North Central Regional Nitrate Soil Testing Project[1]

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INTRODUCTION:

Although preplant soil nitrate (NO_3-N) 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), soil NO_3-N testing in humid regions is currently receiving substantial research attention. 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 pre-sidedress soil NO_3 test (PSNT) (Magdoff et al., 1984). Research conducted in the humid regions of the U.S. (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. 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 heavy-textured soils during the overwinter period and may contribute available N to subsequent crops. Therefore, interest also exists in evaluating preplant soil NO_3 tests for use in predicting crop N response and need for applied N in humid regions.

In view of the high current interest in development and implementation of soil NO_3 tests as techniques for improving agronomic efficiency of N and reducing potential water quality problems associated with N use on cropland, a North Central Regional Research Committee (NC-98 Nutrient Management in Conservation Tillage to Improve Productivity and Environmental Quality) initiated a core experiment to provide a regional evaluation of soil NO_3 tests. The NC-98 committee includes representatives from most of the Land Grant Universities in the region, and the members of this committee include university faculty and USDA scientists with expertise in soil fertility, soil chemistry, soil microbiology and biochemistry, and soil physics. Ultimately, the Committee plans to use the data collected in this project to prepare a regional publication on use of soil NO_3 tests in the North Central

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Region. The objective of this paper is to summarize the 1989 and 1990 results from the core experiment on soil nitrate tests conducted through the regional project.

MATERIALS AND METHODS

A common protocol was established for use by all potential cooperators in the regional project. In 1989, the regional project concentrated on evaluation of the PSNT, and in 1990, both preplant and PSNT tests were evaluated. The following procedures were used in the regional project.

<u>Treatment Specifications</u> - An adapted corn hybrid was grown using recommended production practices for all production practices except N fertilization. Nitrogen treatments included a no N check plot and a "non-N limiting" treatment to assure an adequate N supply for the crop based on N response functions determined at the site, local university N recommendations, or other methods to avoid N deficiency. The check and non-N limiting treatments were replicated at least 4 times. Where starter fertilizer N or manure were 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 one year prior to use in this study.

<u>Soil Sampling and Analysis</u> - 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 8 cores per plot. Pre-sidedress 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 prior to analysis to avoid changes in inorganic N content. Nitrate-N and exchangeable ammonium-N (optional) in the samples were determined using accepted, readily referenced procedures.

<u>Site Characteristics</u> - 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 pre-sidedress soil sample collection, and daily minimum and maximum temperatures were obtained from the nearest weather station.

<u>Plant Data</u> - Planting date, plant density, and corn hybrid were recorded for each location. Grain yields were determined in at least 4

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 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.

Data Analysis - Data from all cooperators was compiled and summarized for each year. SAS REG techniques (SAS Institute, Inc., 1982) were used to determine the relationships between relative yield and soil NO_3-N content. Relationships reported in this paper were determined using both linear-segmented plateau (LRP) and quadratic-segmented plateau (QRP) models.

RESULTS AND DISCUSSION

The source and previous crop information for sites included in the 1989 and 1990 projects are summarized in Table 1. The project involved 42 sites in 1989 and 74 locations in 1990. Most of the studies were done where the previous crop was corn, alfalfa, or soybeans with a smaller number of locations following small grains.

Table 1. Source and previous crop information for soil samples used in regional project.

		Previous crop				
Year	State	Corn	Alfalfa	Soybeans	Small grains	Other
		No. of observations				
1989	Maryland	2	--	1	--	--
	Minnesota	7	--	--	1	--
	Nebraska	6	--	--	--	--
	Wisconsin	15	10	--	--	--
1990	Iowa	2	--	9	--	--
	Kansas	--	--	--	2	--
	Michigan	4	1	2	--	--
	Minnesota	8	1	4	2	1
	Nebraska	9	--	1	--	--
	Ohio	2	--	1	--	--
	South Dakota	--	--	1	3	--
	Wisconsin	14	7	--	--	--

Figure 1 illustrates the relationships between relative corn yield and pre-sidedress soil NO_3 test values for various previous crops when data from 1989 and 1990 are combined. The LRP model is shown in Fig 1, and comparable data for the QRP model is shown in Table 2. For all 1989 and 1990 observations (Fig.1-A), a R^2 value of 0.47 is obtained with the LRP model for the relationship between relative yield and 0-1 ft PSNT values. This R^2 value is typical of those frequently observed when NO_3 soil test data from numerous sites and years are combined. Use of the QRP model to describe this data does not improve the R^2 value (Table 2), but the critical value for the PSNT is increased from 16 to 23 ppm N. Use of 0-2 ft samples in the PSNT gives only a small increase in R^2 value for the relationship with relative yield (Fig. 1-B), and again, the critical value for the LRP model is lower than for the QRP.

The R^2 values for both models and sampling depths are somewhat higher when only data for corn following corn is considered (Fig. 1-C and 1-D). However, use of the 0-2 ft sampling depth instead of 0-1 ft gave only very modest improvements in the fit of the models. Critical values for the 0-1 ft PSNT for corn following corn from the regional study (18 ppm N) is lower than the 20 to 25 ppm N range in critical values identified in previous work with the PSNT (Magdoff et al., 1990; Blackmer et al., 1989; Fox et al., 1989).

For corn following soybean, PSNT test values were not closely related to relative yield in either of the models used (Fig 1-E and 1-F); however, the relationship is based on fewer observations than were used for the combined data or for where corn was the previous crop. As shown in Table 2, an acceptable R^2 value for the relationship between 0-2 ft PSNT values and relative yield is obtained with the QRP model, but the critical value for the PSNT is much lower (7 ppm N) than with the remaining models.

Where alfalfa or small grains were the previous crops (Fig 1-G and 1-H), no satisfactory relationship between PSNT values and relative yield was found. For corn following alfalfa, all observations were near 100% relative yield, indicating little or no response to added N for PSNT values in the 10 to 30 ppm N range. This finding suggests that the previous alfalfa crop provided an adequate amount of N to meet the needs of the following corn crop in essentially all of the 19 site-years included in the study. The range in PSNT values across sites indicates substantial variation in the rate of N mineralization from the alfalfa residues likely due to differences in climatic or management factors. For corn following small grains, all PSNT values were low (<15 ppm N), but no relationship with relative yield was apparent.

Figure 2 illustrates the annual variation in the relationship between relative yield and PSNT values for 1989 and 1990 sites where corn was the previous crop. In general, comparison of Figures 2-A and 2-C shows that yield and PSNT values were more closely related in 1989 than in 1990, and the critical values for the PSNT were substantially different between the two years (22 ppm N in 1989 vs. 15 ppm in 1990). As in the combined data, there was little advantage to using a 0-2 ft sampling depth over 0-1 ft samples, and the R^2 values obtained with the LRP and QRP models were quite similar; however, the critical values for the QRP model were

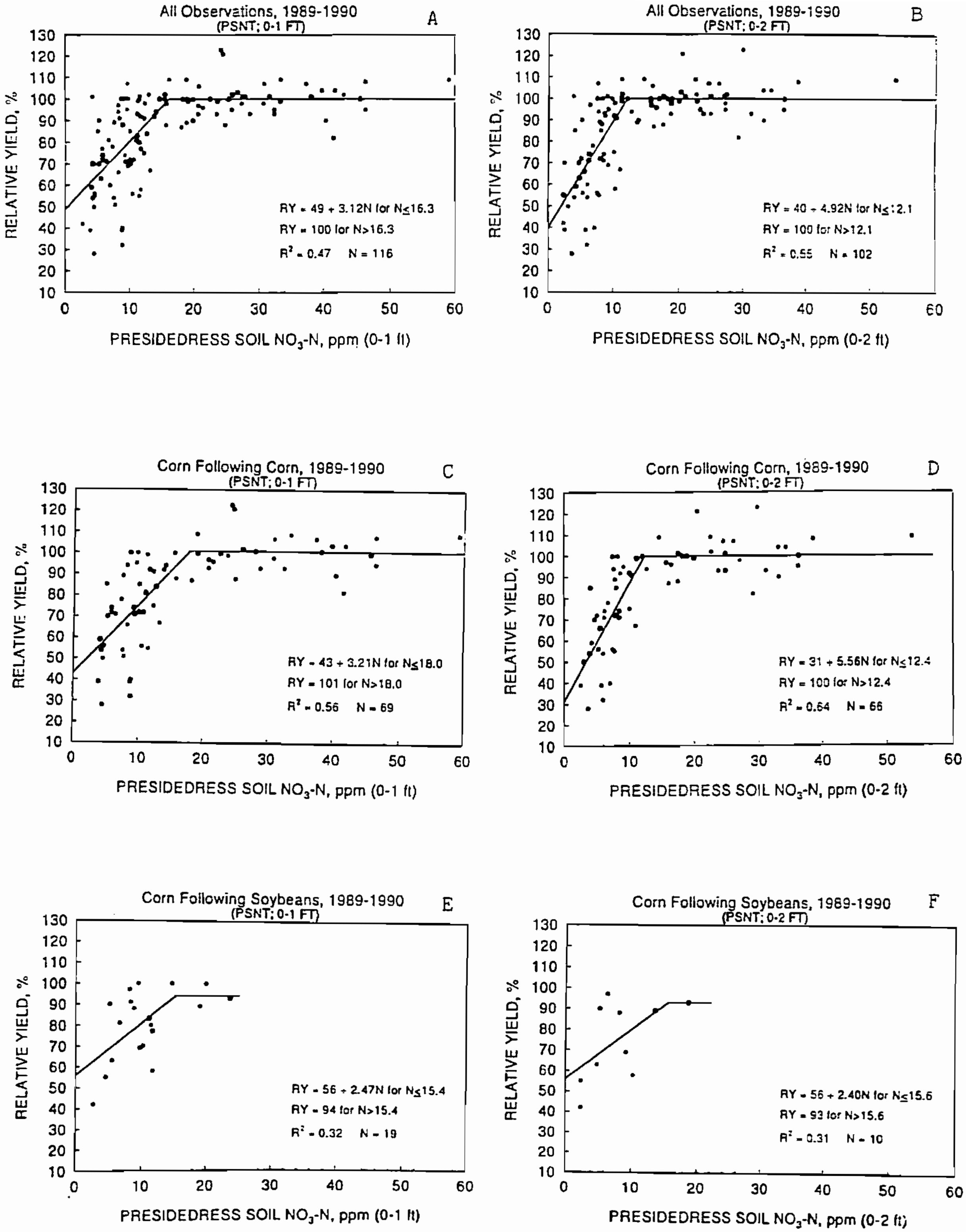

Fig. 1. Relationships between relative corn yield and pre-sidedress NO_3-N tests, combined data, 1989 and 1990.

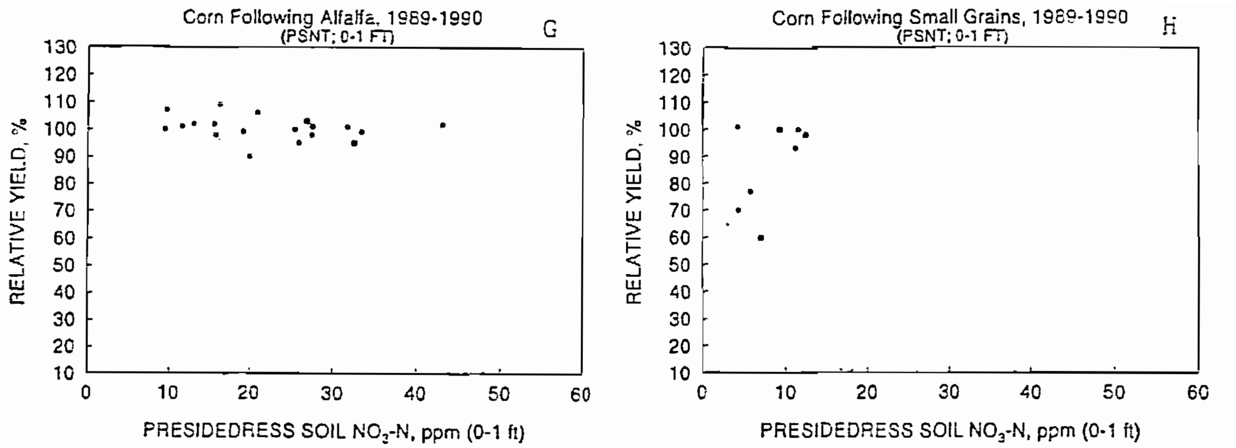

Fig. 1. (con't.) Relationships between relative corn yield and pre-sidedress NO_3-N tests. combined data, 1989 and 1990.

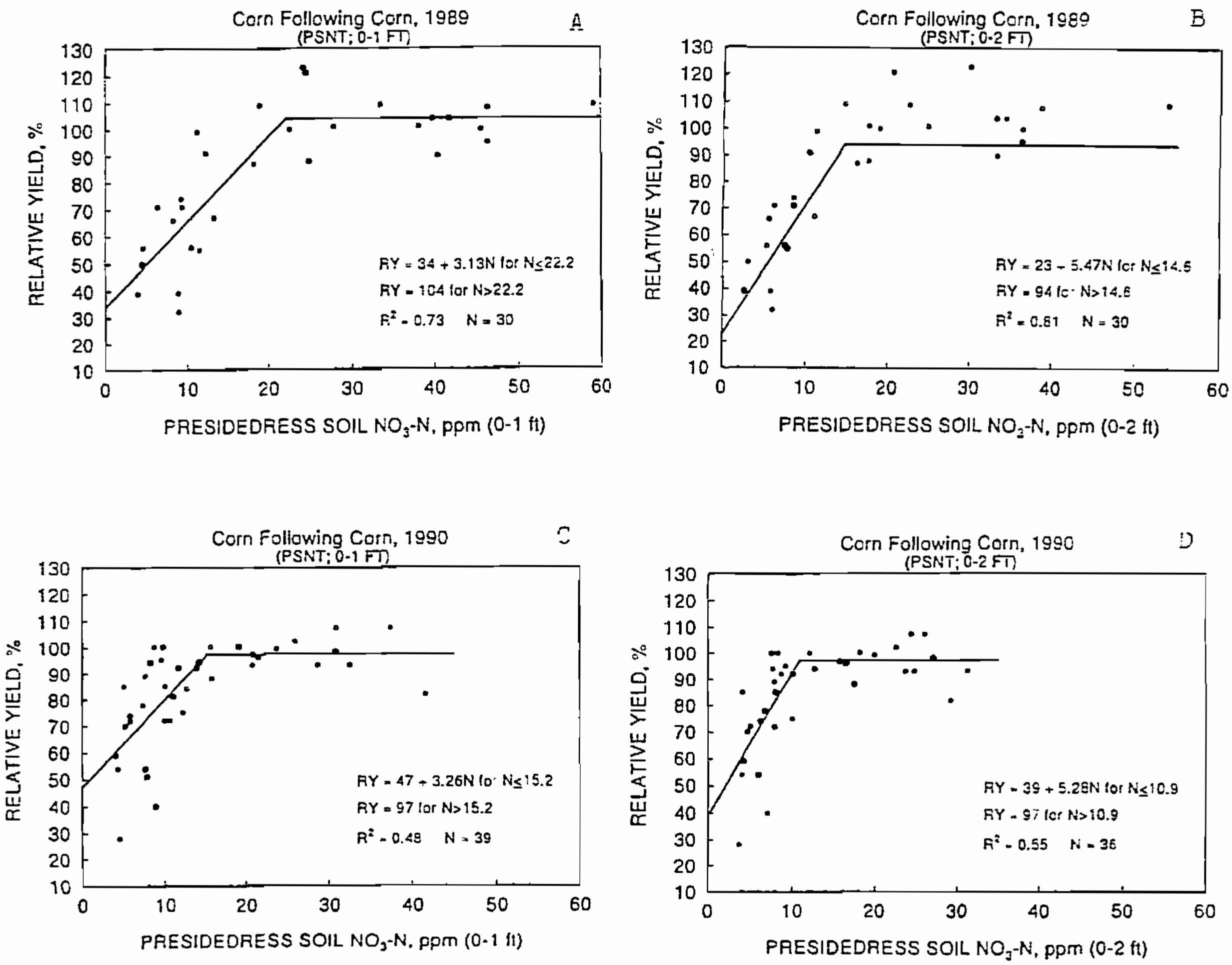

Fig. 2. Relationships between relative yield and pre-sidedress NO_3-N tests for corn following corn in 1989 and 1990.

Table 2. Relationships between relative corn yield and soil nitrate test values.

Soil test1/	Year	Previous Crop	Soil depth	Regression method2/	Equation	Critical NO_3-N value	Plateau Yield	R^2	n
			-ft-			-ppm-	-%-		
PSNT	1989-90	All Observations	0-1	LRP	RY = 49 + 3.12N	16.3	100	0.47	116
				QRP	RY = 42 + 4.99N -0.106N^2	23.6	101	0.47	116
			0-2	LRP	RY = 40 + 4.9N	12.1	100	0.55	102
				QRP	RY = 32 + 7.89N -0.229N^2	17.3	100	0.55	102
PSNT	1989-90	Corn	0-1	LRP	RY = 43 + 3.21N	18.0	101	0.56	69
				QRP	RY = 35 + 5.08N -0.097N^2	26.2	101	0.56	69
			0-2	LRP	RY = 31 + 5.56N	12.4	100	0.64	66
				QRP	RY = 19.21 + 9.32N -0.268N^2	17.4	100	0.64	66
PSNT	1990	Corn	0-1	LRP	RY = 47 + 3.26N	15.2	97	0.48	39
				QRP	RY = 36 + 6.0 -0.148N^2	20.3	97	0.49	39
			0-2	LRP	RY = 39 + 5.28N	10.9	97	0.55	36
				QRP	RY = 14 + 12.21N -0.453N^2	13.5	97	0.56	36
PSNT	1989	Corn	0-1	LRP	RY = 34 + 3.13N	22.2	104	0.73	30
				QRP	RY = 20 + 5.83N -0.102N^2	28.7	104	0.71	30
			0-2	LRP	RY = 23 + 5.47N	14.6	94	0.81	30
				QRP	RY = 17 + 7.60N -0.164N^2	23.1	105	0.80	30
PSNT	1989-90	Soybeans	0-1	LRP	RY = 56 + 2.47N	15.4	94	0.32	19
				QRP	RY = 42 + 5.9N -0.176N^2	16.8	91	0.35	19
			0-2	LRP	RY = 56 + 2.40N	15.6	93	0.31	10
				QRP	RY = -2.6 + 25.77N -1.955N^2	6.6	82	0.53	10
PSNT	1989-90	Alfalfa	--->	No fit					
PSNT	1989-90	Small Grain	--->	No fit					

Table 2.(cont.) Relationships between relative corn yield and soil nitrate test values.

Soil test1/	Year	Previous Crop	Soil depth	Regression method2/	Equation	Critical NO_3-N value	Plateau Yield	R^2	n
			-ft-			-ppm-	-%-		
PPNT	1990	All Observations	0-1	LRP	$RY = 70 + 1.75N$	16.4	98	0.18	72
			0-1	QRP	$RY = 68 + 242N - 0.044N^2$	27.5	100	0.18	72
			0-2	LRP	$RY = 67 + 2.32N$	12.4	96	0.23	71
			0-2	QRP	$RY = 65 + 3.47N - 0.093N^2$	18.7	97	0.23	71
PPNT	1990	Corn	0-1	LRP	$RY = 63 + 2.17N$	15.5	97	0.26	39
				QRP	$RY = 61 + 2.98N - 0.058N^2$	25.8	100	0.25	39
			0-2	LRP	$RY = 57 + 3.26N$	12.3	97	0.43	38
				QRP	$RY = 49 + 5.95N - 0.184N^2$	16.2	97	0.45	38
PPNT	1990	Alfalfa	0-1	No fit					
			0-1	No fit					
			0-2	No fit					
			0-2	No fit					
PPNT	1990	Soybean	0-1	LRP	$RY = 64 + 2.04N$	15.0	95	0.21	17
				QRP	$RY = 59 + 4.03N - 0.133N^2$	15.1	89	0.23	17
			0-2	LRP	$RY = 66 + 1.96N$	15.0	95	0.21	17
				QRP	$RY = 61 + 3.99N - 0.142N^2$	14.1	89	0.23	17
PPNT	1990	Small Grain	0-1	LRP	$RY = 49 + 3.97N$	12.8	100	0.68	7
				QRP	$RY = 46 + 5.38N - 0.116N^2$	23.2	109	0.64	7
			0-2	LRP	$RY = 63 + 3.61N$	10.4	100	0.44	7
				QRP	$RY = 60 + 4.93N - 0.146N^2$	16.9	102	0.40	7

1/ PSNT = pre-sidedress soil nitrate test; PPNT = preplant soil nitrate test.

2/ LRP = linear-segmented plateau model; QRP = quadratic-segmented plateau model.

substantially higher than with the LRP method. The LRP approach has been used to describe the yield vs. soil NO_3-N value relationship in several previous studies with the PSNT (Magdoff et al., 1984; Blackmer et al., 1989; Fox et al., 1990). The year to year variation in the R^2 values (Fig. 2) and in the critical value for the PSNT suggests that annual variation in the predictive value of the test is likely if the PSNT is interpreted using a single critical value and calibration data obtained by combining data from several years.

A preplant soil NO_3 test to predict crop N needs is attractive to producers because it could allow preplant N applications and avoid the need for soil sampling and sidedress N applications during the early part of the corn growing season when producers are often occupied with other tasks. Therefore, a preplant sampling time was included in the regional NO_3 testing project in 1990. Relationships between relative corn yield and preplant soil NO_3-N values for various previous crops are illustrated in Figure 3.

Data in Figure 3-A and 3-B show a poor relationship between preplant soil NO_3-N content and yield when data from all sites is combined. This is at least partly due to inclusion of observations from sites where the previous crop was a legume. Preplant NO_3 tests measure mainly residual NO_3-N within the soil depth sampled, and legume N contributions are not determined. It seems likely that release of available NO_3-N from the legume residues was incomplete when the preplant soil samples were taken. The relationship between yield and preplant NO_3-N test value is improved when the analysis is limited to sites where the previous crop was corn (Fig. 3-C and 3-D) especially where a 0-2 ft sampling depth was used. Although the R^2 value shown for the 2 ft preplant sampling depth in Figure 3-D is some what lower than that shown for the PSNT (Fig. 1-C), 0.43 vs. 0.56, respectively, the preplant test seems to have potential for use following corn if a 0-2 ft sampling depth is used. The improvement in R^2 value when only corn following corn observations are used and with deeper soil sampling is consistent with the theory that preplant tests mainly reflect the influence of residual NO_3-N from previous production practices.

The critical value for the 0-2 ft preplant NO_3 test shown in Figure 3-D is about 12 ppm N or 100 lb NO_3-N/acre. This value is reasonably consistent with the 135 lb NO_3-N/acre critical value for 0-3 ft samples identified in earlier work (Bundy and Malone, 1988). The year to year variation in R^2 values and critical values of the models for preplant tests in Figure 3 cannot be determined from the 1990 data, but additional information to address this issue is being collected in 1991.

Figures 3-E, 3-F, 3-G, and 3-H illustrate the poor relationship between preplant NO_3 tests and yield where the previous crop was a legume. As discussed earlier, release of mineralizable N from the legume residues is not complete when the preplant samples are taken. Therefore, preplant tests are not likely to be useful following forage legumes such as alfalfa, and may have low predictive value following soybeans.

Preplant NO_3 tests have potential for predicting corn yield response following small grains (Fig. 3-I and 3-J). Based on a limited number of

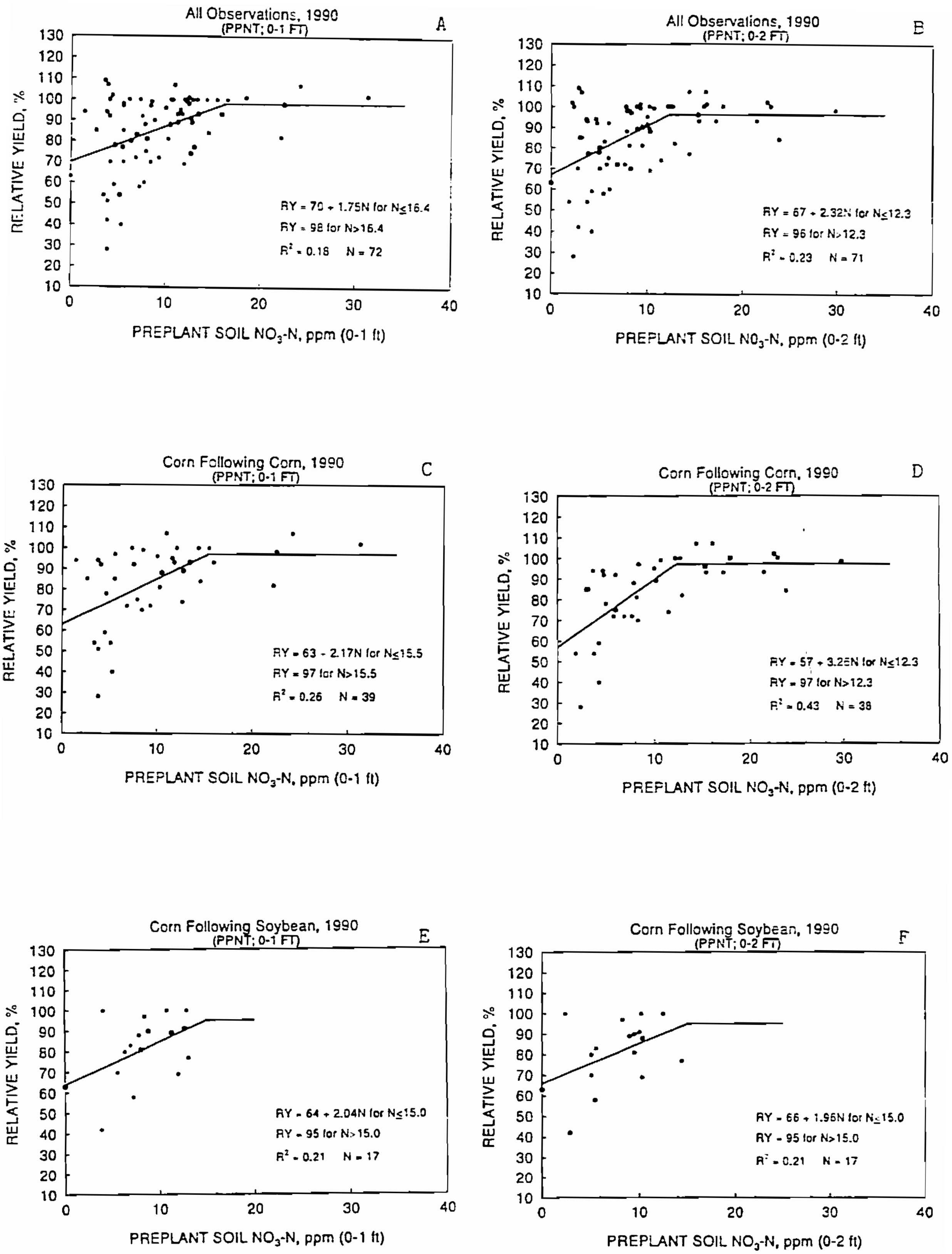

Fig. 3. Relationships between relative corn yield and preplant NO_3-N tests, 1990.

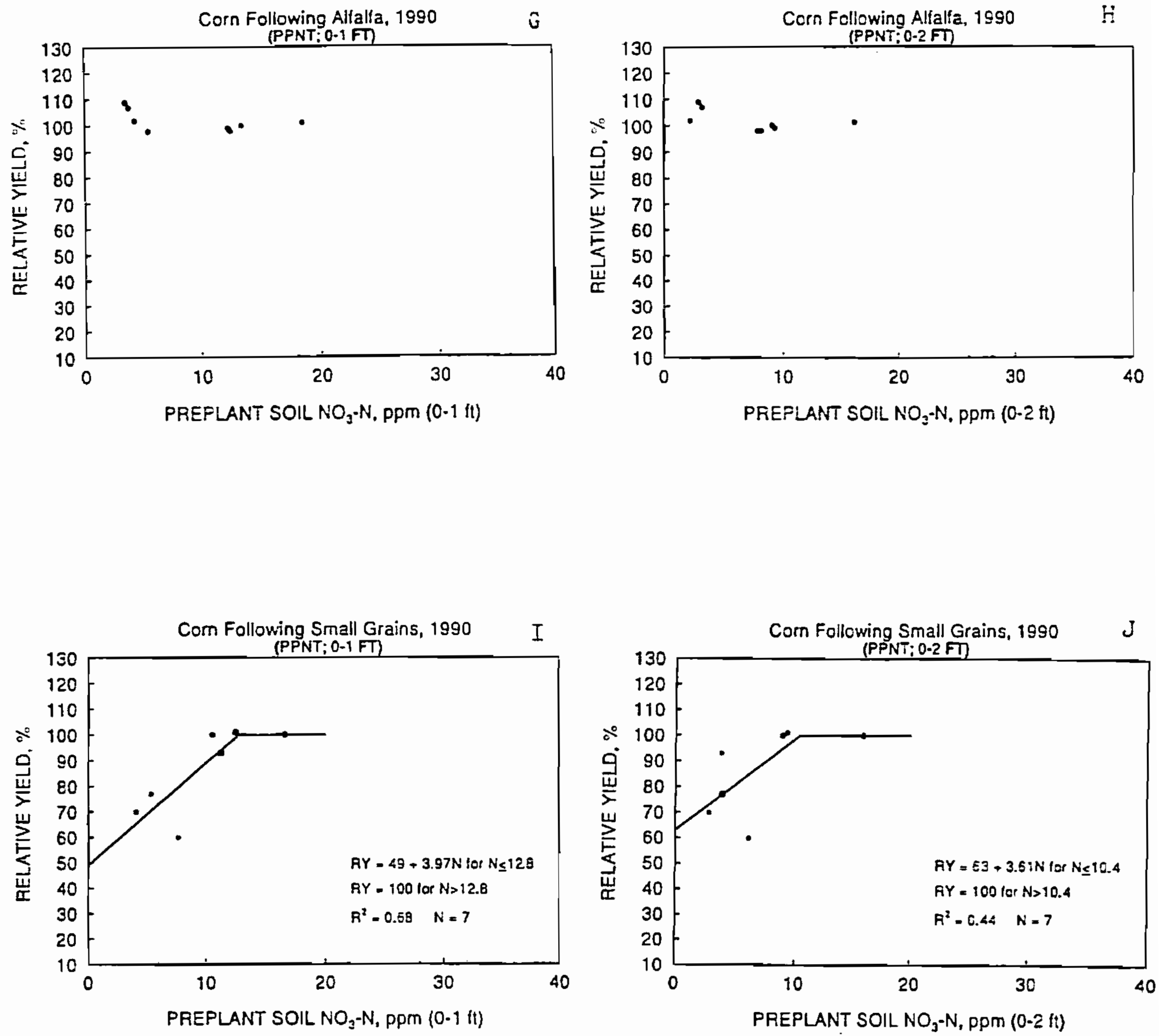

Fig. 3. (con't.) Relationships between relative corn yield and preplant NO_3-N tests, 1990.

observations, a good relationship (R^2 = 0.68) was found between relative yield of corn and 0-1 ft preplant NO_3-N test values. Surprisingly, this relationship has better predictive value with 0-1 ft samples that with deeper samples.

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