.3	24.8	92	91	101
27	89	WI	MAR-CMC	45	90	sil	4		2.3				A	C	C				5	MP	114	180	16.5	32.5	40.5	33.4	90	95	95
28	89	WI	MAR-AC	45	90	sil	4		2.3				A	A	C				0	MP	114	180	14.5	11.8	26.8	20.3	131	126	104
29	89	WI	SPA-CC	45	90	sl	2		1.7				C	C	C				3	CP	95	179	8.5	9.3	12.3	10.4	90	94	96
30	89	WI	SPA-CMC	45	90	sl	2		2				C	C	C				1	CP	95	179	5.0	3.5	11.3	11.1	110	115	96
31	89	WI	SPA-AC	45	90	sl	2		1.7				A	A	C				0	CP	95	179	3.5	2.3	11.8	9.1	138	137	101
32	89	WI	ARL-CC	45	90	sil	3		2.7				C	C	C				0	CP	104	170	31.0	37.8	41.8	33.1	154	152	101
33	89	WI	ARL-CMC	45	90	sil	3		2.6				C	C	C				1	CP	104	170	42.0	41	59.3	54	161	153	105
34	89	WI	ARL-AC	45	90	sil	3		2.9				A	A	C				0	MP	104	170	12	9.5	43.3	27.4	188	186	101
35	89	WI	MAD-CC	45	90	sil	3		3.7				C	C	C				0	D	112	170	21	17.3	22.8	19	155	161	96
36	89	WI	MAD-CMC	45	90	sil	3		3.4				C	C	C				1	D	112	170	21	16.5	25	17.6	147	175	84
37	89	WI	MAD-AC	45	90	sil	3		3				A	A	C				0	MP	112	170	8.5	7.8	21	16	176	174	101
38	89	WI	FEN-CC	45	90	sil	3		3.3				C	C	C				2	CP	102	179	26.5	29	46.5	38.8	147	146	101
39	89	WI	FEN-CMC	45	90	sil	3		3.9				C	C	C				1	CP	102	179	19	20.3	46.5	36.5	157	160	98
40	89	WI	FEN-AC	45	90	sil	3		2.7				A	A	C				0	MP	102	179	2	2.5	20	13.8	131	136	96
41	89	WI	MER-AC	45	90	sil	3		3.5				A	A	C				0	MP	115	187	4.5	3	26	19.3	126	121	104
42	89	WI	SHA-AC	45	90	sil	3		3.6				A	A	C				0	MP	115	187	7.8	5.6	32.5	27.1	115	117	98
43	89	WI	VAL-AC	45	90	sil	4		3				A	A	C				0	MP	115	187	3	5.3	33.4	22.8	115	115	100
44	90	IA	76	42	94	l	4	5.9	4.9	24	242				S	C			0	CP	123	173	6.3	5.1	11.5		118	148	80
45	90	IA	80	42	94	l	4	6.8	4.9	68	182				S	C			0	D	124	169	4	2.4	9.5		128	128	100
46	90	IA	81	42	94	l	4	7.1	3.5	54	240			C	S	C			0	CP	117	169	8	9.5	6.7		132	163	81
47	90	IA	82	42	94	sil	2	7.1	4.9	110	438			C	C	C			0	CP	122	171	10.3	8.2	11.1		141	174	81
48	90	IA	84	42	94	sil	3	7.1	3.7	72	290				C	C			0	CP	121	163	14.6	23.9	12.7		169	201	84
49	90	IA	85	42	94	l	2	6.4	4.2	22	168			C	S	C			0	D	116	163	5.5	5.1	10.3		87	124	70
50	90	IA	86	42	94	sil	4	5.9	3.7	33	197				S	C			0	CP	121	163	10.8	10.2	14.8		172	172	100
51	90	IA	87	42	94	sil	5	6.1	4.6	15	136				S	C			0	D	115	183	6.9	5.6	11.2		123	148	83
52	90	IA	89	42	94	sil	5	6.7	4.1	97	836				S	C			0	D	121	164	13.1	14.4	11.8		150	195	77
53	90	IA	90	42	94	sil	5	7.3	4.1	28	130				S	C			0	D	115	176	12.7	10	8.4		163	179	91

Appendix Table 1. NC-201 data base (continued).

Ref	Yr	State	I.D.	Lat	Long	Txt	Drn	pH	OM	P	K	86	87	88	89	90	91	92	M	Till	PPNT	PSNT	PP1	PP2	PS1	PS2	Ylo	Yhi	RY
													CROP GROWN								JULIAN DAY		SOIL NO_3-N				YIELD		
54	90	IA	91	42	94	sil	3	6.4	3	72	922				S	C			0	CP	121	164	12.9	12.5	20		161	161	100
55	90	KS	NAgr.-NT	39	98	sil	2	6.7	3	82	613				O	C			0	NT	128	152	11.3	3.8	11.2	8.6	171	184	93
56	90	KS	NAgr.-CP	39	98	sil	2	6.7	3	82	613				O	C			0	CP	128	160	12.5	9.3	4.2	3.9	177	175	101
57	90	MI	Shiawas	44	85	sl	4	6.8	2.2	51	118		A	A	C	C			2	CP	117	162	5.5	8.4	20.8	15.7	118	122	97
58	90	MI	Ingham	44	85	sl	4	6.8	3.5	20	143				S	C			0	NT	134	163	8.4	8.3	8.2	6.4	148	153	97
59	90	MI	Eaton-N	44	85	sl	4	7.1	3.6	33	84		C	S	C	C			0	CP	117	157	2.6	3	5	4.1	124	146	85
60	90	MI	Eaton-S	44	85	sl	3	6.2	3	11	80		C	S	C	C			0	CP	117	157	3.7	4.7	8.2	7.7	133	141	94
61	90	MI	NBPT2	44	85	l	4	6.9	3.5	77	261		S	C	S	C			0	NT	130	171	11.3	9	19	13.6	148	166	89
62	90	MI	NBPT1	44	85	l	4	7.3	2.9	38	101		C	S	C	C			0	NT	130	171	5.3	4.3	8.9	7.1	51	128	40
63	90	MI	KBS-21	44	85	sl	2	6.6	1.5	33	106		A	A	A	C			2	NT	102	163	5.5	8.2	15.8	10.2	149	152	98
64	90	MN	SwanLake	46	94	scl/l/cl	2	5.6	6.7	22	111		W	W	S	C			0	NT		165			23.6	18.7	97	104	93
65	90	MN	A	46	94	cl	5	8.1	5.5	6	124		C	S	C	C			0	MP	102	176	5.1	3.8	4.3	4	80	148	54
66	90	MN	B	46	94	sil	2	6.2	M	31	138		C	C	C	C			0	CP	91	183	3.4	1.9	7.6	6	88	163	54
67	90	MN	C	46	94	fsl	4	7.1	2	100	168		C	C	C	C			0	CP	107	169	12.1	17.9	8.7	8.3	136	136	100
68	90	MN	D	46	94	cl	4	5.8	5.5	83	210		A	A	A	C			0	MP	102	172	13.4	9.1	9.5	9.8	160	160	100
69	90	MN	E	46	94	cl	4	5.6	5	28	142		S	C	S	C			0	D	102	172	8.8	9.5	5.2	5.2	147	163	90
70	90	MN	F	46	94	cl	5	8.0	6	5	99		C	CRP	C	C			0	CP	103	149	8.4	8.3	5.2	4.7	106	151	70
71	90	MN	G	46	94	sic	4	6.7	4.8	34	126			C	O	C			0	CP	122	172	7.7	6.1	7	6	97	162	60
72	90	MN	H	46	94	sil	2		4				A	swC	P	C			0	D	123	186	6.1	7.8	18.4	15.6	140	140	100
73	90	MN	I	46	94	sil	2		4				C	C	C	C			0	D	123	177	10	15.3	21.5	16.5	167	174	96
74	90	MN	J	46	94	sil	2	6.6	3	23	108		A	A	C	C			2	D	121	184	14.4	12.7	15.6	12.1	145	145	100
75	90	MN	K	46	94	sil	2	6.3	4	100	182		C	C	C	C			0	CP	121	184	1.4	3.7	14.2	12.7	161	171	94
76	90	MN	L	46	94	l	2	7.0	3	60	227		C	C	S	C			0	D	121	173	7.2	5.5	11.8	10.3	107	184	58
77	90	MN	M	46	94	cs	1		2				R	S	R	C			0	MP	109	166	4.1	2.8	4.3	2.5	81	116	70
78	90	MN	N	46	94	ls	1		1	68	77		S	C	S	C			3	NT	114	169	3.8	2.9	2.7	2.4	41	98	42
79	90	MN	O	46	94	cl	5	5.3	6	32	139		C	C	C	C			0	MP	108	149	12.7	11.5	5.8	6.3	123	166	74
80	90	NE	M-90	41	100	sicl	3	7.3	2.5	25	310		C	C	C	C			0	D	125	167	22.2	12.9	41.6	29.2	115	140	82
81	90	NE	CI-90	41	100	sil	2	7.9	1.2	9*	320		C	C	C	C			0	D	124	181	4	4.8	11.7	8.7	97	105	92
82	90	NE	CD-90	41	100	sil	2	7.4	1.2	6*	320		C	C	C	C			0	D	124	181	24.2	16.1	30.9	24.5	64	60	107
83	90	NE	CH5-90	41	100	l	3	6.5	2				C	C	C	C			0	CP	101	165	9.1	6.6	12.3	10.1	120	160	75
84	90	NE	CH3-90	41	100	lfs	3	6.8	0.7				C	C	C	C			0	RT	101	165	4.5	4.3	4.1	4.3	99	168	59
85	90	NE	CH9-90	41	100	scl	3	6.8	2				C	C	S	C			0	RT	110	164	12	10.3	9.8	9.2	125	181	69
86	90	NE	CH7-90	41	100	scl	3	7.0	2				C	C	C	C			0	CP	109	163	6.8	5.8	5.8	5.1	105	146	72
87	90	NE	N.Plat100	41	100	sil	2	7.4	1.6	7*	416		C	C	C	C			0	RT	78	170	4.6	5	7.3	6.8	157	201	78
88	90	NE	N.Plat200	41	100	sil	2	7.4	1.4	7*	360		C	C	C	C			0	RT	78	170	12.8	10.2	7.6	7.9	186	209	89
89	90	NE	N.Plat300	41	100	sil	2	7.3	1.4	6*	430		C	C	C	C			0	RT	78	170	11.6	10	9.6	9.2	195	205	95
90	90	ND	NW	48	100	fsl	4	7.2	1.8	16*	690		CRP	C	C	C			0	CP	95	158	9.7	11.1		4.4	102	144	71
91	90	ND	SE	48	100	fsl	4	7.2	1.8	16*	690		CRP	C	C	C			0	CP	95	158	8.5	15.4		2.5	99	168	59
92	90	ND	SW	48	100	lfs	3	7.2	1.8	16*	690		C	CRP	C	C			0	CP	95	158	14.5	13.7		4.7	143	179	80
93	90	ND	SE	48	100	lfs	3	7.2	1.8	16*	690		C	CRP	C	C			0	CP	95	158	10.3	9.4		2.3	155	174	89
94	90	OH	Wooster	40	83	sil	2	6.4	2.1	18	90		C	C	C	C			0	NT	113	165	3.8		7.8		77	151	51
95	90	OH	Hoytville	40	83	sic	5	6.9	3.7	78	150		W	C	S	C			0	CP	120	165	0	0	5.5	4.8	95	151	63
96	90	OH	S.Charles	40	83	sil	4	6.1	1.9	35	125		C	C	C	C			0	MP	115	163	3.8	2.4	4.5	3.7	37	132	28
97	90	SD	Codington	45	100	sicl	3	6.2	4.2	12	125		SF	W	B	C			0	CP	141	183	10.6	8.9	9.3		131	131	100
98	90	SD	Brookings	45	100	sil	2	6.2	3.1	19	180		W	SG	O	C			0	CP	130	183	5.4	3.9	5.7		102	132	77
99	90	SD	Highmore	45	100	sicl	3	6.4	3	36	540		C	W	W	C			0	CP	165	183	16.6	15.9	11.5	11.2	79	79	100
100	90	SD	Clay	45	100	sicl	2	6.2	3.1	20	240				S	C			0	CP	130	176	7.8	10.3	8.9	10.3	96	109	88
101	90	WI	Hum-CC	45	90	sl	2	7.0	3.4	33	250		A	A	C	C			2	CP	87	171	9.3	7.7	10	8	92	133	69
102	90	WI	Mar-CC	45	90	sil	4	7.0	4	43	238		A	A	C	C			0	MP	87	171	7.5	6	13.9	10.1	120	146	82
103	90	WI	She-CC	45	90	l	3	7.3	4.2	64	215		P	C	C	C			0	MP	88	172	16	21.5	28.7	23.7	161	179	90
104	90	WI	Fen-CC	45	90	sil	3	6.3	3	61	165		C	C	C	C			2	MP	85	170	11.8	17.2	20.8	24.8	138	138	100
105	90	WI	Arl-CC	45	90	sil	3	6.4	4.5	53	170		C	C	C	C			0	CP	95	169	8.5	10.7	23.7	20	172	181	95
106	90	WI	Spa-CC	45	90	sl	2	6.9	4.2	55	210		A	C	C	C			3	CP	86	170	7.3	12.2	9.8	7.5	171	178	96

Appendix Table 1. NC-201 data base (continued).

												CROP GROWN								JULIAN DAY			SOIL NO_3-N				YIELD	
Ref	Yr	State	I.D.	Lat	Long	Txt	Drn	pH	OM	P	K	86	87	88	89	90	91	92	M	Till	PPNT	PSNT	PP1	PP2	PS1	PS2	Ylo	Yhi	RY
107	90	WI	Mad-CC	45	90	sil	3	6.8	3.7	56	200		C	C	C	C			0	D	95	169	9.3	6.9	10.7	7.9	125	184	68
108	90	WI	Hum-Cm	45	90	sl	2	7.0	3.4	33	250		A	A	C	C			5	CP	87	171	5.5	3.2	10.1	8.1	150	129	86
109	90	WI	Mar-CmC	45	90	sil	4	7.2	4.5	49	330		A	A	C	C			1	MP	87	171	11	14.4	37.4	26.1	133	124	107
110	90	WI	She-CmC	45	90	l	3	7.3	4.2	64	215		P	C	C	C			3	MP	88	172	31.3	22.6	26	22.6	172	165	104
111	90	WI	Fen-CmC	45	90	sil	3	6.3	3	61	165		C	C	C	C			5	CP	85	170	22.5	29.8	30.8	27.1	156	154	101
112	90	WI	Arl-CmC	45	90	sil	3	6.1	3.7	32	157		C	C	C	C			1	CP	95	169	13.5	15.4	32.5	31.3	164	173	95
113	90	WI	Spa-CmC	45	90	sl	2	6.9	3.1	78	315		A	C	C	C			6	CP	86	170	15.5	23	19.1	18.2	183	181	101
114	90	WI	Mad-CmC	45	90	sil	3	6.4	3.7	60	195		C	C	C	C			1	D	95	169	10.5	7.9	15.8	17.5	151	174	87
115	90	WI	Hum-LC	45	90	sl	2	7.0	2.7	33	250		A	A	A	C			0	CP	87	171	3.8	3.2	9.7	7.6	139	136	102
116	90	WI	Mar-LC	45	90	sil	4	6.8	4.5	47	252		C	A	A	C			0	MP	87	171	12.5	7.9	27.4	18.8	129	132	98
117	90	WI	She-LC	45	90	l	3	7.4	4.3	27	155		A	A	A	C			0	MP	88	179	3.5	2.9	16.3	11.3	156	149	105
118	90	WI	Fen-LC	45	90	sil	3	6.9	3	67	150		A	A	A	C			0	NT		170			27.5	20.9	174	172	101
119	90	WI	Arl-LC	45	90	sil	3	6.6	4.5	32	145		A	A	A	C			0	MP	95	169	18.5	16.2	31.7	26.9	200	202	99
120	90	WI	Spa-LC	45	90	sl	2	6.9	2.6	22	170		A	A	A	C			0	D	86	170	4.3	2.2	15.6	11.3	177	174	102
121	90	WI	Mad-LC	45	90	sil	3	6.6	3	23	123		A	A	A	C			0	MP	95	169	12.3	9.3	19.2	15.6	181	185	98
122	91	IL	Kane-PI	40	89	sil	4	6.0		56	200				C	C	C		0	CP	97	144	4	3.8	3.5		129	145	89
123	91	IL	Boone-C	40	89	si	3	6.1		76	244				A	A	C		0	MP	97	151	3.5	3.1	7.3		93	99	94
124	91	IL	Boone-M	40	89	si	3	6.4		60	224				C	B	C		0	NT	97	151	1.5	1.1	7.3		88	110	80
125	91	IL	Logan-Fu	40	89	sicl	4	6.2		50	126				W	S	C		0	D	96	148	7	5.3	7		149	173	86
126	91	IL	Champ-Ko	40	89	si	4	5.9		40	194				C	S	C		0	D	119	142	5.3	3.8	9		101	136	74
127	91	IL	DeKalb	40	89	sil	4	5.3		42	180				A	A	C		0	MP	100	144	4.5	4	9.8		174	176	99
128	91	IL	LaSalle-B	40	89	sicl	5	6.2		23	143				C	S	C		0	NT	105	155	3.8	4.2	6.8		111	122	91
129	91	IL	Macon-FPS	40	89	sil	4	5.2		45	188				S	W	C		0	CP	117	155	1.8	1.9	2.5		56	97	58
130	91	IL	Madis-We	40	89	sil	4	6.3		32	67				S	W	C		1	NT	84	154	3.8	3.2	2.3		64	142	45
131	91	IL	Steph-Ke	40	89	sil	3	6.1		131	352				S	C	C		7	NT	106	150	6.8	8.3	10.8		178	175	102
132	91	IL	Steph-We	40	89	sil	3	6.5		43	120				S	C	C		0	CP	106	150	32.8	23.4	51.5		196	200	98
133	91	IL	Warr-Da	40	89	sil	4	6.9		37	173				S	C	C		0	NT	106	149	5.8	7.2	5.8		162	157	103
134	91	IL	Warr-El	40	89	sil	4	6.7		43	152						C		0	CP	106	141	3.3	3.4	4.3		136	168	81
135	91	IL	Wayn-Gl	40	89			6.1		61	173					W	C		0	MP	92	143	6.3	7.7	2.8		40	66	61
136	91	IL	Will-Mc	40	89	sil	4	6.5		21	154				S	C	C		0	NT	101	137	3	2.4	6.3		44	98	45
137	91	IL	Effing-Ja	40	89	sil	4	6.3		38	98				S	C	C		0	CP	94	143	4	3.6	5.5		65	133	49
138	91	IL	Kane-Lo	40	89	sicl	5	6.1		40	136				C	S	C		0	NT	97	144	4.3	3.9	4.3		159	169	94
139	91	IL	Kend-Ke	40	89	sicl	5	6.8		80	220				C	C	C		0	MP	101	136	7.8	7.3	8.5		129	145	89
140	91	IL	Madis-Da	40	89	sil	4	6.1		33	86				S	W	C		0	CP	84	142	0.8	0.7	6.3		110	164	67
141	91	IL	Madis-Wi	40	89	sil	5	6.1		21	86					V	C		0	NT	84	154	2.5	2.8	2.5		76	121	63
142	91	IL	Pike-Ga	40	89	sil	3	5.2		131	332				C	S	C		0	NT	83	148	4	4.1	4.5		141	183	77
143	91	IL	Steph-Ko	40	89	sil	3	6.7		85	332				C	C	C		6	CP	106	151	5.8	6.2	6.3		85	109	78
144	91	IL	Warr-Da	40	89	sil	4	5.9		54	155				C	S	C		0	CP	106	141	12.5	11.1	34.3		169	166	102
145	91	IL	Wayn-Br	40	89	sil	5	7.1		41	166				W	C	C		0	NT	106	143	4	2.8	10.8		91	90	101
146	91	IL	Will-JJC	40	89	sicl	5	6.5		21	159				C	O	C		0	NT	101	137	3	2.4	7		30	103	29
147	91	IL	Wood-Co	40	89	sil	4	5.8		46	148				C	S	C		0	NT	96	150	5	4.5	8		162	182	89
148	91	IL	Wood-Sh	40	89		4	6.5		91	400					S	C		0	NT	96	150	9.8	8.8	15.3		77	71	108
149	91	IL	Effing-Sc	40	89	sil	5	5.2		111	216				S	C	C		0	CP	84	142	6.5	11.6	7.8		163	165	99
150	91	IA	96	42	94	l	4	6.3	6.7	31	178					S	C		0	RT	130	163	4.3	4.1	9.3	7.5	129	184	70
151	91	IA	97	42	94	sil	2	7.0	4.5	100	358					C	C		0	CP	134	163	6	5.6	8.6	7.3	107	184	58
152	91	IA	98	42	94	sicl	2	6.9	4.7	15	213					S	C		0	D	129	162	3.1	3.2	9.2	7.1	93	150	62
153	91	IA	99	42	94	cl	4	6.1	4.9	19	166					S	C		0	RT	129	162	3.1	3.1	6.3	5.4	108	152	71
154	91	IA	100	42	94	sil	2	7.2	3.1	27	103					C	C		0	CP	144	164	9.8	8.7	19.9	19.5	165	165	100
155	91	IA	103	42	94	sil	2	6.0	2.7	35	87					C	C		1	D	122	158	12.2	12.9	48.1	70.1	157	157	100
156	91	IA	104	42	94	sil	2	7.0	3.4	90	196					S	C		0	D	115	155	5	7.2	10.5	10.3	202	202	100
157	91	IA	105	42	94	sicl	3	7.3	4.7	72	299					S	C		0	D	107	157	5.6	5.9	10.4	9.4	142	142	100
158	91	IA	106	42	94	sicl	5	7.0	4.4	140	411					S	C		0	NT	119	157	8.4	7.5	9.2	8.6	158	158	100
159	91	IA	108	42	94	sil	2	6.7	4.4	46	215					S	C		0	D	133	157	8.6	7.2	14	13.4	137	137	100

Appendix Table 1. NC-201 data base (continued).

														CROP GROWN							JULIAN DAY		SOIL NO_3-N				YIELD		
Ref	Yr	State	I.D.	Lat	Long	Txt	Drn	pH	OM	P	K	86	87	88	89	90	91	92	M	Till	PPNT	PSNT	PP1	PP2	PS1	PS2	Ylo	Yhi	RY
160	91	IA	109	42	94	sicl	4	6.9	3.6	29	135					S	C		0	CP	142	164	7.2	6.2	6	5.3	113	113	100
161	91	IA	110	42	94	sicl	5	6.2	3.9	76	231					S	C		0	NT	121	156	9.3	8.4	14.7	12.1	161	161	100
162	91	KS	CF-01	39	98	sil	3	7.0		42	400			S	C	S	C		0	D		151			14.9	10.1	83	117	71
163	91	KS	CF-02	39	98	sil	3	6.6		35	350			S	C	S	C		0	D		148			9.1	6.2	57	61	93
164	91	KS	CF-03	39	98	sil	3	5.9		134	660			S	C	S	C		0	CP		151			11.1	8.8	70	106	66
165	91	KS	AL-01	39	98	sil	3	6.8		23	290			SG	S	O/Cl	C		0	MP		151			15	9.3	73	73	100
166	91	KS	AL-02	39	98	sil	3	6.7		22	250			SG	S	O/Cl	C		0	MP		151			15.3	10.9	52	63	83
167	91	KS	AL-03	39	98	sil	3	6.6		14	220			SG	S	O/L	C		0	MP		151			9	7.7	66	78	85
168	91	KS	AL-04	39	98	sil	3	6.8		15	230			SG	S	O/V	C		0	MP		151			15	9.5	66	78	85
169	91	KS	HV-01	39	98	sl	3	6.0	1.8	200	400				S	C/T	C		2	D	83	128	28.6	22.1	8.5	5.9	150	152	99
170	91	KS	SG01	39	98	l	2	6.1	2.0	111	420				C	W/SG	C		0	CP	61	112		15.0		12.0	156	156	100
171	91	KS	SG02	39	98	sl	2	6.3	1.6	123	490				W/S	C	C		0	CP	61	112					169	169	100
172	91	MI	BatCreek	44	85	sl	2	6.6		166	156					W	C		0	MP	134	149	14	11.5	25	21	146	162	90
173	91	MI	Quincy	44	85	sl	2	6.3		92	224					C	C		2	MP	130	151	34	28	58	48	104	116	90
174	91	MI	Traverse	44	85	ls	2	6.6		80	76					S	C		0		130	170	2.5	2.1	13.3	11.1	81	87	93
175	91	MN	F	46	94	sicl	5	6.8	4.5	19	232			A	A	C	C		3	MP	113	168	13.1	11	10.5	9.7	161	173	93
176	91	MN	O	46	94	sil	2	6.9	M	26	150			A	A	A	C		0	CP	133	157	5.3	6.3	17.9	13.9	207	207	100
177	91	MN	A	46	94	cl	5	7.6	M	18*	229			A	A	C	C		2	MP	101	154	14.1	12.2	9.7	7.6	152	185	82
178	91	MN	C	46	94	l/cl	4	6.0	5	48	162			SF	C	S	C		0	CP	100	151	4.1	4.6	6.8	6.6	95	144	66
179	91	MN	D	46	94	c	3	7.6	4	18*	232			S	Sg	Sg	C		0	MP	112	157	3.7	4.3	7.9	6.8	136	174	78
180	91	MN	G	46	94	cl	4	6.9	5	45	192			S	Sg	S	C		3	CP	112	163	2.2	1.6	4.6	4.6	104	176	59
181	91	MN	H	46	94	l	2	5.2	2.5	80	165			A	A	A	C		0	MP	108	163	10.9	6.2	13.7	10.2	175	175	100
182	91	MN	I	46	94	fsl	3	6.5	2	32	160			S	C	S	C		0	D	99	155	8.8	6.4	9	5.9	149	171	87
183	91	MN	J	46	94	ls	1	6.9	2	36	125			Sg	S	Sg	C		0	MP	99	154	2	1.5	4.3	3.5	99	150	66
184	91	MN	K	46	94	l	2	6.9	2.5	48	152			A	A	S	C		0	D	100	156	7.3	6.3	7.5	6.6	177	186	95
185	91	MN	L	46	94	sil	2	6.1	3.5	45	270			C	S	Sg	C		0	D	112	156	4.5	3.1	5.8	4	115	221	52
186	91	MN	M	46	94	sil	2	7.2	3	32	136			A	A	C	C		0	CP	101	162	10.8	10.7	12.3	9.3	159	175	91
187	91	MN	N	46	94	sil	2	6.5	3.5	45	95			Sg	A	A	C		0	MP	101	162	8.6	5.1	18.5	11.5	174	174	100
188	91	MN	SwanL(A)	46	94	scl	2	6.7	4.9	22	111			Sg	S	C	C		0	NT	145	163			15.5	9.9	98	138	71
189	91	MN	SwanL(B)	46	94	scl	2	6.7	4.9	22	111			Sg	S	C	C		0	MP	145	163			14.1	10	138	166	83
190	91	NE	N91-1	41	100	sil	4	5.9	3.7	41	405			C	C	C	C		0	NT	112	163	3.3	4	4.7	4.8	151	196	77
191	91	NE	N91-2	41	100	sicl	3	5.5	4	58	343			S	C	S	C		0	NT	112	163	3.7	5.1	4	5.6	161	189	85
192	91	NE	N91-3	41	100	sicl	3	5.3	2.8	19	323			C	C	C	C		0	NT	112	163	2.4	3.4	20.7	13.2	232	247	94
193	91	NE	N91-4	41	100	sicl	3	6.0	3.7	54	678			C	C	C	C		0	MP	113	163	10	13.6	10	13.2	163	163	100
194	91	NE	N91-5AA	41	100	fsl	2	6.2	2.3	45	272			C	C	C	C		0	NT	113	168	8.9	7.4	2.9	3.2	109	158	69
195	91	NE	N91-5AN	41	100	fsl	2	6.2	2.3	45	272			C	C	C	C		0	NT	113	168	8.9	7.4	2.9	3.2	96	163	59
196	91	NE	N91-6	41	100	sicl	2	5.6	3	32	303				C	C	C		0	CP	113	169	9.4	7.1	2.5	5.6	138	148	93
197	91	NE	N91-7AA	41	100	sicl	5	6.4	3.1	79	558			C	C	C	C		0	MP	113	168	6.8	6.4	6.2	7.2	116	166	70
198	91	NE	N91-7AN	41	100	sicl	5	6.4	3.1	79	558			C	C	C	C		0	MP	113	168	6.8	6.4	6.2	7.2	98	172	57
199	91	NE	N91-8AA	41	100	sicl	3	6.4	2.7	30	348			S	SG	SG	C		0	NT	119	169	5.1	4.7	5.1	3.9	56	207	27
200	91	NE	N91-8AN	41	100	sicl	3	6.4	2.7	30	348			S	SG	SG	C		0	NT	119	169	5.1	4.7	5.1	3.9	57	204	28
201	91	ND	Oakes	48	100	lfs	3	7.7	2	5*	136			C	C	C	C		0	D	113	163	0.6	1.4	3.2	2.6	99	168	59
202	91	SD	SERes.Sta	45	100	scl	2	5.7	3.3	20	225			S	C	S	C		0	CP	FALL	163	4.5	4.8	11.3		105	107	98
203	91	SD	Aurora	45	100	sil	2	6.0	3	13	170			Sg	Sg	Sg	C		0	MP	141	169	7.8	7.6	6.7		117	156	75
204	91	SD	Watertown	45	100	sicl	2	6.3	3	11	145			Sg	Sg	Sg	C		0	MP	FALL	165	4.2	5.2	7		128	141	91
205	91	WI	Hum-CmC	45	90	sl	2	7.0	1.7	47	220			C	C	C	C		1	CP	92	157	3.3	2.9	7.5	5.5	126	135	93
206	91	WI	Fen-CC	45	90	sil	3	6.7	3.2	59	170			C	C	C	C		3	CP	91	156	4.5	5.4	11.8	8.6	139	142	98
207	91	WI	Fen-CmC	45	90	sil	3	6.7	3.5	69	190			C	C	C	C		3	CP	91	156	8.5	8.3	14.8	10.8	132	140	94
208	91	WI	Fen-AC	45	90	sil	3	6.7	2.2	85	170			A	A	A	C		0	CP	91	156	4.8	3.3	20.5	12.3	152	149	102
209	91	WI	Arl-CC	45	90	sil	3	7.1	3.5	110	175			C	C	C	C		0	CP	84	154	5	4.3	18.3	13.3	125	189	66
210	91	WI	Arl-CmC	45	90	sil	3	7.1	3.6	96	175			C	C	C	C		1	CP	84	154	4.3	3.6	33.5	19	197	199	99
211	91	WI	Arl-AC	45	90	sil	3	6.9	4.1	42	130			A	A	A	C		0	MP	84	154	4.8	3	36.5	19.9	192	196	98
212	91	WI	Mad-CC	45	90	sil	3	6.4	4.2	93	245			C	C	C	C		0	CP	85	150	17.3	14	26.8	21	122	131	93

Appendix Table 1. NC-201 data base (continued).

														CROP GROWN							JULIAN DAY			SOIL NO_3-N				YIELD	
Ref	Yr	State	I.D.	Lat	Long	Txt	Drn	pH	OM	P	K	86	87	88	89	90	91	92	M	Till	PPNT	PSNT	PP1	PP2	PS1	PS2	Ylo	Yhi	RY
213	91	WI	Mad-CmC	45	90	sil	3	6.5	3.9	110	240			C	C	C	C		1	CP	85	150	15.3	12.9	26.5	20.3	146	138	106
214	91	WI	Mad-AC	45	90	sil	3	6.6	3.5	26	95			A	A	A	C		0	MP	85	150	11.8	10.1	38.3	26.8	207	207	100
215	92	KS	CBelt	39	98	sicl	5	6.3	3.5	41	239						C	C	0	NT	121	177	5.2	7.1	3.5	4	64	105	61
216	92	KS	CF-01	39	98	sic	5	6.1		77	280					C	S	C	0	CP	104	164	4.5	4.5	1.5	2	79	161	49
217	92	KS	HV-065	39	98	fsl	1	6.7		170	460				C	C	T	C	7	CP	121	158	12.5	21.3	3.9	18.9	152	152	100
218	92	KS	JW-01	39	98	sicl	3	6.0		18	455				W	S	C	C	0	NT	125	160	10.8	12.7	6.5	6.4	60	154	39
219	92	KS	HV-06	39	98	l	2	6.7		150	285				C	S	C	C	0	CP	121	156	11	7.3	12	8.8	123	150	82
220	92	KS	MG-02	39	98	sic	4	6.6		58	220				C	C	C	C	0	MP	134	164	5.3	7.8	14.5	13.3	176	193	91
221	92	KS	SG-03	39	98	sil	3	7.0		20	205				S	C	S	C	0	CP	114	157	14.3	12.1	14.8	13.4	112	160	70
222	92	KS	SG-04	39	98	l	2	7.4		33	220				S	C	SD	C	1	CP	61	157	6.6	5.4	6.5	5.3	124	144	86
223	92	MN	A	46	94	cl	5	7.2	6	14	158				C	S	C	C	0	MP	105	161	3.2	3.1	6.5	5.2	106	156	68
224	92	MN	B	46	94	cl	5	6.4	6	43	214				C	A	A	C	0	MP	105	161	5.4	3.9	11.2	8.7	153	168	91
225	92	MN	C	46	94	sicl	5	6.0		7	153				C	S	S	C	0	CP	105	162	2.8	2.5	8.8	6.3	107	165	65
226	92	MN	D	46	94	c	5	7.5		40	261				S	W	O	C	0	MP	118	162	10.5	8.1	20.4	12.9	121	144	84
227	92	MN	E	46	94	sil	2	6.6		35	129				S	C	S	C	0	CP	104	164	2.2	2.3	8.6	7.6	105	140	75
228	92	MN	F	46	94	sil	2	6.4	M	31	168				C	C	S	C	0	CP	104	164	4.7	3.7	14.4	14.6	115	146	79
229	92	MN	G	46	94	sil	2	6.7		15	117				A	A	C	C	0	CP	105	164	3	2.6	9.8	7.9	77	138	56
230	92	MN	H	46	94	sil	2	6.0	M	21	83				A	A	C	C	0	CP	104	164	3.4	2.7	17.4	11.8	145	163	89
231	92	MN	I	46	94	ls	1	6.2	3	54	155				R	Lu	R	C	0	MP	92	153	1.2	1.2	5.1	3.6	95	148	64
232	92	MN	J	46	94	ls	1	6.5	1.5	117	207				P/S	C	C	C	3	MP	105	156	3.4	4	6.9	6.2	109	176	62
233	92	MN	K	46	94	sil	2	6.5	2	93	205				C	S	C	C	4	D	105	161	5.3	6.4	11	10.2	149	149	100
234	92	MN	L	46	94	l-	2	5.6	2.5	93	160				S	C	C	C	4	D	98	155	4.7	3.9	15	10.8	91	121	75
235	92	MN	M	46	94	sil	2	6.5	2.5	24	95				C	S	C	C	3	NT	121	175	3.4	3.1	13.4	9	91	123	74
236	92	MN	N	46	94	l	2	5.8	3	39	232				O	A	C	C	3	CP	105	156	4.4	4.7	7.7	7	111	171	65
237	92	NE	N92-1	41	100	sicl	3	5.8	3.4	43	686				S	C	S	C	0	D	118	157	6.7	5.5	8.5	6.8	181	235	77
238	92	NE	N92-2AA	41	100	sicl	3	6.3	3.4	38	500				C	C	C	C	0	D	121	157	4.9	5.8	7.8	6.9	172	205	84
239	92	NE	N92-2AN	41	100	sicl	3	6.3	3.4	38	500				C	C	C	C	0	D	121	157	4.9	5.8	7.8	6.9	140	230	61
240	92	NE	N92-3	41	100	sicl	3	6.1	3.1	46	618				S	C	S	C	0	D	118	157	4.8	4	7.3	6.2	130	183	71
241	92	NE	N92-4AA	41	100	sicl	3	6.0	2.6	11	458				S	C	C	C	0	NT	121	158	3.7	3.4	5	4.6	119	180	66
242	92	NE	N92-4AN	41	100	sicl	3	6.0	2.6	11	458				S	C	C	C	0	NT	121	158	3.7	3.4	5	4.6	98	192	51
243	92	NE	N92-5	41	100	sicl	2		2.8						A	A	C	C	0	D	118	169	3.7	4.3	6.8	6.3	170	200	85
244	92	NE	N92-7	41	100	sil	3	7.5	1.5	23	493				C	C	C	C	0	NT	118	168	2.8	3.7	7.4	7.3	94	177	53
245	92	NE	N92-10	41	100	sicl	3	6.8	2.5	25	310				C	C	S	C	0	D	127	162	8.7	7.6	11.8	8.9	205	241	85
246	92	ND	A	48	100	lfs	3	7.8	1.6	2*	38				C	C	C	C	0	CP	120	157	1.9	2.1	1.8	1.9	42	108	39
247	92	ND	B	48	100	fsl	4	7.9	1.9	2*	49				C	C	C	C	0	D	120	156	1.2	0.9	2.7	2.4	23	85	27
248	92	ND	C	48	100	fsl	2	7.7	2.7	2*	20				C	C	C	C	0	D	119	156	3.8	3.8	5.3	5.1	83	122	68
249	92	ND	D	48	100	lfs	3	8.0	2.1	2*	33				C	C	C	C	0	D	119	156	2.4	2.4	4.1	3.5	59	113	52
250	92	SD	Brk2	45	100	sil	3		3.7								S	C	0	FC	126	167	8.6	6.7	9.1		99	124	80
251	92	SD	Brk1	45	100	sil	3		3.1						O	W	O	C	0	CP	93	137	4.1	4.8	10.8		85	99	86
252	92	SD	Cod	45	100	sicl	2		4.1						C	B	W	C	0	CP	129	168	18.3	12.9	19.9		61	58	105
253	92	SD	Cly	45	100		3		3.1						S	C	S	C	0	D	FALL	167	4.1	2.9	8.1		128	152	84
254	92	WI	Fen-CC	45	90	sil	3		2.7						A	C	C	C	3	CP	97	163	4.5	4	13.8	10.3	110	133	83
255	92	WI	Fen-CmC	45	90	sil	3		2.8						A	C	C	C	6	CP	97	163	5.3	4.5	13.5	10.1	117	134	87
256	92	WI	Fen-ACC	45	90	sil	3		2.9						A	A	C	C	0	CP	97	163	5.8	5.1	14.3	11.1	100	133	75
257	92	WI	Arl-CC	45	90	sil	3		3.8						C	C	C	C	0	CP	93	160	5.8	4.8	10	6.9	91	169	54
258	92	WI	Arl-CmC	45	90	sil	3		3.4						C	C	C	C	0	CP	93	160	3.3	3.1	19.8	15.6	129	133	97
259	92	WI	Arl-ACC	45	90	sil	3		3.6						A	A	C	C	0	CP	93	160	6.3	7.3	16.8	13.9	185	201	92
260	92	WI	Ree-CC	45	90	sil	4		3.1						C	C	C	C	0	CP	99	170	5.5	4.9	13.8	9.3	100	135	74
261	92	WI	Ree-CmC	45	90	sil	4		3.6						C	C	C	C	0	CP	99	170	4.8	4.9	18.8	12.6	107	107	100
262	92	WI	Ree-ACC	45	90	sil	3		2.5						A	A	C	C	0	CP	99	170	8.5	6.1	15.8	10.4	123	135	91
263	92	IL	SCHMID	40	89	sil	4	5.5		62	252					C	C	C	0	CP	104	152	2.3	3.8	2.3	1.9	137	196	70
264	92	IL	JANSEN	40	89	sil	4	6.3		100	296					S	W	C	1	NT	104	143	49.8	45.1	40.8	34.6	190	184	103
265	92	IL	KELLOGG	40	89	sicl	5	7.3		64	215					C	C	C	0	D	120	161	12.3	10	14	10.1	174	202	86

Appendix Table 1. NC-201 data base (continued).

														CROP GROWN							JULIAN DAY			SOIL NO_3-N				YIELD	
Ref	Yr	State	I.D.	Lat	Long	Txt	Drn	pH	OM	P	K	86	87	88	89	90	91	92	M	Till	PPNT	PSNT	PP1	PP2	PS1	PS2	Ylo	Yhi	RY
266	92	IL	LONG	40	89	sil	3	5.3		75	274					C	S	C	0	D	120	161	3.5	2.9	7.3	5.6	140	182	77
267	92	IL	KEMP	40	89	sil	2	6.6		74	181					C	C	C	0	CP	119	163	1	0.9	6.8	6.3	130	151	86
268	92	IL	KOMB	40	89	sil	3	7.0		66	220					C	S	C	0	CP	105	142	4.5	3.8	7	5.3	200	225	89
269	92	IL	OCONN	40	89	sil	4	6.3		21	166					C	S	C	0	NT	120	136	3.3	2.7	6.7	5.5	146	187	78
270	92	IL	PIERSON	40	89	sicl	5	5.9		54	195					C	S	C	0	D	119	162	1.8	1.5	9.5	6.8	148	192	77
271	92	IL	ROSENTRET	40	89	sil	4	6.3		65	176					C	S	C	0	D	105	141	9	7.8	11.3	9.4	218	212	103
272	92	IL	ZEH2	40	89	sil	5	6.8		79	337					C	S	C	5	D	106	140	11.3	9.5	16.5	11.5	145	145	100
273	92	IL	LLJC	40	89	sil	3	6.4		30	246					C	S	C	0	D	114	148	7	5.9	10.3	7.4	167	209	80
274	92	IL	REIF	40	89	sil	4	5.3		10	200					C	S	C	0	CP	104	142	3.3	2.9	3.3	2.3	110	200	55
275	92	IL	SANSON	40	89	sil	4	6.9		53	176					C	S	C	0	NT	105	141	6.3	5.1	7.8	6.1	138	200	69
276	92	IL	SHERTZ	40	89	sil	4	5.9		100	400					C	S	C	0	NT	105	142	7.5	6.1	10.8	8.4	199	209	95
277	92	IL	WENZ	40	89	sil	3	6.1		100	225					C	S	C	1	D	119	163	5.5	5	7.8	5	158	203	78
278	92	IL	ZEH1	40	89	sil	5	6.1		29	186					A	A	C	0	MP	106	140	4.8	5.3	21	14.6	204	208	98
279	92	IL	BROWN	40	89	sil	4	6.6		100	400					C	CRP	C	1	D	119	173	28.8	26.6	39.3	32.3	223	212	105
280	92	IL	COLBURN	40	89	sil	3	6.0		97	295					C	S	C	0	NT	105	142	5.5	4.8	10.3	7.4	180	205	88
281	92	IL	DAVIS2	40	89	sil	4	6.7		48	246					C	C	C	0	NT	105	142	5.3	4.6	6	5	98	169	58
282	92	IL	FECKE	40	89	l	4	6.4		23	181					C	S	C	0	D	120	136	3	2.3	6.5	5.4	107	184	58
283	92	IL	HEST1	40	89	sil	3	6.1		32	227					C	S	C	0	NT	118	152	4	4.3	4.5	4.5	141	207	68
284	92	IL	HOFFMAN	40	89	sil	3	5.2		100	400					C	S	C	0	NT	105	141	4	3.9	8	6.5	135	153	88
285	92	IL	BLUE	40	89	sicl	5	6.8		26	113					C	S	C	0	D	106	140	5	4.4	5.8	4	121	153	79
286	92	IL	DAVIS1	40	89	sil	4	6.8		63	226					C	C	C	0	NT	105	142	3	2.8	7	5.5	95	153	62
287	92	IL	HEST1	40	89	sil	3	6.1		25	190					C	S	C	0	NT	118	152	4.5	4.3	6.3	4.8	90	205	44
288	92	IL	KELLOGG	40	89	sicl	5	7.1		90	236					C	CRP	C	0	D	120	161	17.8	20.3	25.3	24.8	199	207	96
289	92	IL	KOCH	40	89	sil	3	6.8		75	262					C	C	C	0	D	119	163	3.8	3	7	5.5	76	117	65
290	90	IL	GUCKER	40	89	sicl	5	6.1		28			S	C	S	C			0			184			2.8		137	178	77
291	90	IL	BLUE	40	89	sicl	5	7.0					S	C	S	C			0	D	119	160	7.3	5.8	10.5		126	134	94
292	90	IL	WENZEL	40	89	sil	3						S	C	S	C			1	D	116	179	12.8	11.1	13.5		151	168	90
293	90	IL	BEHRNS	40	89	sil	5	7.3						C	S	C			0	D	151	187	4.3	4.6	13		139	151	92
294	90	IL	DEVORE	40	89	sil	4	6.1						C	S	C			0	D	119	160	3.5	5.3	11.8		113	127	89
295	90	IL	GERLING	40	89	sl	3	7.0								C			0		119	160	3.5	2.5	4.5		102	123	83
296	90	IL	ROGERS	40	89	sl	3	6.8								C			0	MP	120	158	2.8	2.6	1.8		81	121	67
297	90	IL	HUSTEDII	40	89	fsl	3	6.1						C	C	C			0	D	131	176	4.7	3.2	7		97	124	78
298	90	IL	KEITZMAN	40	89	sicl	5	5.7						C	S	C			1	CP		178			55.3		149	149	100
299	90	IL	WILKEN	40	89	sicl	5	6.1						C	S	C			0	D	131	176	3	2.5	3		132	157	84
300	90	IL	LONG	40	89	sil	3	6.6						C	S	C			0	D	113	164	8.8	7.6	14.8		136	146	93
301	90	IL	KELLOGG	40	89	sicl	5						C	C	C	C			0	MP	116	177	6.3	5.6	7.8		123	128	96
302	90	IL	KOCH	40	89	sil	3						C	C	C	C			0	CP	113	164	7.8	10.4	12.8		141	144	98
303	90	IL	DAVIS	40	89	sil	4	6.7								C			0		121	157	8	9.5	5.5		144	160	90
304	90	IL	ELLOIT	40	89	sil	4	6.2								C			0		121	156	6.5	5.1	4.3		118	148	80
305	90	IL	HIGGINS	40	89	cl	5	6.7					S	C	S	C			0	NT	113	177	6.5	6.3	6		143	177	81
306	90	IL	BEHRENDS	40	89	sil	4	5.8					S	C	S	C			0	D	122	156	2	2.5	2.8		99	162	61
307	90	IL	FARMER	40	89	sil	4	6.3								C			0	D	122	156	4.8	3.8	7.2		89	165	54

Key to Headings in Appendix Table 1 .

Ref = Numerical reference for each site.
State = State where site was located.
Lat = Average latitude for state.
Txt = Soil surface texture.
Drn = Drainage class, where:
1) excessively drained;
2) well drained;
3)moderately well drained;
4) somewhat poorly drained;
5) poorly drained.

Yr = Year of data collection.
I.D. = Site identification supplied by cooperating scientist.
Long = Average longitude for each state.
pH = Soil surface pH determined in 1:1 soil:H_2O.
OM = % organic matter (M = medium).
P = ppm soil surface extractable phosphorus by Bray and Kurtz-P1 or *Olson-sodium bicarbonate.
K = ppm soil surface exchangeable potassium

Crop = Record of crop or cropping system for study year and previous years, where:

Symbol	Common name	Scientific name
A	Alfalfa	*Medicago sativa* L.
B	Barley	*Hordeum vulgare* L.
C	Corn	*Zea mays* L.
Cl	Clover	*Trifolium sp.* L.
CRP	Various in set aside acres	
L	Lespedeza	*Lespedeza sp.* L.
Lu	Lupine	*Lupinus sp.* L.
O	Oat	*Avena sativa* L.
P	Pea	*Pisum sp.* L.
R	Rye	*Secale cereale* L.
S	Soybean	*Glycine max* L.
SD	Sudan grass	*Sorghum x drummondii* (Steudel) Millspaugh & Chase
SF	Sunflower	*Helianthus annuus* L.
SG	Sorghum	*Sorghum bicolor* (L.) Moench
Sg	Unidentified small grain	
swC	Sweet corn	*Zea mays* L.
T	Triticale	*x Triticosecale* spp.
W	Wheat	*Triticum aestivum* L.
V	Vetch	*Vicia sp.* L.

M = Manure history, where:
0) none;
1) applied in study year;
2) applied 1 yr prior to study year;
3) applied 2 yr prior to study year;
4) applied 1 and 2 yr prior to study year;
5) applied study year and 1 yr prior;
6) applied study year and 2 yr prior;
7) applied study year and 1 and 2 yr prior.

Till = Tillage system employed in study year, where:
MP - moldboard plow or turn plow;
CP - chisel plow
RT - ridge tillage
NT - no-till
D - disk
FC - field cultivation

Julian Day = day of study year when PPNT or PSNT sample was taken

Soil NO_3-N = ppm soil nitrate , where:
PP1 - PPNT 0- to 1-foot depth;
PP2 - PPNT 0- to 2-foot depth;
PS1 - PSNT 0- to 1-foot depth;
PS2 - PSNT 0- to 2-foot depth.

YIELD = Corn grain yield in bushels/acre @ 15.5% moisture (1 bu=56lb):
Ylo - yield with no fertilizer N (check)
Yhi - yield @ non-N-limiting treatment

RY = Percent relative yield
= [mean check (0 N) yield / mean non-N limiting yield] x 100