DOES IT PAY TO FERTILIZE CORN WITH NITROGEN?[1]

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After the spike in natural gas price in the winter of 2000-2001 the price of natural gas and N fertilizers have fluctuated, but remained above previous historic levels. Seasonal trends have also resulted in both N product availability and high cost issues, including this fall. With this trend, are there N fertilizer use practices that should change, or does crop response to N fertilization pay no matter the cost? Crop nutrient applications should be determined by evaluating expected return from each input. If allocation is required due to limited product availability, product price, or available financial resources, then decisions about fertilizer use should also be judged against other crop production needs, enterprise requirements, and overall farm business goals. Considering all potential inputs for producing crops, the focus should be on garnering optimum positive return. Following is information to help guide N fertilization decisions when prices are high or product availability is short.

Nitrogen Fertilization

Corn is quite responsive to N supply and thus management is critical for profitable production. Of importance is setting an economical application rate and adjusting total N inputs by accounting for N available from all sources – rotation following alfalfa and soybean, manure, byproducts, and secondary fertilizers like weed-and-feed, starter, and ammoniated phosphates. These sources can supply significant amounts of crop available N, and if properly accounted for and managed, will greatly lower overall primary fertilizer N application and cost.

Timing of application is important to help assure that applied N remains in the soil for crop use. Also, risk of N loss and thus potential for reduced yield becomes more important when refining to optimal or perhaps less than optimal rates. Therefore, practices should be avoided that enhance buildup of soil nitrate at times when losses are more probable. In Iowa, most nitrate leaching occurs in the early spring period and denitrification in the later spring. Spring preplant application close to planting or sidedress typically provides the least risk from loss – although if weather and soil conditions are favorable, late fall application can be comparable but risk and probability of loss increases because of the increased time applied N is exposed to the environment. An example of the specific environmental effect on N loss was demonstrated in work by Baker et al. (1995) where they applied N from fall to late sidedress (Table 1). In a dry year, corn yield with fall application was not different from early spring and both were better than with late spring. In a wet year, mid-May to late spring application had higher yield. If primary N fertilizer applications must be made in the fall, they should be targeted to soils and geographic areas with lowest loss potential, they should be limited to anhydrous ammonia (no

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fall urea or UAN solution), and application should not occur until soils have cooled sufficiently to slow nitrification (temperature at the 4-inch soil depth 50°F and expectation is for continued cooling, which on average occurs during early-to-mid November across Iowa).

Crop rotations have a large impact on corn N fertilization requirements. One example of the rotation benefit is corn following alfalfa. Research by Morris et al. (1993) in Iowa found virtually no N fertilization need for first-year corn after alfalfa (three of 29 sites had positive net return from application of 50 lb N/acre, the rest did not respond to applied N). Table 2 shows the low number of responsive sites and low optimum N for first year corn after forage legume measured in studies from several states. Response to N is greater and more variable for second-year corn after alfalfa, but less than for continuous corn. Another example of the rotation benefit is the increase in corn yield and lower N requirement when corn is grown after soybean compared to corn following corn. Figure 1 demonstrates this for several sites from recent years in Iowa. Table 3 lists the apparent N contribution from soybean to corn measured in several studies across the Corn Belt. Current suggestions are to account for up to 50 lb N/acre less N fertilization need for corn following soybean than for continuous corn, which is supported by data from Iowa and other states.

Choice of N rate can impact both economic return and residual inorganic-N remaining in the soil. Application at rates greater than corn requirement, along with increased application frequency in rotations such as continuous corn, are main reasons for excess nitrate found in corn cropping systems. Although optimal fertilization rates do vary between years, using the highest-ever produced yield to set N rates will result in over-application and lower economic return most years. It is more appropriate to set rates based on N rate response data rather than the high-yielding year(s). For example, in crop rotation studies conducted at Iowa State University Research Farms located at Ames and Lewis (Figure 2), the variation in yearly optimum N rate did not coincide with annual yield. Also, the highest yielding years did not require the highest N rates. It is common for yearly yield to not be related to optimum N. Choosing a rate based on multiple-year N response data will not limit production in the high yielding years because soil processing typically supplies more plant-available-N in those years and corn is more efficient in exploring the rooting zone and utilizing fertilizer N. The combination of good growing weather, and improved N supply and uptake, results in higher yield without the requirement for higher N application.

The average corn yield response to applied fertilizer N for corn following soybean across many years in Iowa (data from studies conducted in 1979-2004) is shown in Figure 3. Based on this average response, the economic optimum N rate is 125 lb N/acre [at a 10:1 corn ($/bu):N ($/lb) price ratio], which interestingly is the middle of the currently suggest range of 100 to 150 lb N/acre for corn following soybean (ISU Extension publication PM-1714, Blackmer et al., 1997), and which was the N rate range suggested 20 years ago by Voss and Schrader (1984) in the ISU Extension publication PM-905 “Crop Rotations-Effect of Yields and Response to Nitrogen.”

Crop and N prices both influence economic optimal N rates, with higher optimal rates when N price is low and crop price is high, and conversely, lower rates when N price is high and crop price is low. Within a corn price range from $3.00 to $1.50/bu, reduction in optimum N rate is not large unless N prices are relatively very high (Figure 4). One should carefully consider the prices used in these evaluations – the price now may not be what it is in the future or at harvest.

Using the approach outlined in Nafziger et al. (2004) for analyzing economic optimum return to N from many individual site-years of data, the highest return to N for Iowa response data occurs at 120 lb N/acre for corn following soybean (Figure 5). Return to N does not change appreciably around the highest return, with a range that is approximately 20 to 30 lb N/acre above and below the highest return or from 100 to 150 lb N/acre (assuming within approximately $1.00/acre of the maximum return, and using a 0.10 N:corn price ratio, which has been a common price ratio over the years). This N rate range coincides with the suggested range in Voss and Schrader (1984) and Blackmer et al. (1997) for corn following soybean. Figure 5 also indicates that N applied at the top end of this range would supply optimal N at 90% predicted sufficiency, while N applied at the low end of this range would supply optimal N at 45% sufficiency. This analysis also indicates there is little to be gained from applying N above 150 lb N/acre when corn follows soybean. Decreasing or increasing the price ratio affects the return level, the range of greatest return to N, and the range for N sufficiency (Figure 5). At a N:corn price ratio of 0.05, highest return shifts to 150 lb N/acre and at a N:corn price ratio of 0.15 highest return shifts to 100 lb N/acre. This data analysis should help producer decisions regarding N applications as their expectation for corn pricing and N cost fluctuates, and should help with risk management and understanding financial benefit or penalty if applied N is not optimal in a given season. As mentioned earlier, the price ratio has held fairly constant over time, and changes in N rates should be weighed carefully in regard to corn prices for grain sold or expected sales. There are three main impacts of changing price ratios: one, the economic penalty for over-application increases significantly when N price becomes relatively high (this penalty is almost non-existent at low relative N price); two, the range of greatest economic return to N becomes smaller and the rate sufficiency moves to lower N rates when N price becomes relatively high; and three, the range in greatest return to N and rate sufficiency move to higher N rates when corn price is high relative to N. Currently, N prices are high, but this must be weighed relatively to the price received for corn grain. This type of response data analysis data can also be used to help judge use of differently priced N products.

For continuous corn, return to N is greater compared to corn following soybean due to larger yield increase from N application and the highest return to N occurs at 170 lb N/acre, which is 50 lb N/acre higher. Also, a constant range in highest return to N rate occurs from approximately 150 to 200 lb N/acre (Figure 6), which coincides with the suggested N rate range of 150 to 200 lb N/acre in Voss and Shrader (1984) and Blackmer et al. (1997) for continuous corn. At a N:corn price ratio of 0.05, highest return shifts to 200 lb N/acre and at a N:corn price ratio of 0.15 highest return shifts to 140 lb N/acre.

Manure is an excellent source of crop available N. Multiple studies in Iowa show both high corn yield and high nutrient availability from manure application. In some instances corn yields with applied manure are higher than with fertilizer alone. Appropriately utilizing manure N is another opportunity to lower fertilizer N use.

Ways to Maintain and Even Improve Crop Yields While Refining Nutrient Costs

- Rotate crops to achieve higher yields and reduce N applications
- Account for rotation N benefits when planting corn after soybean, alfalfa, or other legumes
- Don't apply fertilizer rates greater than 150 lb N/acre for corn following soybean and 200 lb N/acre for continuous corn
- Time N fertilizer and manure application appropriately for most efficient crop use
- Account for all intended fertilizer N applications – weed and feed, starter, and ammoniated phosphates – before making the primary N fertilizer or manure application
- Investigate use of N diagnostic tools in corn such as soil nitrate testing, in-season plant N stress sensing (leaf chlorophyll reading, canopy sensing, aerial imaging), and fall cornstalk nitrate to help assess corn N fertilization requirements
- Accurately apply fertilizer and manure
- Manage crop production practices such as plant populations, hybrid/varieties, and pest management to ensure high yields but be realistic when setting yield expectations

Summary

High N fertilizer prices, uncertain product supply, and limited financial resources add to the challenge of achieving most profitable crop production. This is especially difficult for management of nutrient inputs because their cost can be a substantial part of all needed production inputs. With careful attention to the nutrient areas affording greatest potential return, applications can be targeted to priority situations critical for producing a crop and optimizing economic return.

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References

Baker, J.L., D.R. Timmons, and R.S. Kanwar. 1995. Placement and timing options for nitrogen applications to improve use-efficiency and reduce nitrate leaching. p. 4.6-4.9. *In* Report of integrated farm management. IFM 16. Iowa State University, Ames, IA.

Blackmer, A.M., R.D. Voss, and A.P. Mallarino. 1997. Nitrogen fertilizer recommendations for corn in Iowa. Publication Pm-1714. Iowa State University Extension, Ames, IA.

Morris, T.F., A.M. Blackmer, and N.M. El-Hout. 1993. Optimal rates of nitrogen fertilization for first-year corn after alfalfa. J. Prod. Agric. 6:344-350.

Nafziger, E.D., J.E. Sawyer, and R.G. Hoeft. 2004. Formulating N recommendations for corn in the corn belt using recent data. *In* Proc. N. C. Ext.-Ind. Soil Fertility Conf., Des Moines, IA. 17-18 Nov., 2004. Potash and Phosphate Inst., Brookings SD.

Voss, R.D., and W.D. Shrader. 1984. Crop rotations-effect on yields and response to nitrogen. Publication Pm-905 (out of print). Iowa State University Extension, Ames, IA.

Figure 1. Difference in average optimum N rate (10:1 corn:N price ratio) and yield between continuous corn and corn following soybean at five sites in Iowa from 2000-2003.

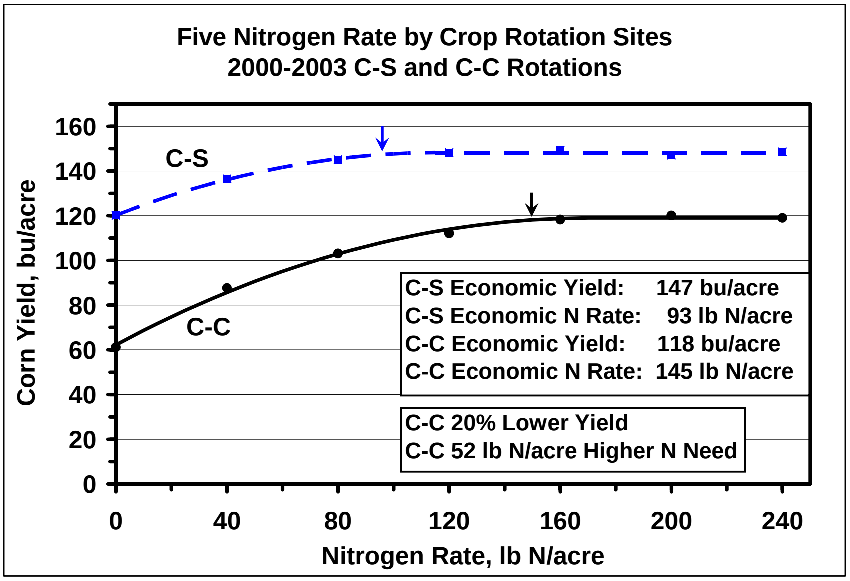

Figure 2. Change in economic optimum N rate (10:1 corn:N price ratio) and corn yield across years at Ames and Lewis, Iowa for continuous corn and corn following soybean from 1999-2004.

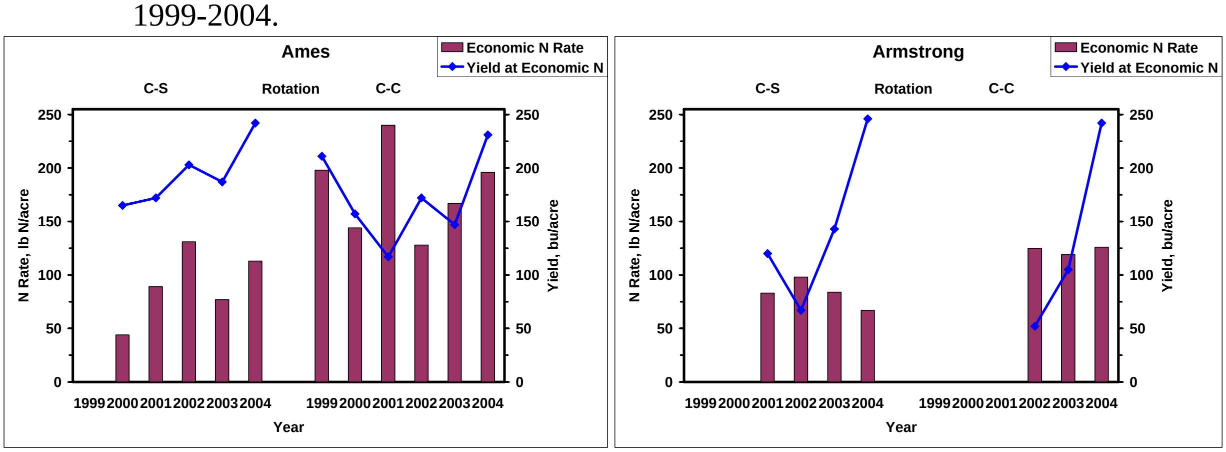

Figure 3. Corn yield response to fertilizer N rate and optimum N averaged from 1979 to 2004 for corn following soybean.

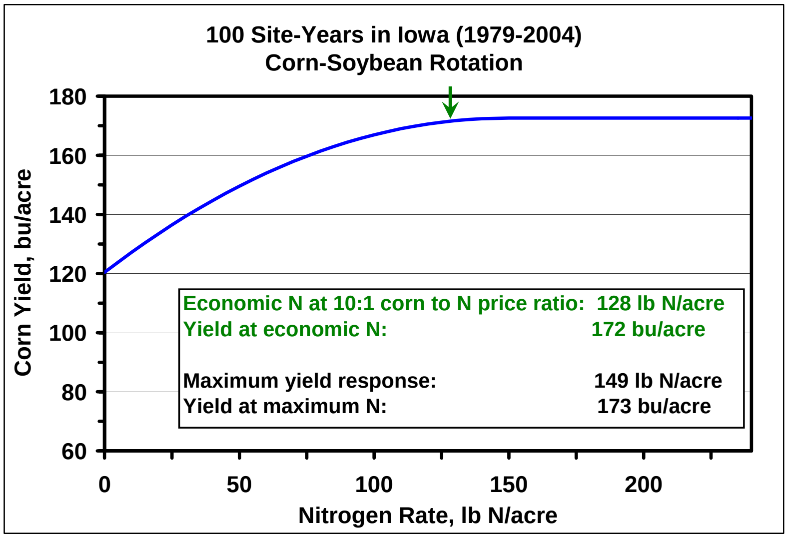

Figure 4. Change in economic optimum N rate for different corn grain and N fertilizer prices. Calculations based on the average yield response for corn following soybean shown in Figure 3.

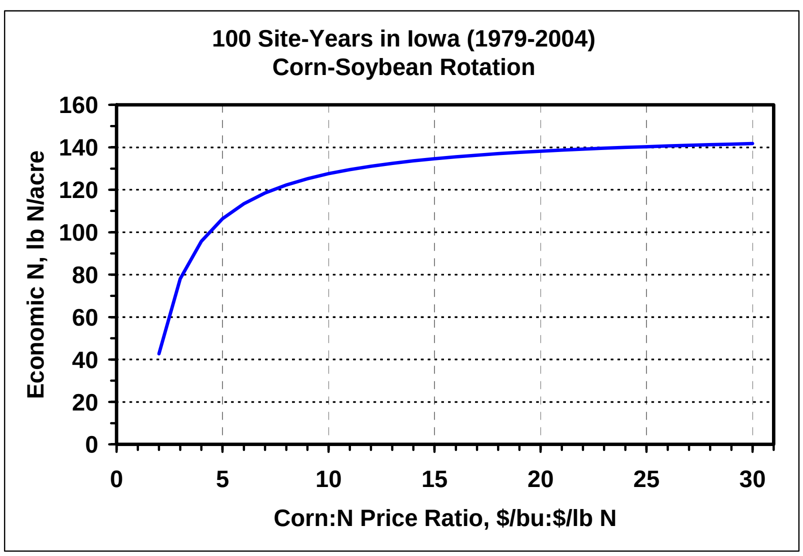

Figure 5. Average economic return to N and rate optima for 93 site-years (1992-2003) in Iowa for corn following soybean. Nitrogen to corn price ratios are 0.05, N at $0.11 and corn at $2.20; 0.10, N at $0.22 and corn at $2.20; and 0.15, N at $0.33 and corn at $2.20.

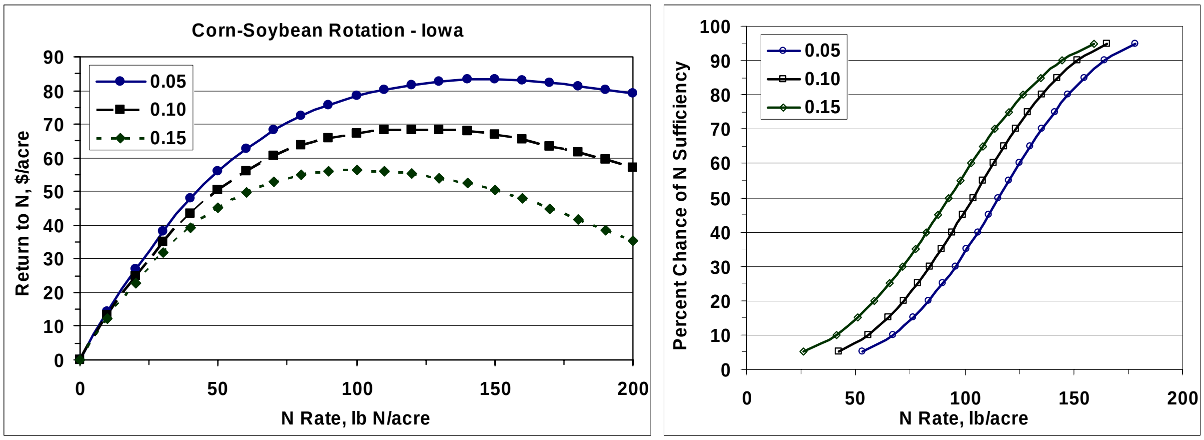

Figure 6. Average economic return to N and rate optima for 28 site-years (1992-2003) in Iowa for continuous corn. Nitrogen to corn price ratios are 0.05, N at $0.11 and corn at $2.20; 0.10, N at $0.22 and corn at $2.20; and 0.15, N at $0.33 and corn at $2.20.

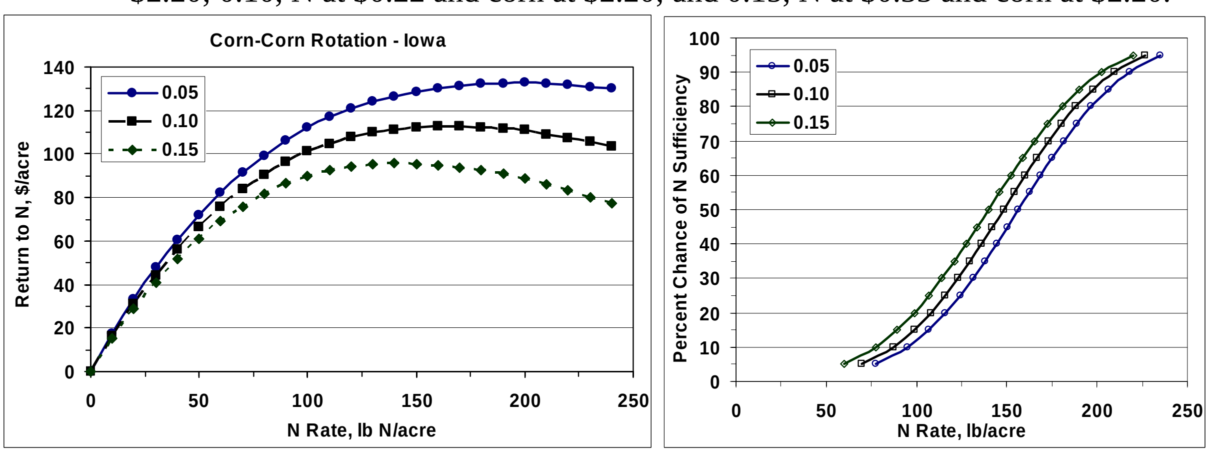

Table 1. Effect of N application timing on corn grain yield in a wet and dry year. Adapted from Baker et al. (1995).

Year	Fall	4/1	4/15	5/1	5/15	6/1	6/15	7/1	Split E.	Split L.	CK
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1989 (Dry)	151	144	149	151	151	138	131	128	143	142	59
1990 (Wet)	114	126	128	128	140	145	143	137	130	136	68

N applied at 112 lb N/acre as liquid fertilizer. Split early was at first cultivation, split late was at second cultivation (half – half rate split). Continuous corn. Baker et al., 1995, Ames, IA.

Table 2. Influence of previous forage legume on subsequent corn N fertilization need.

First Year Corn N Need Following Forage Legume

State	Site Years	Responsive Sites	Optimum N Rate
			lb/acre
Iowa (Voss and Shrader, 1981)	11	0	0
Iowa (Morris et al., 1993)	29	6	25
Wisconsin (Bundy and Andraski, 1993)	24	0	0
Minnesota (Schmitt and Randall, 1994)	5	1	42
Illinois (Brown and Hoeft, 1997)	4	0	0
Pennsylvania (Fox and Piekielek, 1998)	2	0	0

Table 3. Apparent N contribution from soybean to a subsequent corn crop from several studies across the corn belt.

Apparent N Contribution from Soybean

Location	Average	Data Source
	lb N/acre	
Iowa	52	Saw yer (2003)
Iowa	60	Blackmer (1996), Meese (1993)
Missouri	48	Stecker (1995)
Wisconsin	47	Bundy (1993)
Illinois	50	Illinois NWRC (1996)
Nebraska	56	Shapiro (1998)