CORN NITROGEN RESPONSE ACROSS ENVIRONMENTS AND CROP ROTATION

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Introduction

Recent research on corn has tended to show variability in N response. Brown et al. (1993) reported that economically optimal N rates among 77 sites in Illinois ranged from zero to more than 200 lb N per acre. Results from other studies show similar variability in time and space. Even with such variability, results over environments have been combined and used to develop an N fertilizer rate guideline in Illinois based on anticipated corn yield (Hoeft and Peck, 2002). This guideline suggests providing 1.2 lb of N (or a different factor based on the relative prices of corn and N) for each bushel of expected yield for corn following corn, with credits given when corn follows a legume or when manure has been applied to the field. While we know that yields, and thus actual N requirement, cannot be predicted with accuracy, the use of this guideline has proven to be satisfactory in most years and on most fields.

Data from a long-term previous crop x N rate study at Monmouth, Illinois revealed that the economically optimal N rate was 143 lb N/acre for corn following corn, with a yield at the optimal N rate of 146 bu/acre, and so an N requirement of slightly less than 1 lb N/bu (Bullock and Bullock, 1994). For corn following soybean, the optimal N rate was 99 lb N/acre and the yield at that N rate was 174 bu/acre. This is substantially less than the amount of N that would be recommended: 174 bu/acre times 1.2 minus 40 lb N credit for soybean is 169 lb N/acre.

The present study was designed to assess the response to N rate of corn following corn and corn following soybean, over a number of years and locations in Illinois, in order to find predictive relationships to help improve the correspondence between N rate and actual crop use of N.

Approach

Rotations to support this study were established in 1998, and data collection on N rate response has been ongoing since 1999. The study is being conducted at the following sites and soil types (with expected corn yield), on the six University of Illinois Crop Sciences Research and Education Centers: DeKalb – Flanagan sil (175); Monmouth – Sable sicl (180); Urbana – Drummer sicl (170); Perry – Clarksdale sil (140); Brownstown – Cisne sil (115); and Dixon Springs – Belknap sil (bottomland - 140) and Grantsburg sil (upland - 120). The study at the Dixon Springs upland site began one year later than at the other sites.

A split-plot design was used, with previous crop – corn or soybean – as main plots, and N rates – 0, 45, 90, 135, 180, and 225 lb N/acre – on corn split within main plots. Corn followed corn on the same set of plots each year, with each N rate assigned to the same subplot. Soybean was planted into the third main plot each year, in preparation for corn with N rates the following year. Subplot sizes ranged from 10 x 30 to 20 x 50 ft.

Harvest for yield was done on the center two rows of each subplot. Yield data were analyzed using nonlinear regression (PROC NLIN) with the quadratic model. Where the Q-P model did not fit the data well – when yields declined at the higher N rates and/or when the model did not meet convergence criteria – the data were fit to a quadratic model. Economically optimal N rates were calculated from the quadratic function in each case using a cost:price ratio ($ per lb of N:$ per bushel of corn) of 0.10.

Results and Discussion

Of 54 N response curves (27 environments with two rotations – corn and soybean as previous crop – in each environment) generated from 1999 through 2002, the quadratic-plateau (Q-P) model fit the data in 46 cases, and the quadratic model fit the data in five cases, three of which were at the Perry location. There was no significant response to N rate in three cases, all at the Brownstown location under low yields.

As expected, there was a considerable amount of variation in the shape of the response curves over the four years and two rotations at each location. At Urbana (Figure 1) the optimum N rate for corn following corn (CC) ranged from 130 to 225 lb N/acre, and for corn following soybean (SC) the optimum N rate ranged from 107 to 192 lb N/acre (Table 1). In two of the four years, the optimum N rate was higher for SC than for CC, and in 2000, the optimum yield of SC was 63 bushels per acre – more than 50 percent – higher than the optimum yield of CC.

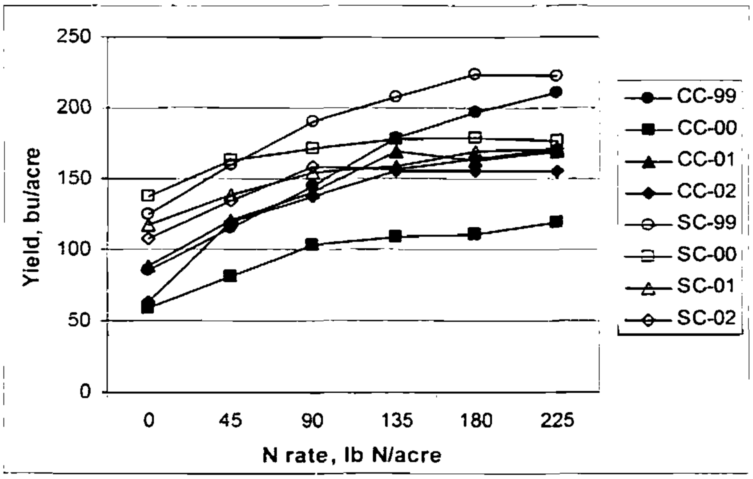

Figure 1. N response by year and rotation at Urbana, Illinois. CC = continuous corn and SC = corn following soybean.

While it is instructive to look at N responses over years, N rate recommendations are best made by averaging data across environments (years and locations), then analyzing the N response defined by these means (Bullock and Bullock, 1994). The average of the N rate optima was less than the optimum based on averages, by 17 lb/ac for CC and by 7 lb/ac for SC (Table 1).

Table 1. Economically optimal N rates, and yields at optimum N rates, for the two crop rotations over four years at Urbana, Illinois.

	Corn-Corn		Soybean-Corn	
Year	**Opt. N rate**	**Opt. yield**	**Opt. N rate**	**Opt. yield**
	Lb N/ac	bu/ac	lb N/ac	bu/ac
1999	225	213	192	222
2000	158	113	107	176
2001	168	167	176	168
2002	130	154	147	165
Average	170	162	156	183
Based on avg. data	187	161	163	183

The response to N rate for the two rotations at Urbana averaged over the four years (Figure 2) fit the Q-P model well. This was generally the case at the other locations as well (Figures 3 and 4) with the possible exception of Perry, where there was a tendency in some years for yields to decrease under high N rates in the CC rotation. This location is of average soil productivity, and it is not clear why yields tended to decrease at high N rates.

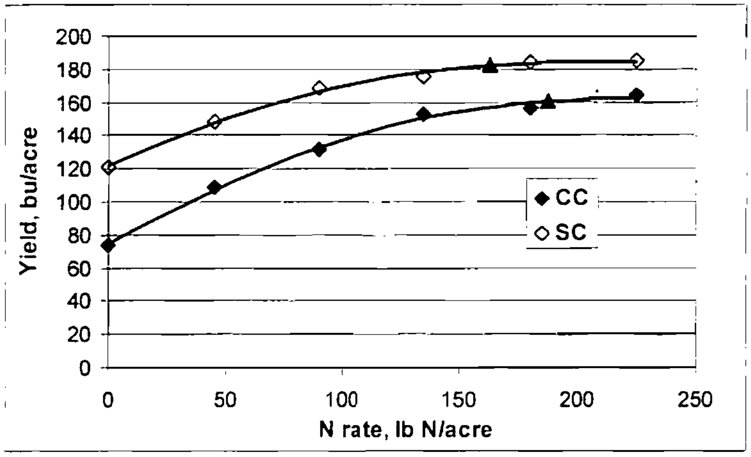

Figure 2. N response for corn following corn and corn following soybean, averaged over four years (1999-2002) at Urbana, Illinois. Triangles (▲) indicate economically optimal N rates and yields at those rates.

One of the questions we are also attempting to answer from this study is whether or not locations (soils and climate) should be grouped to examine overall N response, or whether sites should be examined separately. Table 2 gives the optimum N rates and yields at those rates for each location, based on data averaged over all years at each site. At most locations, yields over these four years agreed reasonably well with expected yields based on soil type and climate. Yields were relatively high and stable at the three Northern Illinois locations, and at optimal N rates, corn following soybean yielded about 21 bu (13 percent) more than corn following corn. At Perry, corn following corn yielded about 4 percent more than corn following soybean; this may have been due to random field effects, with corn following corn (which remains in the same plots) originally assigned to more favorable portions of the field. In Southern Illinois, yields were more variable over years. and confidence in observed optima is not as high (Figures 3 and 4).

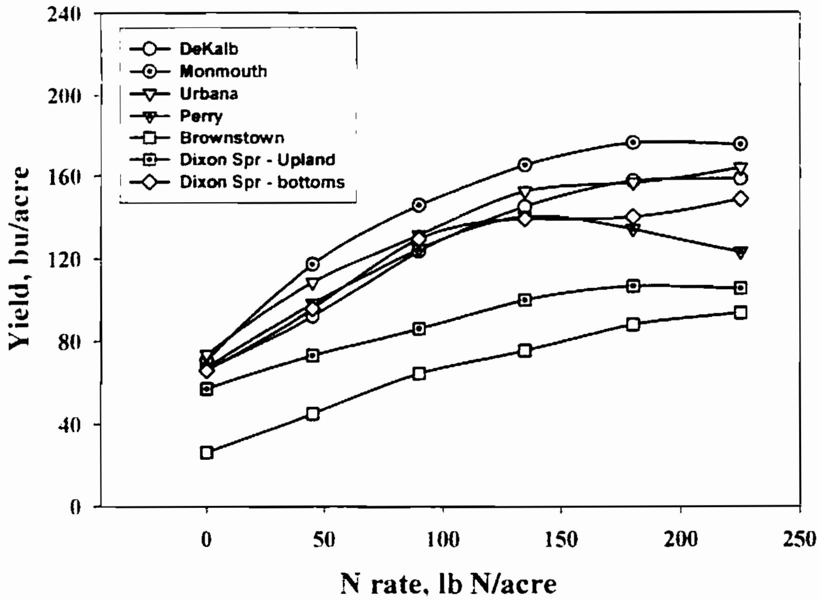

Figure 3. N response by location for corn following corn. Data are averaged over four years (1999-2002) at each location.

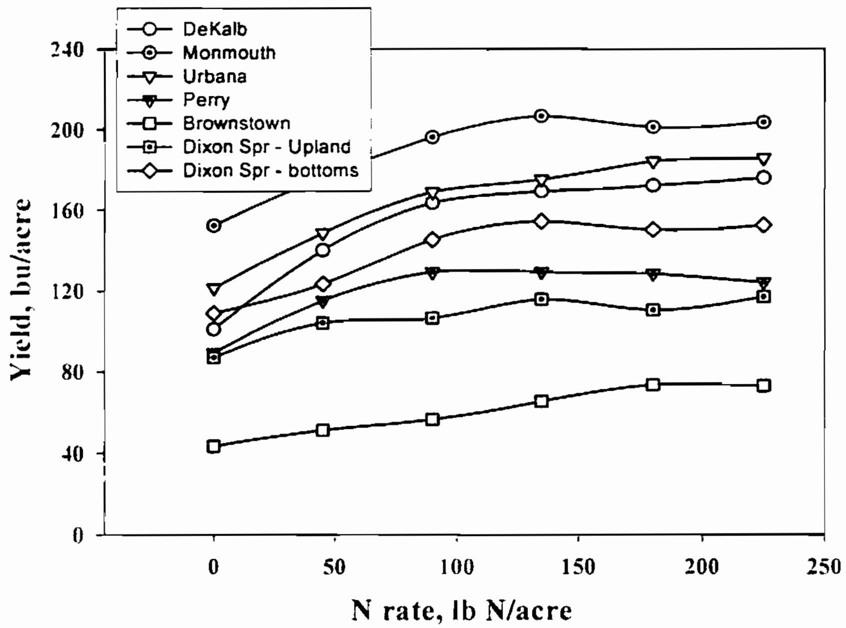

Figure 4. N response by location for corn following soybean. Data are averaged over four years (1999-2002) at each location.

Table 2. Optimum N rates and yields at optimum N rates. Optima are calculated using data averaged over four years (1999-2002.)

		Optimal		
Location	Rotation	N rate	Yield	lb N/bu*
		lb N/ac	bu/ac	
Dixon Springs-bottomland	Corn-corn	156	144	1.1
	Soy-corn	135	151	1.2
Dixon Springs-upland	Corn-corn	177	105	1.7
	Soy-corn	107	112	1.3
Brownstown	Corn-corn	225	94	2.4
	Soy-corn	193	72	3.2
Perry	Corn-corn	127	132	1.0
	Soy-corn	88	127	1.0
Urbana	Corn-corn	187	161	1.2
	Soy-corn	163	183	1.1
Monmouth	Corn-corn	173	174	1.0
	Soy-corn	127	202	0.8
DeKalb	Corn-corn	206	159	1.3
	Soy-corn	126	172	1.0
Average over 27 sites	Corn-corn	174	137	1.3
	Soy-corn	131	145	1.2

*40 lb "soybean N credit" added to calculate this ratio for corn following soybean.

While there are differences in N response among locations, the similarity in the general shape of the N response among locations (Figures 3 and 4) does not clearly suggest location-specific modifications in the way N is recommended. At Brownstown, even though yields were low and unresponsive to N two of four years, corn required relatively high N rates to produce relatively low yields. On the other hand, the highest average yield – corn following soybean at Monmouth – required relatively less N to produce these yields. The resulting weak but negative correlation between optimum N rate and optimum yield (Figure 5), might suggest that the N rate recommendation factor does not remain constant with yield level.

Based on the response to N rate based on all of the data (Figure 6), the optimum N rate for corn following corn was 174 lb N/acre, which produced a yield of 137 bu/acre; the N rate to yield ratio was 1.27 lb N/bu. For corn following soybean, 131 lb N produced 145 bu/acre; when the 40-lb N credit is added to this N rate, the ratio is calculated as 1.18. While individual years and sites show considerable divergence from the average, our results tend to confirm that using 1.2 lb. N per bushel of expected yield, with appropriate adjustments, is a reasonable N use guideline. At the same time, expecting this guideline to result in exactly meeting the N requirement of the crop in a particular field in a given year is clearly not realistic; when we look back on the data from any one site-year, the optimal N rates were almost always "too high" or "too low" based on measured N response. Thus while the yield-goal-based guideline is thus not a good *ex post* descriptor of N need, it is the best predictor that our applied research has been able to generate.

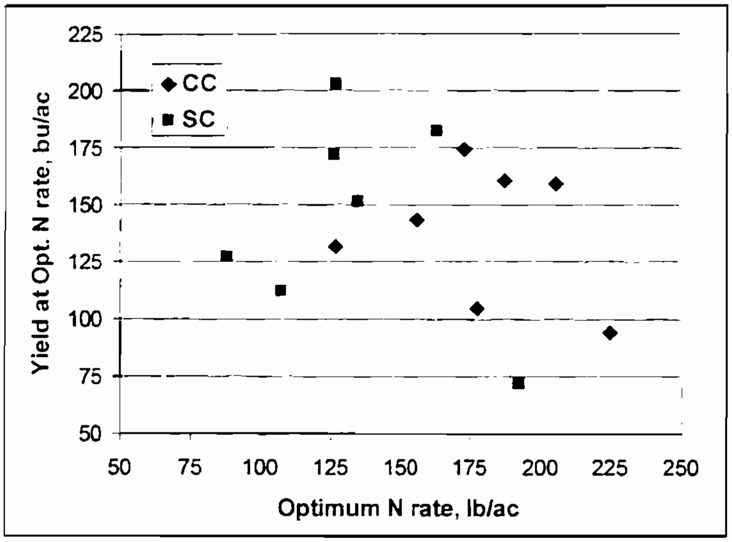

Figure 5. N rate and yield optima for each of the 7 locations. based on N response data averaged over four years.

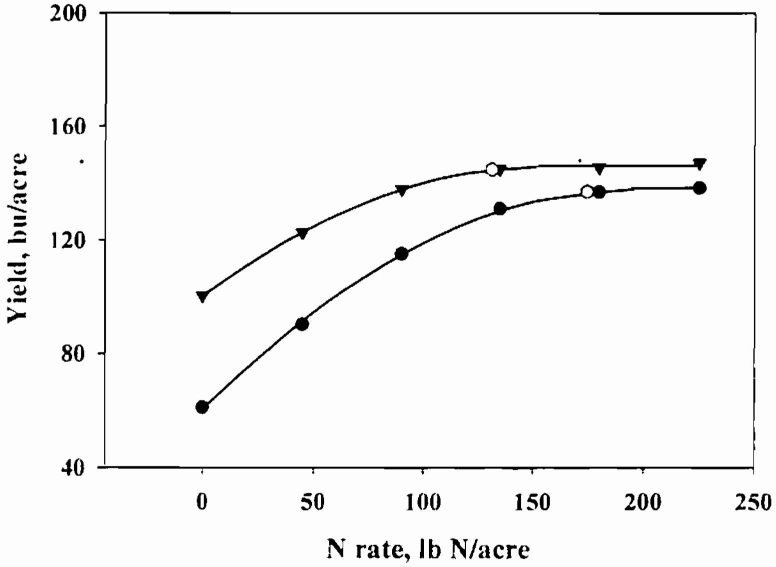

Figure 6. N response curves for corn following corn (•) and corn following soybean (▼) over 27 Illinois environments, 1999-2002. Hexagons indicate optima.

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