NUE IN PRACTICE: WILL N-EFFICIENT CORN HYBRIDS SELL?

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Abstract

Efficient use of nitrogen (N) fertilizer is becoming increasingly important in corn production due to rising N fertilizer prices and growing concerns about N contamination of ground and surface waters. Seed companies are also beginning to develop hybrids with N use efficiency (NUE) improved through trait introduction. The introduction of such hybrids will bring new questions about the value of higher NUE, and about risk management associated with decreasing, or not increasing, N use rates as grain yields increase. In order to see if current, commercial hybrids respond differently to N rate, we grew nine Burrus Hybrid corn hybrids at five N rates for three years at Urbana, Illinois. Averaged across years, the N rate × hybrid interaction for yield was significant. The economically optimum N rates (EONR) differed significantly among hybrids, ranging from 122 to 201 lb N/acre. The yield increase from no N to the EONR (Δyield) ranged among hybrids from 80 to 117 bu/acre, and NUE, calculated here as Δyield divided by the EONR, ranged from 0.48 to 0.66 bu/lb N. The net return to N at the EONR was highest for the two hybrids that had the highest Δyield and the highest yield at the EONR. One of these hybrids had a high NUE value, while the other had only an average NUE. From a practical standpoint, we think that the value of NUE as a trait may be less than the value provided by the ability to produce high grain yields at an appropriate N rate.

Introduction

In response to increasing N prices and to concerns about N moving into surface and groundwater, a new approach developed by Sawyer et al. (2006) encourages producers to apply the economic optimum N rate (EONR), rather than a yield-goal-based rate or one chosen to produce maximum yields. The price of N and the price of corn are taken into account to determine EONR. In a 24-year study by Vanotti and Bundy (1994), EONR values ranged between 160 and 170 lb N/acre. We have seen much wider ranges among years in some of our work in Illinois.

Research to test the hypothesis that different hybrids require different amounts of N fertilizer has shown mixed results. Tsai et al. (1984) reported that hybrid B73×Mo17 had a large response to spring-applied N, while Pioneer 3732 responded little. Mackey and Barber (1986) also found hybrid differences in response to N fertilizer. On the other hand, Bundy and Carter (1988) concluded that adjusting N application rates for individual corn hybrids did not improve corn yield. Gardner et al. (1990) recommended that producers manage their N programs in a similar way for all hybrids, while Hatlitligil et al. (1984) found no genotype × N fertilization rate interaction, and thus concluded that hybrid responses to N fertilization rates were similar.

Nitrogen use efficiency (NUE) is a complex plant trait that incorporates both uptake efficiency and utilization efficiency (Below, 2002). The NUE of a corn plant can be increased by increasing either the N uptake or N utilization efficiency, or both. Mackey and Barber (1986) found that the root growth of a plant affected N uptake, which in turn affected yield response to nitrogen. The hybrids with greater root length had greater N uptake and higher yields. Uribelarrea et al. (2006) found that hybrids resulting from the Illinois High Protein strain had high N uptake efficiency resulting from roots that were better at absorbing and translocating N, while hybrids resulting from the Illinois Low Protein strain had high N utilization efficiency resulting from high sugar levels and enhanced mechanisms for starch synthesis.

The recent announcement by commercial corn seed companies of efforts to develop hybrids with higher NUE, and presumably less need for N fertilizer, has increased interest in whether N fertilizer rates can and should be adjusted based on hybrid type. We undertook this study to see how nine commercial corn hybrids differed in their response to N rate, measured as differences in EONR, yield at EONR, NUE (measured here as yield efficiency) and the economic return to N at the optimum N rate. In particular, we wanted to see if high NUE, which is a trait currently under development, will by itself add value to corn hybrids.

Materials and Methods

A field study was conducted for three years, 2003 to 2005, at the University of Illinois Crop Sciences Research and Education Center, Urbana, Illinois. Studies were conducted on a Dana silt loam (fine-silty, mixed, superactive, mesic Oxyaquic Argiudolls) in 2003 and 2004 and on a Flanagan silt loam (fine, smectitic, mesic Aquic Argiudolls) in 2005.

The trial was laid out as a split-plot in a randomized complete block design with four replications. Main plots consisted of five N rates (0, 60, 120, 180, 240 lb N/acre), and subplot treatments consisted of nine Burrus (Burrus Hybrids, 826 Arenzville Road, Arenzville, IL 62611) corn hybrids, chosen for their commercial success and to represent a range of maturities. Hybrids, with relative maturity (days) listed in parentheses, included 440 (108), 442 (108), 576 (111), 583Bt (111), 625 (112), 645 (112), 710 (114), 727 (114) and 795B (115). Hybrids 583Bt and 795B contain the YieldGard® (Monsanto, 800 N. Lindbergh Blvd., St. Louis, MO 63167) Bt trait for resistance to European corn borer (*Ostrinia nubilalis* H.). Individual plots were 10 ft (four 30-inch rows) wide and 42 ft. long in 2003 and 2004 and 47 ft long in 2005. Nitrogen was sidedressed as 28% UAN injected between the rows at the V5-V6 growth stage.

Corn was the previous crop in each year of the study. The previous crop received 180 lb N/acre, and produced yields of 160 to 200 bu/acre. Plots were planted on 15 April, 17 April and 17 April in 2003, 2004 and 2005, respectively. The planting rate was 32,000 seeds/acre, with final stands of 29,000 to 30,000 per acre. Weed control was by herbicides and mechanical means as needed. Yields were taken using a plot combine to harvest the center two rows of each subplot, and yields were adjusted to 15% moisture.

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Cary, NC), designating as random years, reps within years, and all interactions with reps and years. The NLIN procedure was used to fit the data to a quadratic plus plateau function. The EONR values for each hybrid were calculated as that point at which the slope of the quadratic response was equal to the ratio of N fertilizer price, set here at $0.32 per lb N, to corn grain price, set at $3.20/bu.

The yield without N was subtracted from the predicted yield at the EONR to calculate Δyield for each hybrid. To estimate NUE, Δyield was divided by the EONR, giving the bushels of corn produced for each lb of N at the EONR. This is sometimes called "yield efficiency" – it does not measure separately how efficiently the plant takes up fertilizer N or uses its N, but incorporates both of these efficiencies. We also calculated both total and marginal net return to N at the EONR for each hybrid, by subtracting the cost of N (EONR x $0.32/lb N) from the crop value, both of total yield and of yield added by use of N (that is, above yield without N.)

Results and Discussion

Both 2003 and 2004 were favorable crop years, while 2005 was dry. Yields averaged over hybrids and N rates were 186, 201, and 161 bu/acre in 2003, 2004, and 2005, respectively, while maximum (plateau) yields, averaged across hybrids, were 212, 241, and 180 bu/acre. Across hybrids, economically optimum N rates (EONRs) were 167, 169, and 135 lb N/acre in 2003, 2004, and 2005, respectively.

Averaged across years, hybrids responded differently to N rate (Fig. 1). Yields of hybrids without N ranged from 107 to 131 bu/acre (Table 1), and coefficients of the linear component of the regression (that is, the slope of the response curve at N=0) ranged from 0.86 to 1.21 bu/lb N. Hybrid EONR values ranged from 122 to 201 lb N/acre, the yield at the EONR ranged from 196 to 227 bu/acre, and Δyield ranged from 80 to 117 bu/acre (Table 1). The highest yield at high N rates was attained by the longest-maturity hybrid 795Bt, and the lowest by the shortest-maturity hybrid 440, but with the exception of the mid-maturity Bt hybrid 583Bt, which also produced high yield, most intermediate-maturity hybrids responded similarly to N and produced similar yields and Δyield values.

Hybrid differences in response to N were relatively modest, making it difficult to assign hybrids to distinctly different N-response categories. Those hybrids of shorter duration tended to respond less to N than those of long duration, similar to the findings reported by Tsai et al. (1984). But it might be expected that short-season hybrids would tend to need less N than longer-maturity hybrids, as a reflection of their lower yield potential and what is likely to be less total N content of the crop at maturity. We tested grain protein content using NIR in one of the years of the study (2004) and in that year hybrids did not differ in grain protein concentration (data not shown). We have no indication that these hybrids differ in their ability to store N in the grain.

While there is certainly interest in using corn hybrids that are efficient in their use of nitrogen, it is also important that the producer have access to hybrids that provide high economic returns to the use of N. In this study, NUE differed considerably among hybrids, from 0.48 to 0.66 bushels of grain produced per lb of N at the EONR, above the yield without N (Table 1). There was, however, little relationship between NUE and the net return to N at the EONR (Fig. 2). We consider the net return to N at the EONR to be an important measure of the value of a hybrid, in that it measures potential profitability, provided that N rates can be set to approximate the EONR for an individual hybrid. If a high NUE arose from high yield at relatively low N rates, then hybrids with high NUE would also produce high net returns to N. Among the hybrids here, one (795Bt) produced a high return and had a relatively high NUE, while the hybrid 583Bt had a high return to N but an average NUE value (Table 1).

One additional question that these data address is the value of using hybrid-specific N rates, compared to the more common approach of using similar or identical N rates for most hybrids. Using the response curves generated, we simulated the net return from using the same N rate for all hybrids compared to the (maximum) net return at the calculated EONR. The EONR calculated using data averaged over hybrids and years was 160 lb of N. Using this N rate for all hybrids instead of the hybrid-specific EONR decreased the net return to N among the nine hybrids by $0.10 to $12.71 per acre, with an average of $4.03 per acre (Table 2). The N rate calculator (Sawyer et al., 2006) shows a maximum return to N at a rate of 168 lb N per acre for corn following corn in Central Illinois. Using that rate across all hybrids would have reduced return to N by an average of $4.08 per acre compared to using hybrid-specific EONR values.

Lowering the rate to 140 lb N per acre decreased the net return to N by $28.29 per acre for the highly N-responsive hybrid 583Bt, and by $7.73 averaged across all hybrids (Table 2). Raising the uniform rate to 180 and 200 lb N per acre decreased the net return by an average of $5.48 and $10.05 per acre, respectively, compared to using hybrid-specific EONR rates. The overapplication of N on hybrids with low EONR values is costly at the higher N rates, while the return increased at high N rates for those hybrids with high EONR values. From these data, it appears that having some foreknowledge of hybrid-specific EONR values will be of economic value, though for most of the higher-yielding hybrids in this study, the cost of underapplication at low N rates tended to exceed the cost of overapplication at high N rates.

We do not know how well this set of hybrids represents commercially available hybrids today, but it seems clear that the economic value of a hybrid is better indicated by its ability to produce high yields at typical N rates than by its ability to produce its yield with relatively low amounts of N fertilizer. While high-NUE hybrids may indeed reduce the amount of N needed to optimize yield, they will need to be high-yielding in order to maximize return to N, regardless at what N rate that return is maximized. This raises a question about the usefulness of high NUE *per se* as a commercial trait. Both the low-yielding 442 and the high-yielding 795Bt had high NUE values in this study, but the 795Bt produced a much greater return, and required more N to do so, than did 442. New, high-NUE hybrids will, in addition to proving that they can produce their yields with “less” N, also will need to be proven to have high yield potential in order to compete.

Conclusions

This study was conducted before the advent of hybrids modified specifically to improve their NUE, and so does not predict what such hybrids might bring with regard to improved NUE. But from a set of diverse hybrids, we have shown that NUE, calculated as the increase in yield divided by the N rate at the EONR, has little direct bearing on the profitability of a hybrid. Instead, the ability to produce high yields, including large yield responses to applied N, is the important determinant of profitability. While the concept of high NUE is appealing, the development of hybrids that require very little N but also produce little additional yield as the N rate is increased are unlikely, at current N and corn prices, be commercially successful in conventional crop production systems where N can be applied up to an optimal amount.

While the ability to have some knowledge of the expected optimum N rate would be helpful to producers, our simulation of returns to different, fixed N rates indicates that this information may be of limited economic value, at least for those hybrids (probably a majority) that are intermediate in their response to N rate. On the other hand, lacking that knowledge and using only intermediate N rates appears to represent little danger of large economic loss from applying either too little or too much N to a particular hybrid. If the price of N rises relatively faster than the price of corn, then the value of knowledge about response of specific hybrids to N rate will increase.

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Figure 1. Response to nitrogen rate of nine Burrus hybrids at Urbana, Illinois. Data are averages over three years, 2003 to 2005.

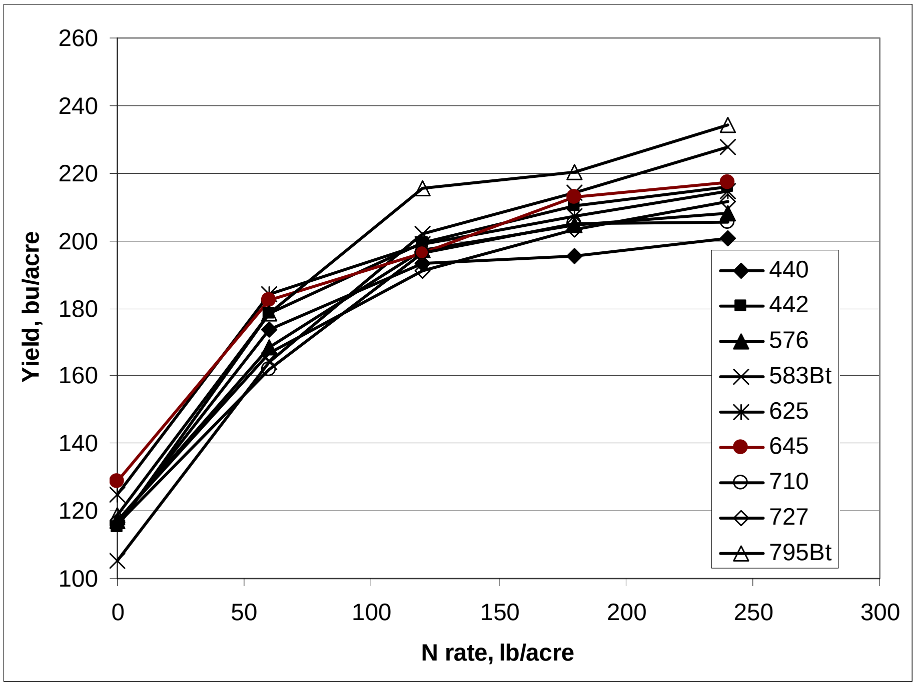

Figure 2. Relationship between NUE and net return to N at the EONR among nine corn hybrids.

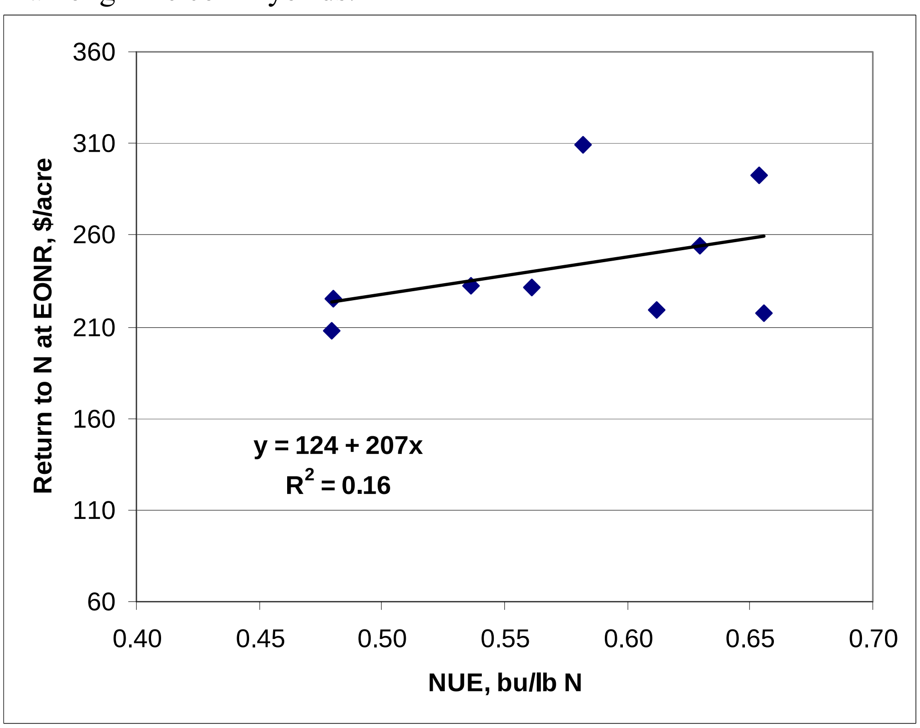

Table 1. Optimum N rate, yield without N and at the optimum N rate, Δ yield, NUE, and net return to N among nine hybrids grown at different N rates over three years (2003-05) at Urbana, Illinois.

	Optimum	Yield			NUE	Return to N at ONR:	
Hybrid	N rate	At 0 N	At ONR	ΔYield	ΔYield÷ONR	Above 0 N	Total
	lb N/acre	------------bu/acre------------			bu/lb N	-------$/acre-------	
440	122	116	196	80	0.66	217	589
442	150	117	211	94	0.63	254	628
576	157	117	205	88	0.56	231	607
583Bt	201	107	223	117	0.58	309	651
625	134	126	208	82	0.61	219	624
645	171	131	213	82	0.48	208	628
710	167	115	205	89	0.54	233	602
727	185	119	208	89	0.48	225	605
795Bt	165	119	227	108	0.65	293	673

Table 2. Estimated loss of return to N at fixed N rates compared to the net return at the EONR for each of nine Burrus hybrids grown at different N rates over three years at Urbana, Illinois. Loss is estimated as the net return at the indicated N rate compared to the net return at the EONR for each hybrid.

	Optimum	Net return	Loss at uniform N rate (lb N/ac):			
Hybrid	N rate	At EONR	140	160	180	200
	lb N/acre	$ per acre	--------------------$ per acre--------------------			
440	122	589	3.95	10.35	16.75	23.15
442	150	628	1.12	1.14	7.35	13.75
576	157	607	2.66	0.10	4.70	11.10
583Bt	201	651	28.29	12.71	3.29	0.00
625	134	624	0.44	6.23	12.63	19.03
645	171	628	6.80	0.85	0.58	5.69
710	167	602	5.91	0.36	1.52	7.65
727	185	605	13.52	4.23	0.19	1.40
795Bt	165	673	6.89	0.31	2.30	8.70
Average			7.73	4.03	5.48	10.05

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