Optimizing Nitrogen Management in Manured Cornfields

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Animal manure can provide N needed for production of corn. A major problem, however, is that manure is not perceived to be a reliable source of plant-available N. Much of the manure-N is known to be lost soon after application to soils, and much of the remaining N is known to persist as forms that are not readily available to the next crop. Recent studies involving 148 on-farm trials show that the late-spring test for soil nitrate has great potential for addressing this problem. The test involves measuring concentrations of nitrate in the surface layer of soils when corn plants are 6 to 12 in. tall, so it assesses N availability just before plants begin rapid uptake of N from soils. The soil test, therefore, can be used to make site-specific estimates of additional fertilizer N needed. Use of the soil test over several years gives producers information they can use to adjust rates of manure application to supply optimal amounts of N in most years. Results of the studies suggest that use of the soil test on manured cornfields should substantially decrease average rates of fertilizer N application while increasing average yields. These changes should increase profits for producers while minimizing losses of N to the environment.

Keywords: Nitrogen, Nutrient management, Water quality, Manure disposal.

INTRODUCTION

Corn producers face great uncertainty when estimating N fertilizer needs for fields that already have received applications of N as animal manure. This uncertainty occurs because there is variability in portions of the manure-derived N that remain in organic forms unavailable for crop uptake and because there is great variability in the portions of the manure-N lost by ammonia volatilization, leaching, or denitrification soon after application. This variability is caused by complex interactions of many factors relating to characteristics of the manure, management practices, and weather. This uncertainty prompts many producers to apply commercial fertilizer with little regard for the quantities of N already applied as manure.

Many studies have shown that soil tests based on nitrate concentrations in the surface foot of soil when corn plants are 6 to 12 in. tall enable site-specific assessments of plant-available N (Magdoff et al., 1984; Blackmer et al., 1989; Fox et al., 1989; Magdoff et al., 1990; Binford et al., 1992). Because soils are sampled more than a month after animal manures are normally applied, such tests should be expected to reduce uncertainty in estimating N fertilizer needs caused by N transformations and losses that occur shortly after the manure is applied.

Studies across a wide range of conditions show remarkable agreement that the critical concentration of soil nitrate-N (i.e., the concentration that distinguishes soils that should be fertilized from those that should not) occurs between 20 and 25 ppm (Bundy and Meisinger, 1994). Relatively little attention, however, has focused on the task of identifying the optimal rates of N application for each soil nitrate concentration likely to be encountered. The objective of this study was to develop recommendations concerning the amounts of fertilizer N that should be applied for various soil test values and to evaluate the benefits of using these recommendations on manured cornfields in Iowa.

MATERIALS AND METHODS

Trials involving measurement of yield response to commercially prepared N fertilizer were conducted in 148 cornfields that had been manured by farmers using their normal practices. The trials were distributed across 28 counties in Iowa, with approximately equal numbers each year from 1992 through 1995. Sites were selected to include variety with respect to common soil types, manure types, rates of application, methods of application, and times of application. Except for N fertilization, soil and crop management practices were those normally used by each farmer. The manure came from beef units at 22 sites, dairy units at 9 sites, swine units at 92 sites, and poultry units at 9 sites. Sixteen sites received 2 or more forms of animal manure. Approximately equal numbers of sites were manured in the fall, winter, and spring before planting. Some sites had not received applications of animal manure since harvest of the previous crop, but these sites had received at least 2 applications of manure in the last 4 years.

Each trial consisted of 16 plots arranged in a randomized complete-block design with 4 replications. Plots were 40-ft. long and 6 rows wide for 30-in spacings or 4 rows wide for 36-38 in spacings. Soil samples were collected when corn plants were 6 to 12 in. tall. Each sample (0- to 12-in depth) was derived from a composite of 32 cores collected from each block. Immediately following soil sampling, four rates of N (0, 30, 60, and 90 lb N/ac as urea or ammonium nitrate) were broadcast on the soil surface. Concentrations of nitrate-N were determined by a flow-injection procedure (Lachat Instruments, Milwaukee, WI; Method 12-107-04-1-B). Grain was hand-harvested from 25-ft sections of the center two rows of each plot. Yields were adjusted to 15.5% moisture content.

Net returns ($/ac) to N fertilization for each plot within all 148 trials were calculated for various price scenarios by subtracting the costs of fertilizer and application from the value of additional grain produced on fertilized plots compared with nonfertilized plots within each block. The price scenarios were selected to include the range of prices usually found in Iowa. The cost of fertilizer application was calculated at $4.50/ac.

For each rate of fertilization within each price scenario, relationships between mean net returns to fertilization and soil nitrate concentrations were plotted as a running average. The point at which the net returns relationship became negative was considered the profit-maximizing critical concentration for the specified rate and price scenario.

RESULTS AND DISCUSSION

Observed yield responses to fertilizer N are summarized in Table 1, where trials are grouped into categories based on soil nitrate concentrations found before the fertilizer was applied. A key finding is that N fertilization had essentially no net effect on yields at the sites having soil nitrate-N concentrations greater than 20 ppm; the yield increases observed were not enough to offset the normal costs of fertilization. Other key findings are that (i) important yield responses to fertilizer N occurred in the soil nitrate categories having less than 20 ppm-N, (ii) the greatest yield responses tended to occur at the sites having the lowest concentrations of nitrate, and (iii) optimal rates of N fertilization tended to decrease with increasing concentrations of nitrate in the soil. These observations show that the soil test can be used to assess amounts of plant-available N in the soil and identify optimal rates of N fertilization.

Table 1. Mean yields of corn as affected by N fertilization rate on 148 manured fields having various concentrations of nitrate before fertilization.

Soil nitrate concentration	Mean yield of grain			
	0 lb N/ac	30 lb N/ac	60 lb N/ac	90 lb N/ac
---- ppm-N ----	----------bu/ac----------			
< 11 (115)†	114	126	130	134
11 to 15 (160)	132	138	145	145
16 to 20 (104)	148	153	153	153
> 20 (202)	157	159	159	159

† Numbers in parentheses indicate the number of blocks (four blocks per trial) testing in each category.

Analyses (not presented here) showed that 90-lb N/ac was adequate to correct N deficiencies at essentially all sites. The tendency for yields to increase with soil nitrate category even when 90 lb N/ac was applied should be attributed primarily to effects of weather on yield potential. Many of the sites with the lowest yield potential due to unfavorable weather during the summer also had the lowest soil nitrate concentrations due to excessive rainfall and losses of N during the spring. The net result is that the category with the lowest yield potential showed the greatest response to fertilizer N. This observation supports the idea that estimates of N fertilizer needs should be based on observed yield responses to fertilizer N rather than on yield potential.

Analyses of data from all sites showed that net returns to fertilization tended to decrease with increasing concentration of nitrate in the soil (Fig. 1). Net returns to fertilization also varied with amounts of fertilizer applied as well as with normal variations in prices of fertilizer and grain. Analyses presented in Fig. 2 show that net returns to fertilization tended to vary with amounts of rainfall before the soils were sampled. The relationships in Figures 1 and 2 show the soil test values at which profits from fertilization became negligible or negative. Different rates of fertilization can be equally profitable at a given soil nitrate concentration if the value of yield increases is offset by the costs of additional fertilizer. These relationships, therefore, provide a basis for making fertilizer recommendations that tend to maximize profits for producers.

A set of recommendations based on relationships shown in Fig. 2 is presented in Table 2. These recommendations offer a compromise between the need for simplicity and the need to maximize profits. The recommendations are given in ISU Extension Pamphlet 1714 (Blackmer et al, 1997). Effects of spring rainfall are considered by selecting between the two columns.

Effects of fertilizer and grain prices are considered by selecting between the upper and lower halves of the table. Soil nitrate concentrations are considered when selecting the best N rate. Recommendations are given for only a limited number of situations, but producers can interpolate to derive recommendations for situations that differ from those given.

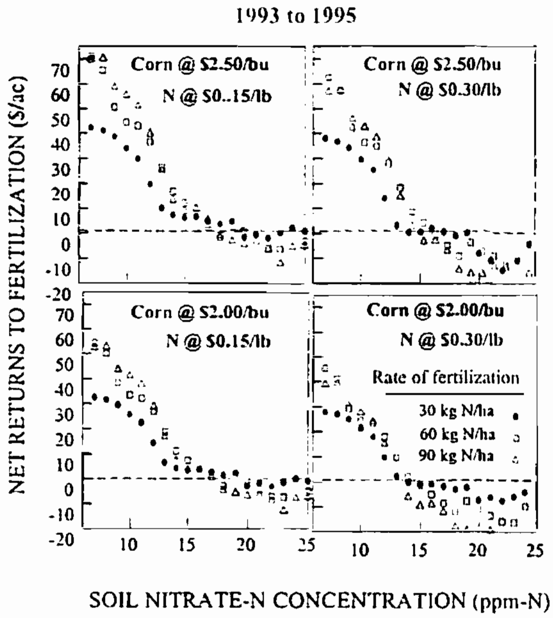

Figure 1. Relationships between mean net returns to fertilization and concentrations of nitrate in the surface foot of soil before fertilization in late spring.

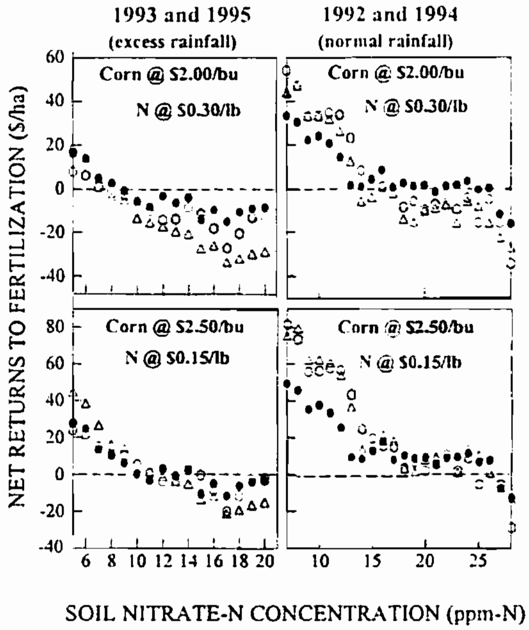

Figure 2. Relationships between mean net returns to fertilization and concentrations of soil nitrate at various antecendent moisture regimes.

Some of the potential benefits of using the recommendations in Table 2 are illustrated in Table 3, which shows that use of the recommendations resulted in higher mean profits than did fertilizing all sites with 0, 30, 60, or 90 lb N/ac. The mean rate of N fertilization for the recommendations presented in Table 2 were 25 lb N/ac for poor prices and 39 lb N/ac for good prices. These rates are substantially less than the producers normally applied because most of the cooperating producers applied more than 100 lb N/ac to the fields surrounding the response trials. Use of the soil test would have provided important economic and environmental benefits when selecting rates at which commercial fertilizers should be applied to manured cornfields.

An additional benefit of soil testing for nitrate in late spring is that it enables site-specific evaluations of manure management practices. Evaluations that reveal when too much or too little has been applied give producers feedback that can be used to adjust rates of manure application toward optimal. Evaluations that reveal which application methods result in the most or least amounts of plant-available N give feedback that can be used to select methods of application that enable the most efficient use of N in animal manure. Feedback given by the soil test, therefore, gives important economic and environmental benefits in addition to those illustrated in Table 3.

Table 2. Nitrogen fertilizer recommendations that would have maximized net returns to fertilization for 148 trials in manured cornfields tested for nitrate in late spring.

Expected prices	Soil nitrate concentrations	Recommended fertilization rate Excess† rainfall	Normal rainfall
	ppm-N	---------------lb N/ac---------------	
Unfavorable‡	0-10	90	90
(corn @ $2.00/bu	11-15	0	60
N @ $0.30/lb)	16-20	0	0§
	> 20	0	0
Favorable	0-10	90	90
(corn @ $2.50/bu	11-15	60	60
N @ $0.15/lb)	16-25	0	30
	> 25	0	0

† Rainfall should be considered excess if precipitation in May exceeded 5 inches.

‡ Under unfavorable prices 1 bushel of corn buys 7 lb. of N, under favorable prices 1 bushel of corn buys 17 lb. of N.

§ Addition of 30 lb/ac had no detectable effects on profits, but producers could reasonably elect to apply this rate.

Table 3. Mean net returns to fertilization across 148 trials in scenarios where fertilizer N was applied according to various recommendation systems.

Recommendation system	Mean net returns to added N Poor prices†	Good prices‡
	---------$/ac across 148 trials---------	
0 lb N/acre at all sites	0.0	0.0
30 lb N/acre at all sites	-2.1	4.8
60 lb N/acre at all sites	-5.3	7.2
90 lb N/acre at all sites	-12.6	4.6
From Table 2§	4.8	13.2

† Corn at $2.00/bu and N at $0.30/lb.

‡ Corn at $2.50/bu and N at $0.15/lb.

§ N rate based on recommendations presented in Table 2. The mean rate of fertilization was 25 lb N/ac for poor prices and 39 lb N/ac for favorable prices.

CONCLUSIONS

Soil testing for nitrate in late spring provides site-specific information that can be used to evaluate and improve management practices relating to the use of N in animal manure as a fertilizer for corn production. By measuring nitrate in the soil after early losses of manure-N have occurred, the soil test shows the rate of commercial fertilizer needed to compliment amounts of plant-available N in the soil. These same measurements enable identification of manure application practices that utilize manure N more efficiently and thereby reduce the need for commercially prepared N fertilizers. Key benefits of such soil testing include more profit for corn producers and less loss of N from cornfields to the environment.

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