EVALUATION OF THREE N RECOMMENDATION SYSTEMS FOR CORN YIELD AND RESIDUAL SOIL NITRATE

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Proper N application rates are required for continued economic and environmental viability of U.S. agriculture. Application at rates below that required for economic optimum will place U.S. farmers at a competitive disadvantage in the world market. On the other hand, excessive rates of N fertilizers may result in contamination of ground water.

MATERIALS AND METHODS

Experiments were conducted on about 75 farms throughout Illinois from 1990 through 1992 to evaluate the efficacy of three N recommendation systems for corn. In this paper we will report the results from 1990 and 1991. The first of the three recommendation systems consisted of the current University of Illinois system, in which proven yield (based on a 5-year average) for a field is multiplied by 1.2 lbs N/bushel for continuous corn, with (downward) adjustments if corn follows a legume or if manure has been applied. For corn following soybeans, this adjustment is 40 lb N per acre, and for corn following a full stand of alfalfa, the rate is reduced by 100 lb N per acre. The amount of available N contained in manure is subtracted from the recommended rate. This system will be designated the proven yield (PY) system. The second system is modeled after the Michigan State University recommendation in which the amount of N found in the top two feet of soil in early spring is subtracted from the normal recommendation. This system will be designated as PPNT. The third system evaluated is the current Iowa State University recommendations (Blackmer et al., 1991), in which adjustments are made based on soil nitrate levels at presidedress time, when corn is 6 to 12 inches tall. This system will be referred to as PSNT.

Experimental sites were selected to provide a measure of the effect of these recommendation systems under varying conditions, including differences in soil type, previous crop, climatic conditions, and manure management. At each location, soil samples were collected in early spring (late March to early April) in 1 foot increments to a depth of 2 feet and again at N sidedress time (late May to early June) as a single sample to a depth of 1 foot. The samples were kept frozen until analysis for NO_3-N, which was done according to Keeney and Nelson, 1982. When corn was 6 to 12 inches tall, N was applied using 6 rates of N evenly spaced from 0 to 100% of the normal recommendation in 1990 and from 0 to 125% of the normal recommendation in 1991. The normal recommendation was determined by multiplying the soil's corn yield potential in bushels per acre (as given in Fehrenbacher et al., 1984) times 1.2 pounds of N, minus corrections based on previous crop or manure application history. Nitrogen

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treatments were injected as urea-ammonium nitrate solutions (28% N). Plant populations were thinned to a uniform stand at each location. Yield was determined by hand harvesting 30 feet of each of two rows. In November, soil samples were collected in 1 foot increments to a depth of 3 feet on the control, highest rate, and a mid-rate treatment for determination of NO_3-N concentration.

A separate experiment was conducted in 1992 to determine the spatial distribution of nitrate and ammonium concentrations in the soil following anhydrous ammonia injection. Anhydrous ammonia was injected to a depth of 8 inches in late April at rates of 100, 150, and 200 lbs N/acre in a Drummer silty clay loam soil at Urbana. No crop was grown during the season. Soil samples were collected to a 1 foot depth about every 2 weeks during May and June, at distances of 0, 3, 6, 9, 12, and 15 inches from the injection band. Additional samples were collected in October.

All experiments utilized a randomized complete block design with 4 replications and were analyzed using the appropriate SAS procedures. When the response to N rate was best described as a quadratic in the form of $N = a + bN + cN^2$, the economically optimum N rate was determined as $N = -(b-R)/2c$, where R is the cost of N in dollars per lb divided by the price of corn in dollars per bushel. We used R = \$0.20 ÷ \$2.50 = 0.08.

RESULTS AND DISCUSSION

Nitrate concentrations ranged from 1 to 38 ppm NO_3-N in the top two feet of soil in early spring, with average and median values of 6 and 4 ppm, respectively. The highest concentration was observed on a field that had received the equivalent of 225 lbs available N/acre as manure in the preceding fall. At presidedress, the average and median NO_3-N values in the top foot of soil were 10 and 7 ppm with a range from 0 to 55 ppm. Again, the highest value was associated with the field that had received the high rate of manure application. Both the average and the median NO_3-N concentrations in the surface foot of soil were higher at sidedress time than in early spring, 10 versus 7 and 7 versus 4, respectively, for sidedress and early spring samples. This increase in concentration from early spring to sidedress time likely resulted from more mineralization than N loss during this period.

Fifteen locations had NO_3-N concentrations above 10 ppm, with 4 of those exceeding 20 ppm. Three of the four locations that exceeded 20 ppm had had manure applied, and there was no significant response to fertilizer N application at any of these three locations. At the fourth location where NO_3-N concentration exceeded 20 ppm, no manure had been applied, and there was a significant response to applied N. Response to applied N was observed at only 2 of the 11 locations where the NO_3-N concentration was between 10 and 20 ppm.

Significant response to applied N was observed at 27 of the 47 locations evaluated (Table 1). For these responsive locations, the optimum yield obtained was almost identical to the yield goal used for calculation of the N requirement, and the average optimum N rate determined in these experiments was within 4 pounds per acre of that recommended using the PY method. For continuous corn, the optimum N rate was 1.16 lb N/bushel of corn produced. For corn after soybeans, the optimum was 1.0 lb N/bushel, which is again very close to the rate recommended under the PY system when one assumes a 40 lb N/acre credit for the preceding soybean crop. The PPNT and PSNT systems, on the other hand, underestimated N needs by approximately 30 and 10 pounds per acre, respectively. Use of the PPNT system would have substantially reduced net income, while use of either of the other two systems would have resulted in net return to N very near the maximum.

All three systems overestimated the amount of N needed for optimum yield at the 20 non-responding locations (Table 2). Closer examination provides some reasons for these overestimates. Four of the locations that did not respond to fertilizer N had received manure applications. All three systems predicted that 3 of these locations would have needed no additional N, but all three predicted a need for N at the location that had received chicken manure. In this latter case, we had neither an accurate estimate of the amount of manure applied nor of the N content of the manure; as a result, a small amount of N was recommended (Table 2). Based on these limited results, it would appear that the PSNT system might have potential for use in those cases where manure is applied on the surface but not incorporated into the soil quickly enough to prevent volatilization loss.

Yields were markedly reduced at 6 of the study locations by drought. Yields averaged only about 2/3 of normal expectations for those locations with some being as low as 1/3 of normal. Four of the six locations had reduced yield in the year prior, thus there may have been more residual N available than normal. If that were the case, however, results from neither the early spring nor sidedress samples indicated such carryover.

Alfalfa was the previous crop at two of the non-responding locations. One of these was also drought affected, thus the need for supplemental N was markedly reduced. The non-drought affected location produced 175 bushels of corn per acre with no supplemental N, indicating that mineralization of the legume residue was greater than normally expected for that location. Both the PPNT and PSNT systems predicted a response to applied N at both of these locations.

There was no obvious reason why the remaining 8 locations did not respond to applied N (Table 3). Yields at these locations were near expectations, and substantially exceeded expectations in some cases. Six of the 8 followed corn, raising again the possibility of N carryover from the prior year. Here again, however, neither of the soil samples revealed significant nitrate levels. Several of the locations had very high P and K soil test values, leading us to suspect that they may have had manure applied in the past. If so, these soils may have had higher mineralization rates than if they had not received manure.

Residual nitrate levels in the surface foot of soil following harvest in the fall increased slightly with increasing N rates at the responding sites (Table 4). At the non-responding sites, nitrate levels at all application rates and at all depths were higher than at the responding sites, indicating some movement of excess N through the profile. These figures were inflated somewhat by the inclusion of the sites that had received manure. Surprisingly, the unexplained non-responding sites were not substantially higher in nitrate concentration than were the responding sites. In all cases, residual NO_3-N concentrations were well below those normally thought to be needed for optimum corn production.

Irrespective of rate of N application, there was little indication of NO_3 movement beyond 6 inches from the point of ammonia application during the first 6 to 8 weeks after ammonia application (Fig. 1). At all application rates, the concentration was highest in the sample taken directly over the band, and decreased by one-half to two-thirds in samples collected only 3 inches from the band. This rapid change in concentration as one moves away from the band will make it very difficult to attain accurate results unless one systematically probes every few inches perpendicular to the direction of application. As an alternative, one might utilize a field test kit to identify the location of the band and then proceed to sample the field according to the known location of the band.

CONCLUSIONS

Based on these results, we think that the both the PY and PSNT systems will provide an accurate estimate of N need when a response to N occurs. Use of the PPNT system showed limited promise on fields that had experienced a yield limiting environment the prior year that may have resulted in carryover of N. The PSNT system showed promise for assisting those producers who surface apply manure without immediate incorporation, or who have limited information available on the rate or concentration of N being applied in the manure. Even under conditions of low yields due to unfavorable weather, where one might expect considerable N to remain unused, we found little nitrate in the upper 3 feet of soil following harvest. Such evidence does not preclude the possible accumulation of organic forms of N that might be released into the profile at a later date and that might result in groundwater contamination. Limited movement of nitrates from the point of ammonia injection in the first few weeks after application will require a carefully planned sampling program in order to utilize the PPNT system on fields that have received a spring preplant application of N.

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Table 1. Relationship between experimentally derived, economically optimum N rates and N recommendations from three recommendation systems.

Number of Locations	Yield Goal	Optimum Yield	Optimum N rate	Recommendation system PY	PPNT	PSNT
	------bushel/acre-----		--------------------lb N/acre--------------------			
			Responding Sites			
27	141	143	141	137	109	130
			Non-responding Sites			
20	140	129	0	123	81	100

Table 2. Relationship between experimentally derived, economically optimum N rates and N recommendations from three recommendation systems as influenced by manure application, environmental factors, and previous crop.

Number of Locations	Yield Goal	Optimum Yield	Optimum N rate	Recommendation system PY	PPNT	PSNT
	------bushels/acre---		--------------------lb N/acre--------------------			
			Manured sites			
4	146	172	0	38	22	31
			Drought affected sites			
6	152	98	0	162	111	125
			Forage legume sites			
2	160	133	0	111	83	90

Table 3. Relationship between experimentally derived, economically optimum N rates and N recommendations from three recommendation systems on non-responding sites.

Location	Soil NO_3-N		Yield	Optimum	Recommendation system		
	PPNT	PSNT	Goal	Yield	PY	PPNT	PSNT
county	-----ppm-----		-bushels/acre-		-----------lb N/acre-----------		
Effingham	4	13	137	115	98	66	105
Effingham	5	12	111	115	138	98	115
Henderson	3	8	97	105	86	62	135
Kane	8	15	139	130	156	92	85
Effingham	12	8	169	115	138	42	135
Stephenson	10	13	140	140	168	88	105
Warren	7	6	144	160	192	136	135
Wayne	3	11	95	115	138	114	125

Table 4. Effect of N application on residual NO_3-N concentration with depth at harvest.

	N Rate, % of Recommended								
	0			60-75%			100-125%		
Sample depth, ft:	0-1	1-2	2-3	0-1	1-2	2-3	0-1	1-2	2-3
	ppm soil NO_3-N								
Responding Sites									
	2.8	1.3	1.3	4.2	1.8	1.2	7.5	2.8	1.7
Non-responding sites									
	5.0	3.8	2.8	7.9	6.4	4.2	11.1	9.0	5.1
"Unexplained" non-responding sites									
	3.6	2.7	2.7	6.3	5.0	3.8	9.9	9.2	4.4

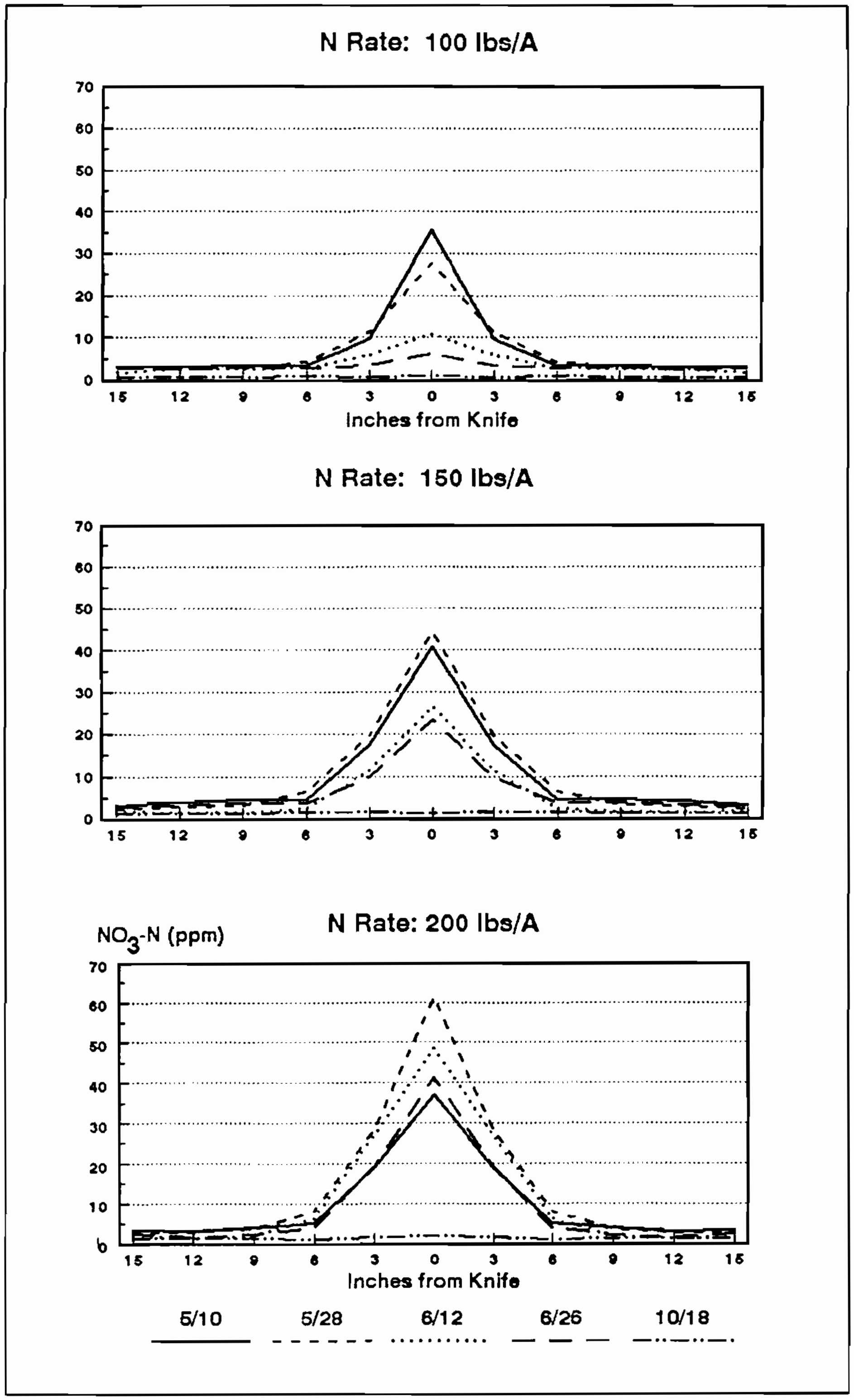

Figure 1. Variation in NO_3-N concentration in upper 12 inches of soil as affected by N rate, time of application, and distance from the injection zone.

PROCEEDINGS OF THE TWENTY-SECOND

NORTH CENTRAL EXTENSION - INDUSTRY

SOIL FERTILITY CONFERENCE

November 18-19, 1992, Holiday Inn St. Louis Airport

Bridgeton, Missouri

Volume 8

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