Fertilizing crops in the new price age – nitrogen

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Introduction

Fertilizers have been at unbelievably high prices, with tight supplies for some fertilizers. Total crop production costs are causing credit supply issues, which complicates decisions to allocate available funds for production expenses. Crop prices are changing rapidly, as are fertilizer prices. High corn and soybean prices certain help pay for expensive fertilizer and provide even greater net return to fertilization. However, the recent reduction in crop prices makes payoff of fertilizer and other production costs more problematic, and uncertain prices makes planning for next year difficult. On top of these monetary issues, mother nature has given us wet conditions in 2008 causing many issues related to nitrogen (N) management, timeliness of field operations, and quite variable crop yields. These issues combined are causing producers to consider changing production practices, including cutting back on fertilizer use. There is no simple answer, and sometimes no change is the correct approach.

Nitrogen rate decisions

Nitrogen applications should be tailored for the crop rotation. As we've know for a long time, corn following different previous crops requires adjustment in N application rates. Figure 1 shows this for a recent four-year period of corn yield response to N rates in a long-term rotation study conducted at the Northeast Research Farm at Nashua, IA. First-year corn following well established alfalfa often needs no N fertilization, and when required only 30-40 lb N/acre. Corn following soybean or second-year corn after alfalfa has similar N application requirement, and less than corn following corn. Corn, either continuous, second-year, or third-year has similar response to N rate and the highest fertilization rate need.

Unfortunately, corn almost always needs N fertilization (other than corn following well established alfalfa), and yield increase with N application is quite good (Figures 1 and 2). Therefore, there are not many opportunities to eliminate application when N prices are extraordinarily high or in short supply. Nitrogen can be supplied from manure, but that is also a valuable commodity and the amount of manure produced in Iowa cannot meet the needs of all corn production. If N fertilizer is in short supply or purchases have to be limited, it is better to apply some N to all fields than to skip fields (other than corn after alfalfa) as the largest yield gains come from the first increments of applied N (Figure 2).

Application rates can be adjusted downward when N fertilizer costs are high relative to corn prices. However, closely observe both N and corn prices before deciding on reducing N applications. Despite the high N prices, corn prices in 2008 were also high and therefore the ratio between the two had not changed dramatically. For 2009, that relationship could be different if corn prices continue lower and N prices remain high. The *Corn Nitrogen Rate Calculator* (http://extension.agron.iastate.edu/soilfertility/nrate.aspx) was updated this summer with Iowa data from N rate trials conducted in 2007. Based on that dataset, the suggested N rates and rate ranges for four N:corn price ratios are listed in Table 1 and shown in Figure 3. The advantage of the calculator is that specific N and corn prices can be compared. For example, with N at $0.43/lb N (anhydrous ammonia at $705/ton) and corn at $4.78/bu, the ratio is 0.09 and the Maximum Return to N (MRTN) rate is 133 lb N/acre for corn following soybean (range 120-146 lb N/acre); with N at 0.73/lb N (ammonia at $1200/ton) and corn at $3.50/bu, the ratio is 0.21 and the MRTN rate is 98 lb N/acre (range 88-110 lb N/acre).

The output from the calculator gives suggested N rate ranges that provide similar profitable return. With high N costs and perhaps the need to allocate limited funds for N fertilizer purchase, one can consider using rates in the lower part of the suggested ranges. Those rates should provide similar yields, but risk of N supply shortage to the crop is greater if N losses occur or if corn is more N responsive than typically found. The rates suggested from the *Corn Nitrogen Rate Calculator* are the same whether N is applied in late fall, spring, or sidedress; therefore, do not decrease the rate for sidedress application timing. Fall and early spring application carries more risk of loss, however, that risk cannot be predicted and it is not appropriate to guess and just increase the rate in an attempt to cover potential losses. When N is expensive, applications above the MRTN rate result in large economic losses. This can be seen in graphs produced from the Corn Nitrogen Rate Calculator (Figure 3). Therefore, high rates are not an economical approach to ensure high yield.

Grow more corn after soybean

If possible, grow more corn after soybean than after corn. Yields will typically be higher with the rotation and N application need lower (Figures 1 and 2). Compared to continuous corn, corn in rotation with soybean has lower N requirement, ranging from 45 to 60 lb N/acre less (Figure 2). And, the average corn yield is 14% lower for continuous corn compared to corn following soybean (Figure 2). For three of the sites in the N rate by rotation study included in Figure 2 that have been harvested as of the writing of this report, continuous corn yields range from 20 to 30% lower. Yield in continuous corn is not always lower than rotated corn, but the frequency of that occurrence is low. Out of the 46 site-years of data from 2000-2007 included in Figure 2, five times continuous corn has had higher yield than corn following soybean (2 to 12 bu/acre range), and only two times has yield for continuous corn been only 0 to 5 bu/acre less than yield of corn following soybean. This means that 39 times (85% of the time) corn rotated after soybean has had more than 5 bu/acre higher yield than continuous corn (5 to 76 bu/acre range, average of 29 bu/acre). In addition, the standard deviation in yield across years and sites is lower for corn grown after soybean than continuous corn (42 bu/acre for rotated corn and 51 bu/acre for continuous corn), indicating less production variation with rotated corn.

Dealing with uncertainty

Decisions as to what N rate to apply in a specific corn production year are influenced by many factors. Important ones, such as rotation and N/crop prices, are discussed above. Other decisions attempt to deal with known, but unpredictable factors influenced by weather such as soil N processing (net mineralization), nitrate losses (denitrification and leaching), and crop N demand. Management of potential losses typically focuses on time of application to minimize nitrate buildup in soil during the springtime and early summer when the potential for loss is greatest. Even application timing and practices used to reduce rate of nitrate formation (such as inhibitors) have limited length of effectiveness which eventually results in nitrate buildup that is then subject to losses (such as an inhibitor loses ability to slow nitrification, wet soils occur mid- to late in the growing season, etc.). In addition, nitrate formed by soil mineralization cannot be controlled, hence the N loss from soil derived nitrate cannot be controlled either. This means that in wet years, corn N response (i.e. the N rate to optimize yield response) will be greater even if loss of applied fertilizer N is perfectly controlled. In addition, soil temperature and moisture directly influence soil N mineralization, which therefore increases/decreases in warmer-wetter years and drier-cooler years. These soil processing factors drive much of the variation in optimal N rates found between years. Additional variation occurs due to loss of applied N.

An example of the yearly variation in optimal N rate and corn yield is shown in Figure 4 for a site at Ames on a Clarion loam soil. That variation is typical. There are many other examples. For instance, small plot N rate trials (in an area of approximately 0.4 acre) conducted in exactly the same location in two producer fields in 2001 and 2003 (corn rotated with soybean, soybean in 2002) resulted in differences in economic optimum N rates between years of 33 and 44 lb N/acre at the respective sites.

Yearly variation in N response and yield is really quite normal, with influences as discussed above. The question that arises is how much does this variation "cost" in terms of yield or economic loss if something other than the optimal rate is applied each year, or even more pertinent, what does this type of variation mean when using MRTN rate recommendations as produced by the *Corn Nitrogen Rate Calculator*? To answer these questions, the N response trial database used in the calculator was queried to determine the economic net return increase potential from use of each site-year economic optimum N rate (0.10 price ratio) compared with using the MRTN rate across all sites. For corn following soybean the average increase was $12/acre and for continuous corn was $19/acre, neither an exceptionally large amount. Those values include both unneeded fertilizer cost with over-applications and yield loss cost with under-applications. The influence of the MRTN rate on percent of maximum yield across economic optimum N rates is shown in Figure 5 for trial sites with corn following soybean. Clearly the MRTN rate is protective of yield, with yield decline of any substance only for a very few trial sites (14 out of 165 sites) with very high economic optimum rates (for example, sites with additional response due to N losses). Response trial datasets, like in the Corn Nitrogen Rate Calculator, are used to help "predict" (recommend) N application need for an unknown future. That approach does provide a reasonable level of confidence for achieving a corn crop's yield potential, within bounds of maximizing but not perfecting economic return to N.

In addition, N rate guidelines cannot be set at a rate to meet the response of all sites. That approach may protect yield for all fields, but is uneconomical and costly to attempt for the majority. That can be seen by looking at economic return results in Figures 3 and 6. Nitrogen rate recommendations are a balancing act between over- and under-application potential. Analysis of large N rate response trial datasets help to not only determine best economic application rates, but also give insight into potential economic consequences for use of suggested rates. Figure 6 shows that the minimization of under- and over-application occurs at the MRTN rate (and within the range of profitable rates). The MRTN rate is not perfect as the point where the two return lines cross is slightly below zero net return ($12/acre). However, that point is not very far below zero (perfection), and thus indicates the "field-to-field" potential return improvement to N rate selection is quite small. Figures 3 and 6 also show that economic risk is much greater for under-application than over-application. At higher N prices relative to corn prices those risks become more similar (Figure 3).

Why does a fairly wide range in site-year economic optimum N rate result in such small differences in yield and economic net return to N application when a constant (recommended) N rate is used at all sites? The main reason is that the yield response curve for individual sites most often has a shape like that in Figure 2, that is, the yield change is very small at rates just below and above the economic optimum and that economic optimum rates are near the maximum corn yield response (near the "flat" part of response curves). This means that N rates can vary around the economic rate but the yield does not change much. Yield has a large impact on net economic return, therefore, net return tends to be stable. This result is why the profitable range of N rates provided by the *Corn Nitrogen Rate Calculator* (Table 1) is within $1.00 of the MRTN rate and that those N rate ranges are fairly wide. As N costs do get more expensive relative to corn price (larger price ratios), the net return curve is more "peaked" and the ranges narrow (Figure 3). This means that N rate decisions and N supply to corn are more critical than with lower price ratios.

Significant N loss situations, like in many areas of Iowa this year, cannot effectively be managed by rate selection (recommendation systems) because occurrence and magnitude of those events is an unknown. Instead, if excessively wet conditions occur, use of tools like estimation of nitrate losses, in-season crop canopy N stress sensing, and soil nitrate testing can be implemented for guidance on supplemental N applications. These tools may not necessarily determine specific application rates, but can help determine if there is adequate N or if additional application is needed. Another approach is just waiting to see what the spring rainfall situation is and using split/sidedress for some N applications, especially when prices are high. As discussed above, attempting to manage potential losses through selection of high application rates is not profitable for long-term N management.

With high costs for N fertilizers, and especially if wet springs continue, careful management of N fertilizer inputs will be more important than ever to help deal with weather induced N loss uncertainty. Also, products designed to enhance effectiveness of N fertilizers (such as urease inhibitors, nitrification inhibitors, controlled release products) are now relatively less expensive with high fertilizer costs. This means that more options are more viable (especially compared to the practice of simply applying a higher N rate) to help provide for good efficiency of applied N and reduce N loss variability. The same holds for following best application timing and method for N fertilizer products.

Working with clientele

Dealers and crop advisers should work closely with their producer clientele to determine the best options and production plans for the upcoming year, and beyond. This is always important, but more so at this time as the fertilizer purchase/supply/price dynamics are changing dramatically and quickly. Decisions made now, when multiplied across the combined crop production acres in Iowa, can have serious and far reaching effects for the 2009 cropping year.

Summary

Nitrogen management for corn production has always been challenging. With current and rapidly changing N fertilizer and corn prices it has become even more challenging, with increased uncertainty and risk. Of main importance is to closely consider prices when deciding

on application rates. The relationship between N and corn prices may or may not have resulted in a need for reducing N applications or using significantly different rates. Also of importance is to manage N inputs in ways to help ensure good efficiency and high crop yield. High fertilizer prices have many producers considering options that may or may not make sense or work well, including blanket reduction in rate or significant change in management such as time of application, fertilizer material, or additive. In many instances, producers are already using good N management practices, and therefore should simply continue as before. For others, there may be room for improvement. Decisions need to be made by producers with concurrent planning with advisers and input providers so new systems can be implemented successfully.

Reference material

Various N management information is available on the ISU Agronomy Extension Soil Fertility Web site at http://www.agronext.iastate.edu/soilfertility/homepage.html. The *Corn Nitrogen Rate Calculator* is located at http://extension.agron.iastate.edu/soilfertility/nrate.aspx. The rationale behind the *Corn Nitrogen Rate Calculator* and other information about corn N fertilization is contained in the publication *Concepts and Rationale for Regional Nitrogen Rate Guidelines for Corn* located at http://www.extension.iastate.edu/Publications/PM2015.pdf.

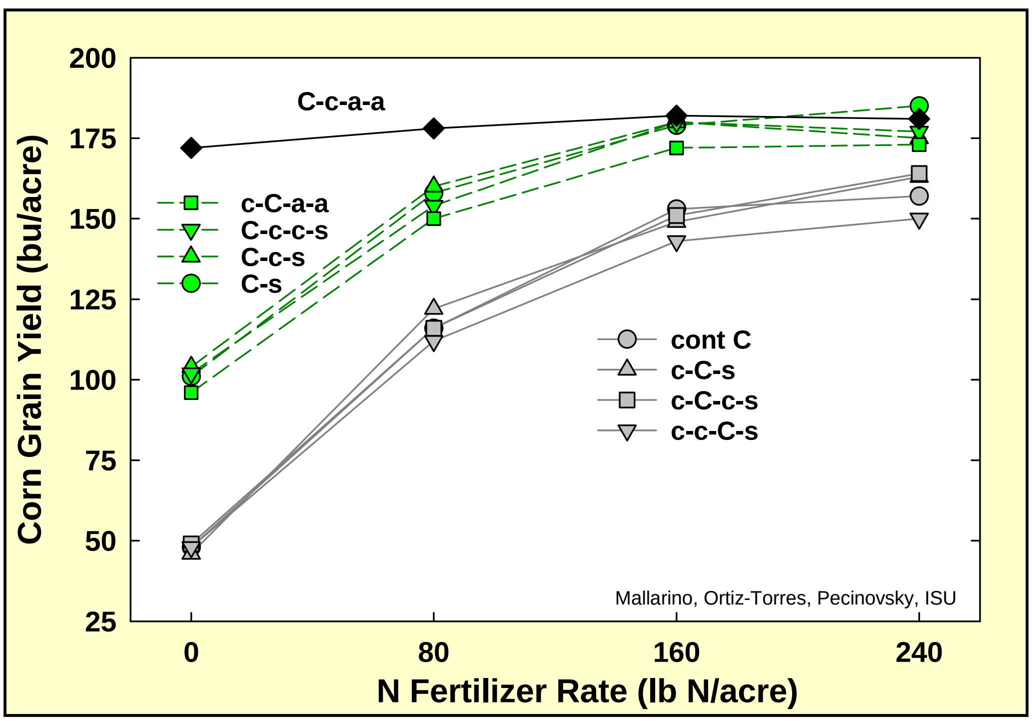

Figure 1. Corn grain yield response to fertilizer N application rate with various corn rotation sequences at Nashua, IA. A.P. Mallarino and K. Pecinovsky, Iowa State University Northeast Research and Demonstration Farm 2006 annual progress report ISRF06-13.

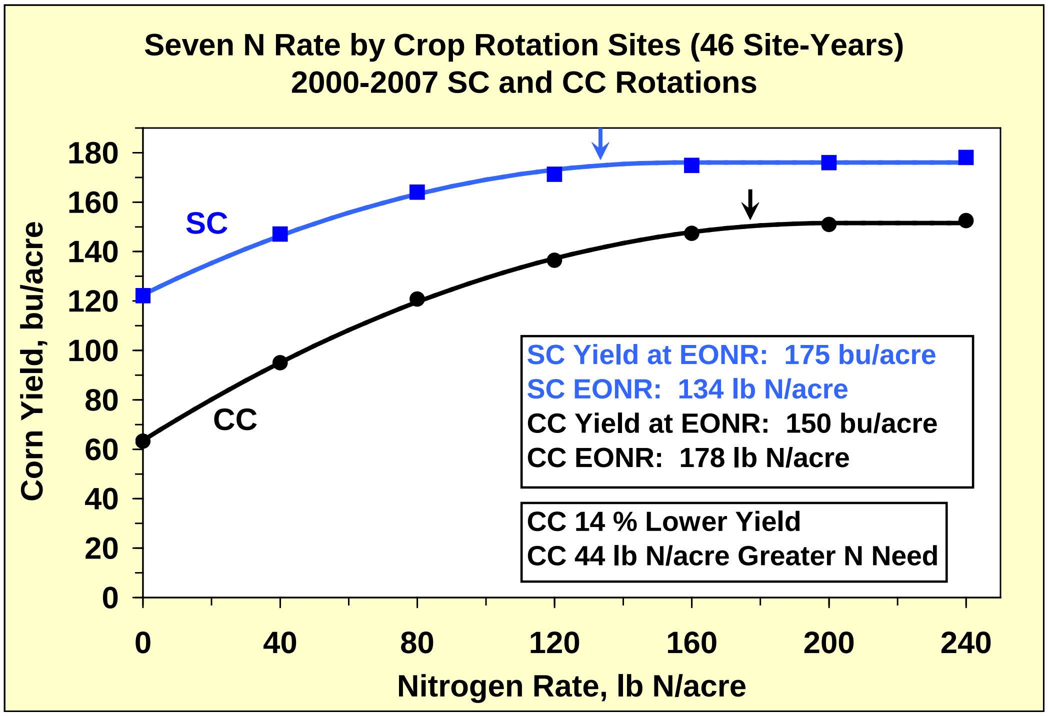

Figure 2. Comparison of corn grain yield response to N fertilizer rate and economic optimum N rate (EONR) at a 0.10 price ratio for corn following soybean (SC) and continuous corn (CC) across seven sites in Iowa from 2000-2007, J. Sawyer and D. Barker.

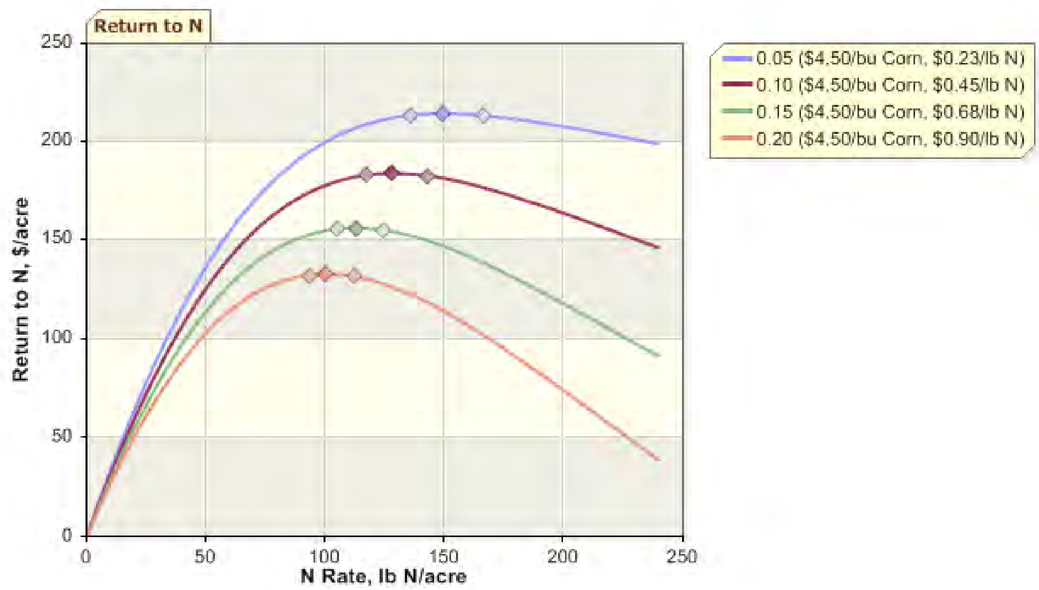

Figure 3. Effect of N:corn grain price ratio on return to N with corn following soybean, based on the current *Corn Nitrogen Rate Calculator* dataset. The solid symbols are the maximum return to N (MRTN) and the light symbols represent the range of similar profitability.

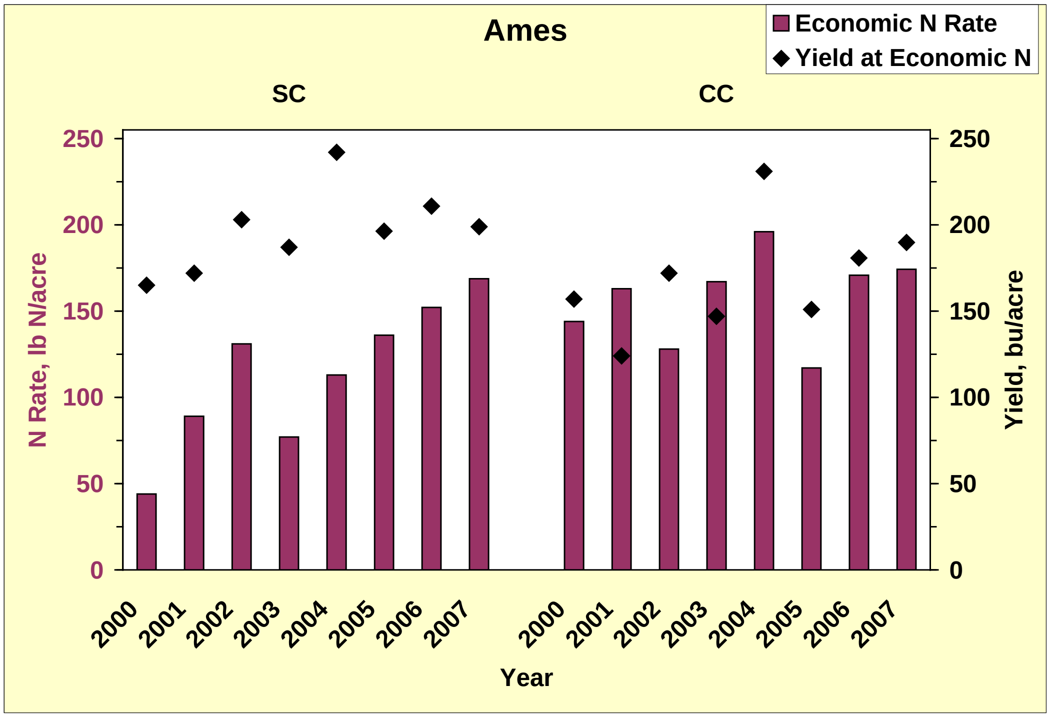

Figure 4. Yearly variation in economic optimum N rate (bars) (0.10 price ratio) and yield at the optimum N rate (symbols) for corn following soybean (SC) and continuous corn (CC) for a site at Ames, J. Sawyer and D. Barker.

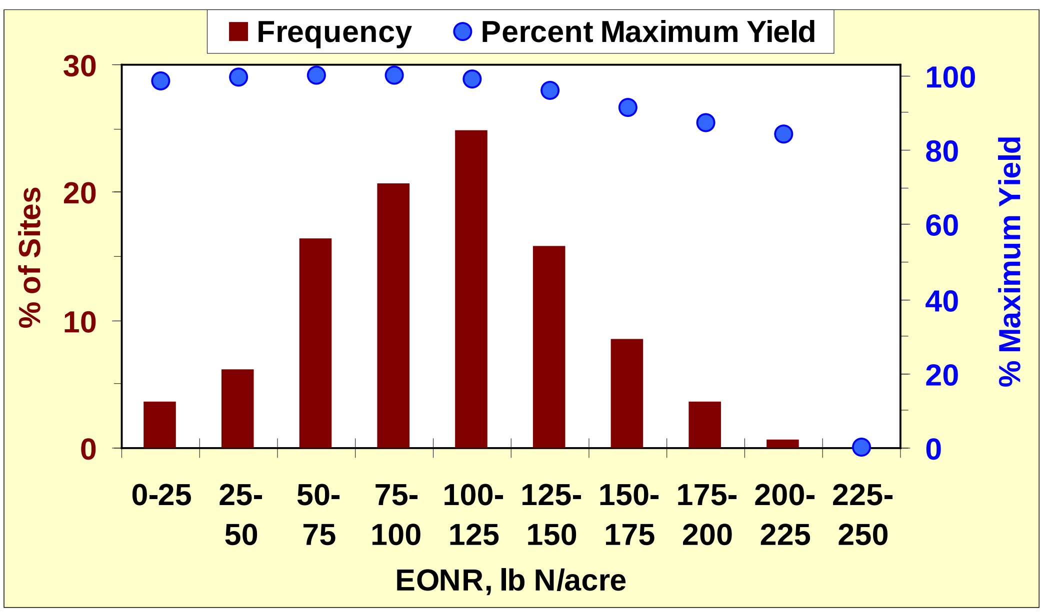

Figure 5. Site-year N rate trial economic optimum N rate frequency (bars) (0.10 price ratio) and percent of maximum yield (symbols) provided if the MRTN rate (128 lb N/acre) is applied at all sites, corn following soybean dataset for Iowa in the *Corn Nitrogen Rate Calculator*.

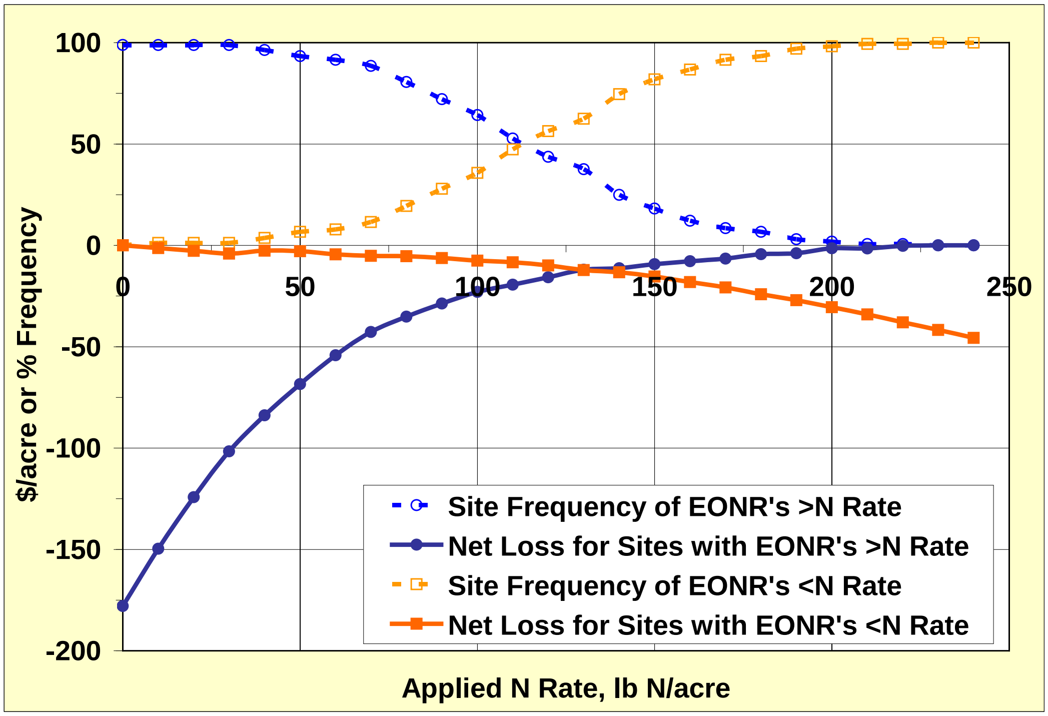

Figure 6. Net return for different N rates applied across the corn following soybean N rate trial database in the *Corn Nitrogen Rate Calculator* and frequency of sites that have site-year economic optimum N rates (0.10 price ratio) above or below each N application rate.

Table 1. Nitrogen rates suggested for corn following soybean and continuous corn based on the current Corn Nitrogen Rate Calculator dataset.

Nitrogen rate guidelines in Iowa for different N and corn grain prices.				
Price	Corn Following Soybean		Corn Following Corn	
Ratio[1]	Rate[2]	Range[3]	Rate[2]	Range[3]
$/lb:$/bu	- - - - - - - - - - - - - - - - -	lb N/acre	- - - - - - - - - - - - - - - - -	
0.05	150	136 - 166	208	194 - 238
0.10	128	116 - 142	183	171 - 199
0.15	113	102 - 124	163	151 - 177
0.20	100	91 - 111	147	137 - 158

[1] Price per lb N divided by the expected corn price. For this table, corn was held at $4.50/bu and N varied from $0.23, $0.45, $0.68 to $0.90/lb N (for example, anhydrous ammonia at $377, $738, $1115, to $1476/ton).

[2] Rate is the lb N/acre that provides the Maximum Return To N (MRTN). All rates are based on results from the *Corn N Rate Calculator* as of July 1, 2008 (http://extension.agron.iastate.edu/soilfertility/nrate.aspx).

[3] Range is the range of profitable N rates that provides a similar economic return to N (within $1.00/acre of the MRTN).