IMPROVING THE EFFICIENCY OF CORN PRODUCTION BY FERTILIZER N MANAGEMENT WITH THE ILLINOIS SOIL N TEST

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INTRODUCTION

Traditional yield-based recommendations for N fertilization of corn are based on the assumption that fertilizers contribute twice as much plant-available N as the soil, regardless of soil type or fertilizer practices. Yet numerous ^{15}N-tracer investigations have revealed that uptake is actually much more extensive for soil than fertilizer N when corn is grown in the Midwest with typical or even excessive fertilization (e.g., Bigeriego et al., 1979; Olson, 1980; Kitur et al., 1984; Blackmer and Sanchez, 1988; Torbert et al., 1993; Jokela and Randall, 1997; Omay et al., 1998; Stevens et al., 2005). These findings are verified by the fact that unfertilized (check) plot yields in N-response studies often exceed the yield increase obtained with fertilization (Lory and Scharf, 2003), and in many such studies, sites have been detected where corn is completely nonresponsive to fertilizer N (e.g., Bundy and Malone, 1988; Blackmer et al., 1989; Fox et al., 1989; Schmitt and Randall, 1994).

There are inherent differences among soils in their capacity to supply plant-available N, which can also be markedly affected by management and cropping practices. The implication is that fertilizer practices should account for differences in soil N availability, and ideally should be implemented on a site-specific basis. This approach has only become feasible with the development of the Illinois soil N test (ISNT), which was designed to estimate potentially mineralizable N, as a means of detecting sites where corn is nonresponsive to N fertilization (Khan et al., 2001). There is an obvious potential for site-specific N management, because recent work by Ruffo (2004) has demonstrated that the ISNT is highly predictive of spatial variability in yield, and can be adequately mapped with a relatively sparse sampling grid (Ruffo et al., 2005).

Recent work by Mulvaney et al. (2006) has demonstrated not only that nonresponsive sites can be reliably detected by the ISNT, but has provided ample evidence of a relationship between test values and crop N requirement, although consideration must be given to other factors that can have a marked effect on mineralization of soil N or the efficiency of crop N utilization. Plant population was identified as being especially important because crop N demand is increased, along with the input of C from crop residues, which promotes the tie-up of plant-available N through immobilization during microbial decomposition. Higher plant populations necessarily affect soil test calibrations (Bray, 1948; Melsted and Peck, 1973), and have long been recognized as an important means of increasing yield on highly productive soils (Dungan et al., 1958).

OBJECTIVES

The work reported was designed to explore the possibility that the ISNT can be utilized to increase the efficiency of corn production by exploiting the interaction of plant population and crop N demand. The specific objectives were:

1) To evaluate the effect of plant population on fertilizer N requirement when corn is grown on soils that test high by the ISNT.

2) To compare the impact on yield and profitability of N fertilizer management with or without plant population adjustment.

MATERIALS AND METHODS

Nitrogen-response experiments were conducted during 2005 on University of Illinois cropland managed by the Department of Agricultural Engineering (site 1) or the Department of Animal Sciences (site 2). The soil series in both cases was a Drummer silty clay loam, but there was a difference in management, with site 1 under a corn-soybean rotation with no manure history, while site 2 was cropped to continuous corn with annual manuring.

A compact randomized triangular plot design (Fig. 1) was adopted, so as to allow equidistant plant spacing for optimal light interception and root growth, while minimizing spatial variability in soil N supply. With this design, 96 plots were established within approximately 0.7 A, accommodating three populations (20000, 24000, or 40000 plants/A) and eight N rates (0, 30, 60, 90, 120, 150, 180, or 210 lb/A) with four replications.

Soil sampling for the ISNT was done in mid-April, by collecting a 4-core composite (0-12 and 12-24 inches) from the central part of each plot where yield data would be collected. The samples were immediately transported to the laboratory, and were thoroughly dried in a forced-air oven maintained at 40ºC. The dried samples were crushed with a mechanical grinder to pass a 2-mm screen, and were then mixed thoroughly before duplicate analysis by the ISNT, as described in a technical note (^{15}N Analysis Service, 2004).

Prior to planting in early May, site 1 was ripped to a depth of approximately 18 inches, so as to alleviate subsoil compaction. Within a week, fertilizer N was applied as urea-NH_4NO_3 solution (28-0-0), using a pressurized sprayer system mounted on a manually propelled tricycle chassis equipped with a pressure regulator and speedometer. Immediately following application, the fertilizer was incorporated by rototilling.

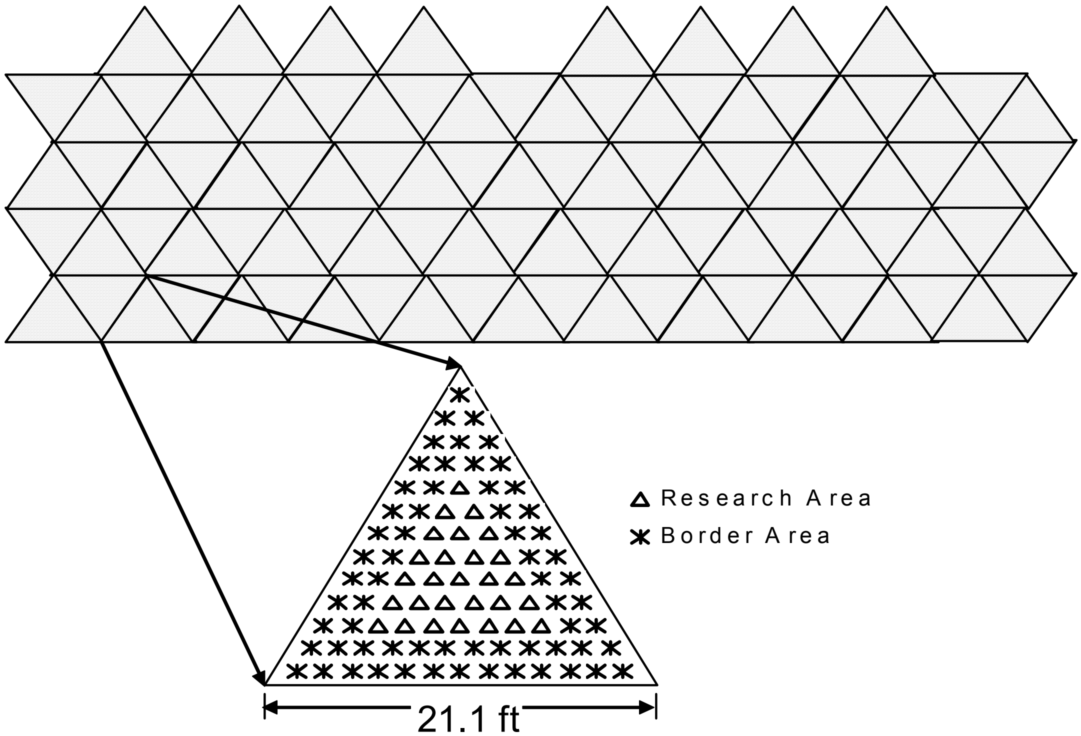

Fig. 1. Plot layout and illustration of equidistant planting scheme for the low planting rate (20,000 plants A^{-1}).

Plots were planted (Pioneer 33J24) with jab planters, after being covered by a tarpaulin that had been perforated with holes pierced at an equidistant spacing of 1.7 ft (20000 plants/A), 1.5 ft (24000 plants/A), or 1.2 ft (40000 plants/A). One replicate was subsequently sacrificed at site 1, due to reduced plant stands caused by pheasant feeding. Weed control was accomplished with a postemergent herbicide treatment, with hand hoeing as necessary. Insecticide applications were made to control root pruning and silk clipping. Owing to dry weather during the growing season, water was applied as needed by sprinkler irrigation, beginning on 7 June for site 1 and on 1 July for site 2. At physiological maturity, grain yield was determined by hand-harvesting the central 61 ft^2 (20000 plants/A), 65 ft^2 (24000 plants/A), or 60 ft^2 (40000 plants/A), and was adjusted to a constant moisture content (15.5%).

Corn response to N fertilization was based on regression analyses performed by fitting a linear, linear plateau, quadratic, or quadratic plateau model to N rate and yield data. Among these response models, the best fit was obtained by quadratic regression, which was subsequently employed for quantifying economically optimum N rate (EONR) and economically optimum yield (EOY) at N:corn price ratios of 0.1, 0.15, 0.2, and 0.25.

RESULTS AND DISCUSSION

Objective 1

Modern corn production relies on high-yielding varieties, high populations, and soils managed for high productivity. The benefit is evident from yield trends in long-term trials such as the Morrow Plots (Aref and Wander, 1998), and has also been documented more generally in the scientific literature (e.g., Cardwell, 1982; Walters et al., 2004). High plant populations create more pressure on soil nutrient supply, and thereby increase fertilizer requirements. This has often been found to hold in N-response studies with corn, whether conducted in Illinois or elsewhere (e.g., Lang et al., 1956; Duncan, 1958; Pesek et al., 1959; Colyer and Kroth, 1968; Mulvaney, 1971; Rhoads et al., 1988; Thomison et al., 1992; Alam et al., 2003; Mulvaney et al., 2006).

The present study provides further evidence that, even with highly productive soils, higher plant populations increase the yield response by corn to N fertilization. This is clearly apparent from Fig. 2 and 3, both of which show a marked increase with population in EONR estimated assuming current prices for N ($0.35/lb) and corn ($1.75/bu). Table 1 shows that the same relationship was observed across a range of N:corn price ratios.

Further examination of Fig. 2 and 3 demonstrates that the economic risk from underfertilization with N is far greater when plant populations are high, as reflected in a much steeper response curve. In contrast, response was quite limited with low populations, as would be expected for soils that test high by the ISNT.

The importance of soil N mineralization is evident from a comparison of Fig. 2 and 3, which reveals that fertilizer N response was greater under continuous corn (site 2) than in a corn-soybean rotation (site 1). This difference is consistent with the higher surface and subsoil ISNT values obtained for site 1 (Table 2), and can also be attributed to earlier irrigation. These same factors are implicated in lower check-plot yields for site 2, which were reduced substantially by increasing plant population from 24000 to 40000 plants/A (Fig. 3). With greater soil N availability at site 1, N fertilization was not economically profitable for the lowest plant population with the highest N:corn price ratio.

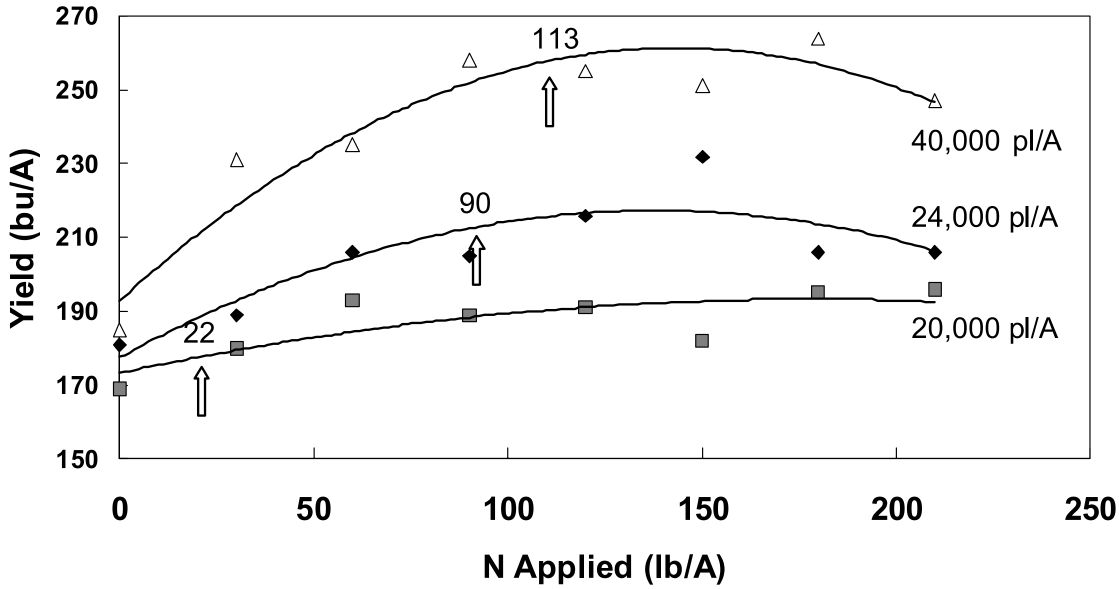

Fig. 2. Interaction of plant population and N rate for site 1 with mean ISNT values of 292-299 ppm for 0-12 inches. Optimum N rates (EONR) indicated above arrows were calculated assuming a N:corn price ratio of 0.2.

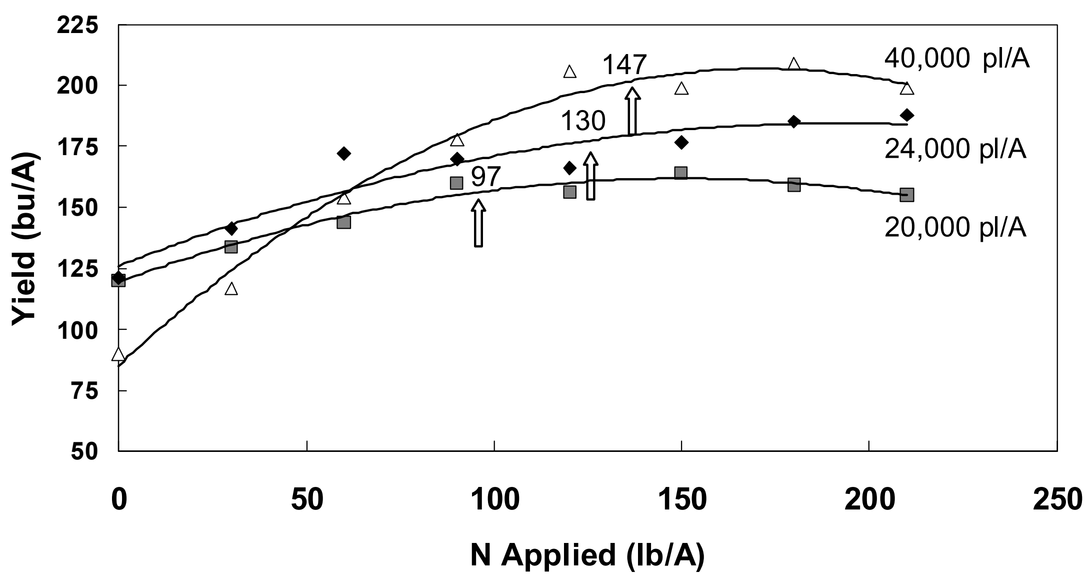

Fig. 3. Interaction of plant population and N rate for Site 2 with mean ISNT values of 249-261 ppm for 0-12 inches. Optimum N rates (EONR) indicated above arrows were calculated assuming a N:corn price ratio of 0.2.

Table 1. Economically optimum N rates (EONR) estimated for different plant populations.

Site	Population	N:corn price ratio†			
		0.10	0.15	0.20	0.25
	plants/A	EONR (lb/A)			
1	20000	100	61	22	0
	24000	114	102	80	78
	40000	128	121	113	106
2	20000	123	110	97	84
	24000	162	146	130	114
	40000	160	153	147	141

†Values reported as a mean of three (site 1) or four (site 2) replicates estimated by quadratic regression.

Table 2. Summary of ISNT data obtained for sites 1 and 2.

Site	Population	Sampling depth (inches)†			
		0-12		12-24	
		Range	Mean	Range	Mean
	plants/A	ISNT value (ppm)			
1	20000	236-360	299	86-239	190
	24000	229-339	293	138-240	197
	40000	229-342	292	148-258	198
2	20000	220-284	249	99-177	149
	24000	235-295	261	99-245	157
	40000	240-281	260	118-240	162

†Values summarized from duplicate analyses of soil samples collected from 24 (site 1) or 32 (site 2) plots.

Objective 2

On the highly productive soils studied, higher EOY values were always obtained by increasing plant population, as is documented by Table 3 across all N:corn price ratios. Of particular interest is the greater uniformity among these values at the highest plant population, regardless of fertilizer cost, which is attributable to the shape of the response

Table 3. Economically optimum yields (EOY) estimated for different plant populations.

Site	Population	N:corn price ratio†			
		0.10	0.15	0.20	0.25
	plants/A	EOY (bu/A)			
1	20000	189	185	179	169
	24000	216	214	212	210
	40000	261	260	258	257
2	20000	160	159	156	153
	24000	183	181	178	175
	40000	206	205	204	203

†Values reported as a mean of three (site 1) or four (site 2) replicates estimated by quadratic regression.

curves (Fig. 2 and 3). The highest plant populations were also the most profitable, increasing the average return by $56/A, as compared to the lowest planting rate (assuming $1.75/bu and adjusting for seed cost). The latter finding has important implications for maximizing the profitability of crop production, since plant uptake of fertilizer N will be promoted when population pressure exceeds soil N-supplying capacity.

CONCLUSIONS

Nitrogen fertilizers cannot be utilized efficiently in corn production without accounting for the soil's capacity to supply plant-available N, which has become feasible with the development of the ISNT. With high-testing soils, fertilizer N response, yield, and profitability can be increased by boosting plant populations. This strategy was highly effective in the present study for irrigated plots with equidistant plant spacing, and will be evaluated through further field trials in 2006.

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