FORMULATING N RECOMMENDATIONS FOR CORN IN THE CORN BELT USING RECENT DATA[1]

Emerson D. Nafziger, John E. Sawyer, and Robert G. Hoeft[2]
University of Illinois, Urbana, IL and Iowa State University, Ames, IA

Introduction

Making N rate recommendations for corn has been one of the most economically important goals of publicly funded crop production and soil fertility personnel and programs over the past five decades. Changes in cropping systems, hybrids, tillage, and other management practices, along with opportunities in site-specific inputs and awareness of the need to minimize the amount of N that reaches surface and ground waters have combined to increase the interest to re-examine N rate recommendations, and to formulate new recommendations if current data support such changes.

The common N rate recommendation system used for many years in the Midwest USA was a yield-goal base factor for continuous corn, with adjustment for previous crops other than corn. However, research has identified poor correlation between individual site-year corn yield and economic optimal N, and that optimal N rates on a specific soil do not change with yield (Vanotti and Bundy, 1994b). At issue also is the concern of too high or low calculated N recommendations when yields are much higher or lower than average. From this, some recommendations have shifted to approaches that don't use yield goal but instead utilize soil-specific N recommendations based on soil productivity classification (Vanotti and Bundy, 1994a) or set ranges for specific rotations (Blackmer et al., 1997). This shift and diversity in recommendation approaches across the Midwest USA has raised questions about the reliability of the approaches currently in use and the appropriateness of N rate recommendations derived from them.

The intent of the work reported here is to analyze recent databases where optimal corn N rate was determined for many site-years, and to use results from that analysis to see whether or not recent research supports the development of an alternative N rate recommendation approach for use in Corn Belt states.

Database

To address empirically the reformulation of N recommendations requires the use of a large amount of N response data collected from the US Corn Belt. Here, we are concentrating on data generated over the past 10 years in Illinois and Iowa, with the exception of one long-term study. The datasets consist of the following:

- Data from small-plot experiments conducted at four sites in productive soils of Central and Northern Illinois, with yields under N rates ranging from 0 to 225 lb N/acre

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[2] Professor of Crop Sciences, University of Illinois, Urbana, IL, Associate Professor of Agronomy, Iowa State University, Ames, IA, and Professor of Crop Sciences, University of Illinois, Urbana, IL.

following both corn and soybean. Data included here were collected from 1999 through 2003, hence comprise 20 site-years of data from each rotation.

- Data from on-farm, field-scale, replicated, N rate studies conducted by Illinois producers from 2000 to 2003, with financial support from the Illinois Department of Agriculture. Most of these trials were located in Northern and Central Illinois, and included N rates ranging from 0 to 200 lb N/acre, in addition to N amounts ranging from 0 to 50 lb/acre used by producers as starter, DAP, etc. Data from 44 trials, 39 corn following soybean and 5 corn following corn, are included here.
- Data from a small-plot, long-term study at Monmouth, Illinois, where N rates ranging from 0 to 240 lb N/ac have been used on corn following corn and corn following soybean since 1983. Hybrids have been updated periodically in this study.
- Data from small-plot experiments conducted from 2001-2003 at 43 on-farm sites across Iowa with corn following soybean and N rates from 0 to 200 lb N/acre.
- Data from small-plot experiments conducted from 2000-2003 at 14 on-farm sites in Northeast and East Central Iowa with corn following soybean and N rates from 0 to 150 lb N/acre. Also, data from 2002-2003 at 12 on-farm, field-scale, non-replicated, N rate sites in Northeast and East Central Iowa with corn following soybean and N rates from 0 to 150 lb N/acre. These experiments were coordinated through the Maquoketa Watershed Project.
- Data from small-plot experiments conducted in 1999-2003 at 6 sites representative of major soil areas of Iowa. Nitrogen rates from 0 to 240 lb N/acre were applied to corn following soybean and corn following corn. Data comprise 21 site-years for each previous crop. The number of years for each rotation at sites is different as the starting year was not the same for all sites.

Results

In this discussion, we will use subsets of the total N response database in order to illustrate possible approaches to using N responses to formulate recommendations. While we believe that combining all data and sorting for various characteristics such as soil productivity might allow us to fine-tune recommendations in some cases, we think that taking a set of defined approaches to these data will help to improve both the accuracy and the understanding of the N recommendations that result. In other words, we do not look at our data here as providing "solid" recommendations for N rates on corn in Iowa and Illinois, though they may not be far off. We will need to assemble all applicable data before we can formulate recommendations.

The traditional approach to using data to make N recommendations is to run a series of N rate experiments over relevant locations and years, and to produce single curves representing the average of the data across site-years (Fig. 1). In most instances, the quadratic + plateau (QP) function can be fit to such data quite well. Data from some individual site-years may be better fit by linear or quadratic functions, and it is not unusual to get no significant response to N, especially with manure history or preceding legume crop. But averaged across numerous site-years, especially if the highest N rate exceeds 200 lb/acre, the QP often fits the data quite well. Once the QP function is calculated, the coefficients of the quadratic portion of the curve can be used to calculate an economically optimal N rate (EONR) value, which is found where the input:output price ratio equals the slope of the quadratic curve. We are using the N cost ($/lb):corn price ($/bu) ratio of 0.1 throughout this paper. In Fig. 1, the EONR is 170 for corn following corn (CC) and 123 for corn following soybean (SC), and yields at the EONR (optimum yield, OY) are 156 and 175, respectively, for CC and SC.

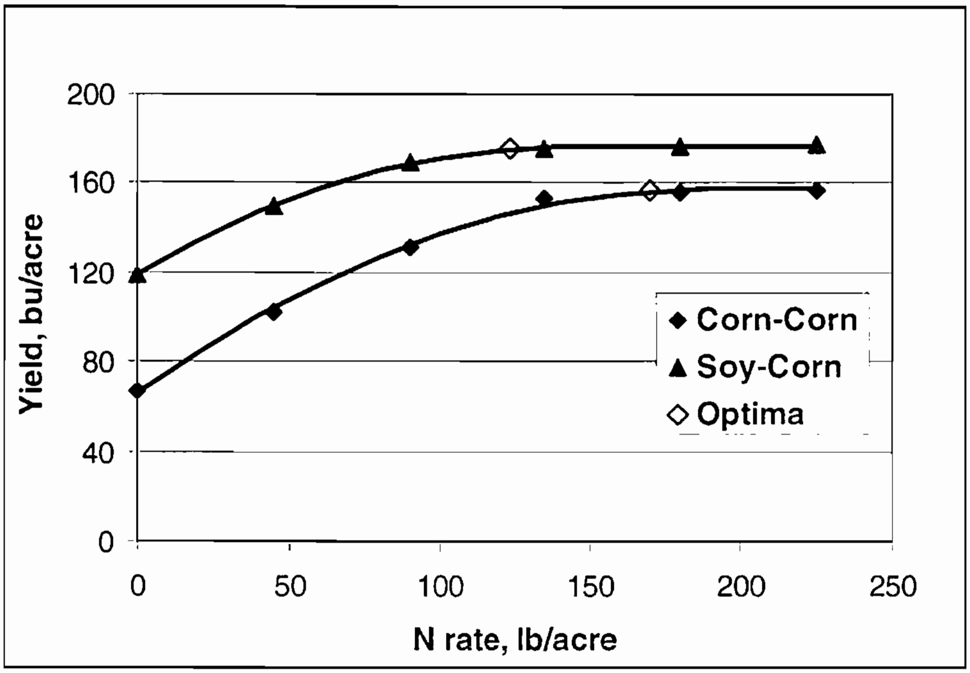

Figure 1. Nitrogen rate response of corn following corn and corn following soybean. Each line represents the average of data from 20 site-years in Northern and Central Illinois, 1999-2003. The optima are calculated based on the N price:corn price ratio ($/lb:$/bu) of 0.1.

This approach to making N rate recommendations has the advantage of being straightforward and intuitive, and it is accurate if we expect future N rate responses to approximate those measured in the research trials used to formulate the response. It also allows us to apply economics quite easily, and hence to suggest how N rates should be changed when the price ratio between the input (N) and the output (corn) changes. While it's not as intuitive, the yield-goal based N recommendation that is in use in many states is derived from such data. Dividing the EONR by the OY shown in Fig. 1 gives a ratio of 1.08 lb N per bushel for CC, close to the 1.1 to 1.2 recommended in Illinois. While we recognize that many of the individual N response curves used to produce this average curve would not have provide such a ratio, using the average in this way is the only way available at present to approximate N needs when anticipated yield and N responses are unknown. In this case, the ratio of EONR to OY for SC, even after adding 40 lb N to the EONR as the soybean credit, is only 0.93, somewhat less than the suggested ratio used to predict N needs.

There are also several disadvantages to the average-response curve approach to N recommendations. First, such a curve tends to imply that the response occurs under "average" conditions, so those who anticipate higher or lower yields most years may see it as inapplicable to their fields. As implied above, basing an N recommendation on the same yield goal for CC and SC is problematic, since the yields of SC usually exceed the yields of CC; which YG should one use? Most important, a single response curve tells us nothing about how variable such responses are over years and fields, and hence cannot provide a sense of economic penalties when N responses in individual fields or years do not conform to the average. This approach begs the question, "If I apply the EONR in given a field in a given year, what are the chances that I really need more or less N than that, and what are the economic costs when that happens?" We believe that we now have enough data to start addressing these questions.

Some of the fundamental questions related to N response are how variable it is over locations and seasons, and whether or not N requirement is related to yield, such that yield or a proxy for yield could be used to better predict N needs. Also, what yield goal or other measure might be appropriate for use in determining corn N need: short-term, long-term, CC, SC, or a measure of relative soil productive capability? For corn following corn, there may be some correlation between yield and the N rate needed to reach that yield (Fig. 2). Still, that correlation is rather weak, and it is clear that a lot of factors besides yield influence the fertilizer N required by the corn crop. It is not clear that the YG-based N recommendation works well for corn, given the large range in EONR:OY ratios among locations (Fig. 2). As indicated by the slope of the regression, the ratio of 1.1 to 1.2 lb N/bu may be higher than we can support with recent data.

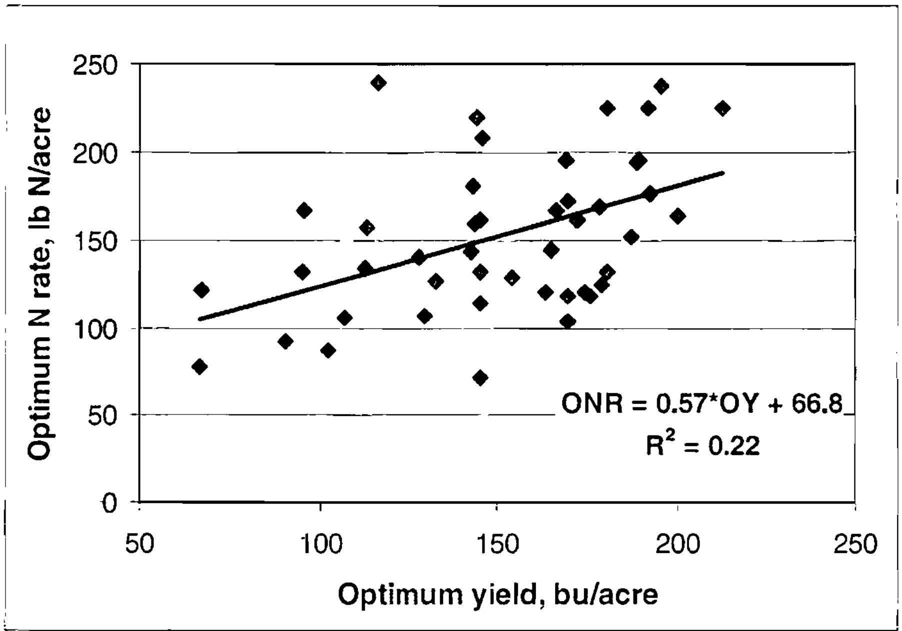

Figure 2. Optimum yields at EONR (OY) and EONR values for corn following corn at 46 site-years in Illinois.

Though we plan to use recent data to examine N recommendation systems for corn following corn, we are in this paper going to focus more on N responses for corn following soybean. We have more data on this cropping sequence, and we have found that the relationship between EONR and OY in this cropping sequence to be weak to non-existent (Fig. 3), suggesting that the accuracy of YG-based N recommendations is called into question more directly. Furthermore, it is our experience, that much of the excessive application of N to corn occurs where corn follows soybean, due to factors that include failure to credit legume N, the use of unrealistically high yield goals, and, as we shall see, the fact that high yields of corn following soybean often require only modest rates of fertilizer N.

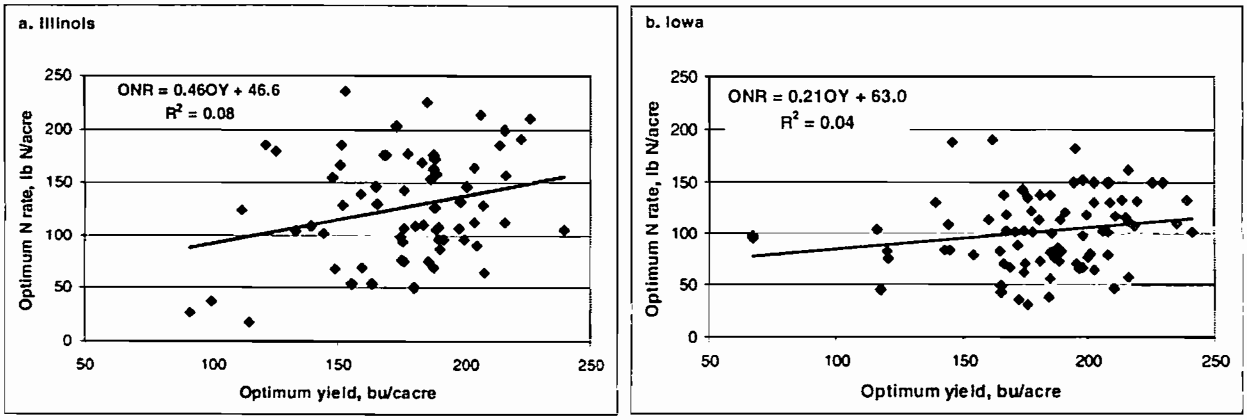

Figure 3. Optimum yields and EONR values for corn following soybean over 72 site-years in Illinois (a) and 81 site-years in Iowa (b).

The distribution of the data in Fig. 3 suggests that, until and unless we are able to develop a useful set of predictors of N response within fields or parts of fields, we might be able to look at site-year EONR values as a population, make statistical statements about expected values, and use such statements as a basis for N recommendations. When we categorize the EONR values shown in Fig. 3, they seem to distribute more or less normally (Fig. 4.)

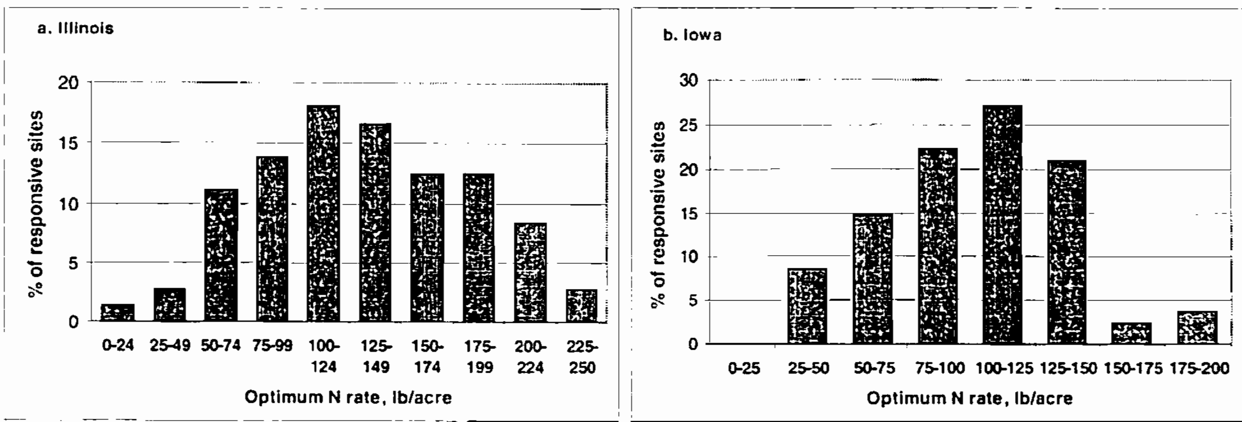

Figure 4. Distribution of EONR values for corn following soybean at 72 site-years in Illinois (a) and 81 site-years in Iowa (b).

One way to use such distributed data is to formulate a plot of predicted sufficiency for given N rates (Fig. 5). This approach has great intuitive appeal in that it allows producers to set N rates in accordance with their risk management philosophy. It does show, however, a considerable difference between the Iowa and Illinois data, with higher optima required to meet a given probability of sufficiency in Illinois. There are data yet to be added to the databases for both states, and that could change these distributions, but it is possible that differing regional soil and climate conditions will lead to different distributions, and hence different "recommended" rates, for these two (and other) states.

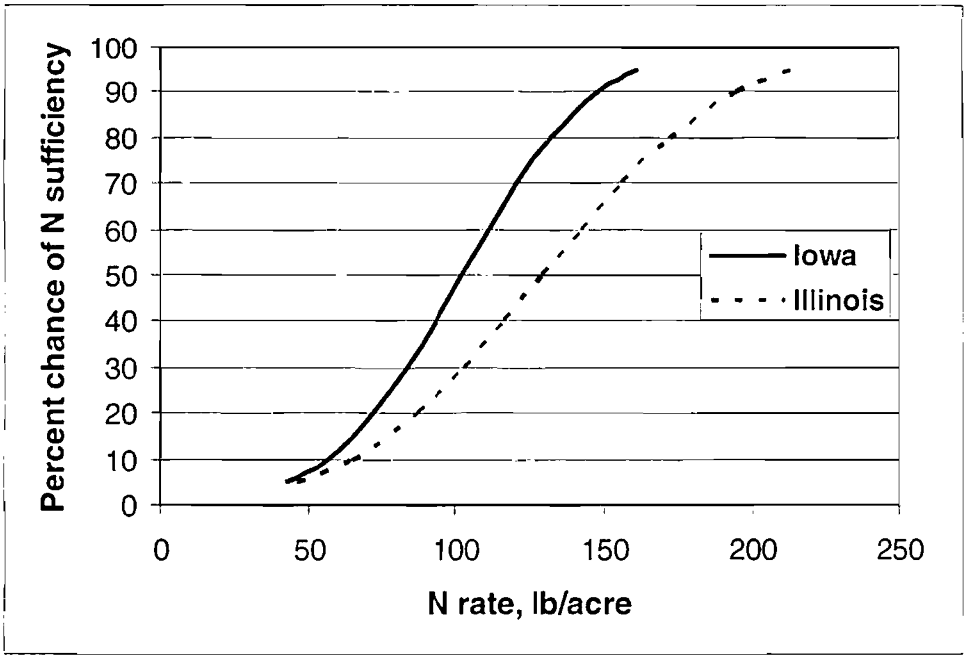

Figure 5. The N rate optima for responsive site-years for corn following soybean, fitted to normal curves. The Iowa data consist of 81 site-years and the Illinois data comprise 72 site-years.

While the approach illustrated in Fig. 5 is conceptually useful, it does not address the question of how much financial benefit or penalty accrues to the use of N rates that turn out (as most are likely to do) not to be "optimal" for the conditions in the season in which a chosen rate is applied. One approach to answering that question is to plot return to N (additional yield times corn price minus N cost) for each site-year, and to average these returns over all response curves. Fig. 6 provides such plots for both the Illinois and Iowa data. The highest return to N was $82.10 at 140 lb of N per acre in Illinois, and $62.25 at 113 lb N per acre in Iowa. Returns were relatively insensitive to N rate in the vicinity of the maximum return, which supports the possible use of a recommendation range for N rate. The rates over which the return was within $1.00 per acre (an arbitrarily chosen amount) of the maximum ranged from 95 to 132 lb N/acre in Iowa and from 120 to 162 lb N/acre in Illinois (Fig. 6).

Conclusions

We believe that data accumulated from a variety of research trials over the past 15 years in Corn Belt states can be used constructively to formulate more effective N rate recommendations for corn. Regardless of whether or not recommendations change, we believe that using some of the approaches outlined here will allow producers and their advisers to employ risk management to N rate decisions, better enabling them to adjust rates for both environmental protection and economic returns. While definitive results from using these approaches will require more data than we have at present, and will need to be tested for regional differences based on soil productivity and climate effects, we consider that the approach that combines a large number of N response curves to generate economic return to N at different rates (Fig. 6) to be the one that best incorporates N response data into useful guidelines for setting N rates.

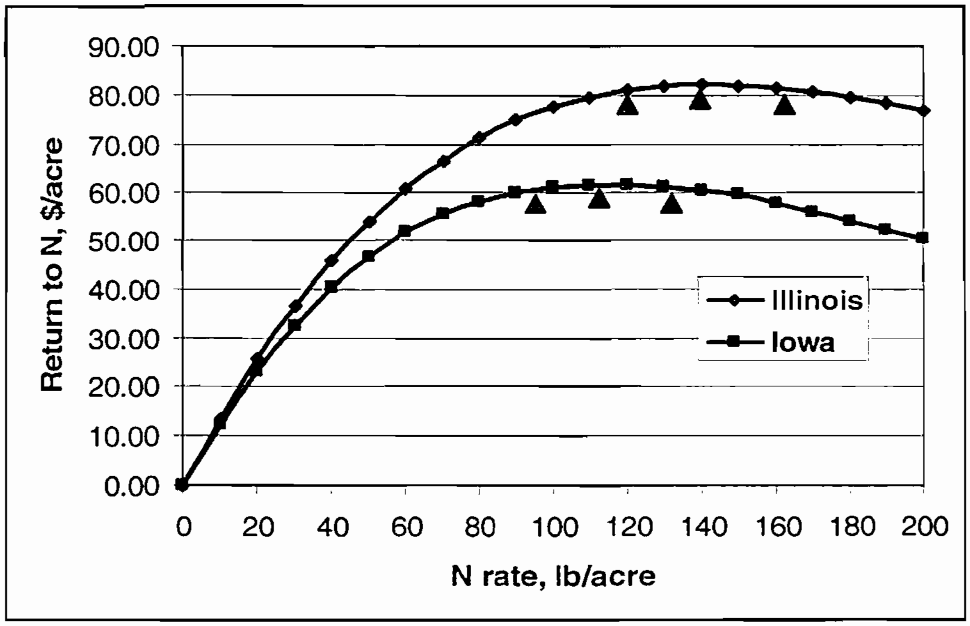

Figure 6. Return to N at different N rates based on averages from 81 Iowa and 72 Illinois site-years for corn following soybean. Symbols (▲) indicate the midpoints (highest return to N) and ends of the range within which the return to N is within $1.00 per acre of the highest return.

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Program Chair:
Bob Hoeft
University of Illinois
Urbana, IL 61801
(217) 333-9480

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