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High Yield Corn Production Can Result in High Nitrogen Use Efficiency

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By Charles Wortmann, Charles Shapiro, Achim Dobermann, Richard Ferguson, Gary Hergert, Daniel Walters, and David Tarkalson

Articles such as "Fixing the Global Nitrogen Problem" by Townsend and Howarth in Scientific American, Feb 2010, are common. Alarm is expressed about the environmental impact of the increasing amount of reactive N in the atmosphere and in terrestrial and marine ecosystems around the globe. Much of this increase is attributed to production and use of N fertilizer. Use of fertilizer N is essential to meet growing global demand for agricultural commodities. Management is key to increasing productivity while also increasing N use efficiency and reducing N losses.

A team of University of Nebraska-Lincoln scientists, with partial funding from the Nebraska State Legislature, addressed this challenge. They conducted 32 irrigated trials across diverse production conditions of Nebraska from 2002 to 2004 to evaluate corn response to rates of split-applied N. The results were reported in two papers published in the January-February 2011 issue of *Agronomy Journal*.

The average maximum yield in these trials was 240 bu/A. When the previous crop was corn (CC) and soybean (CS), the respective mean yields with no N applied were 155 and 165 bu/A, and the mean grain yield increases to reach the yield plateau were 88 and 63 bu/A, respectively. The average economically optimal N rates (EONR) were 155 lb/A for CC and 110 lb/A for CS; this assumed the value of 1 bu of grain was equal to the cost of 8 lb of fertilizer N **(Figure 1; Table 1)**. The mean yield at EONR was 233 bu/A.

Yield with no N applied averaged >160 bu/A with approximately 160 lb/A of N uptake. However, we know from other trials that these levels of yield and N uptake cannot be sustained over several years of no N application, especially for continuous corn. Similar yields and N uptake, with no N applied, are unlikely to occur with similar soil organic matter levels if there is:

- less crop residue return to the soil,
- more ancient soil organic matter with a relatively great proportion in recalcitrant forms, and
- less vigorous crop and root growth with less capacity for nutrient uptake due to various biotic and abiotic constraints.

Such a contrasting situation exists for corn production in Africa, where in a recent study across 22 site-seasons in Uganda, mean grain yield and N uptake with no N applied were 29 bu/A and 41 lb/A, respectively.

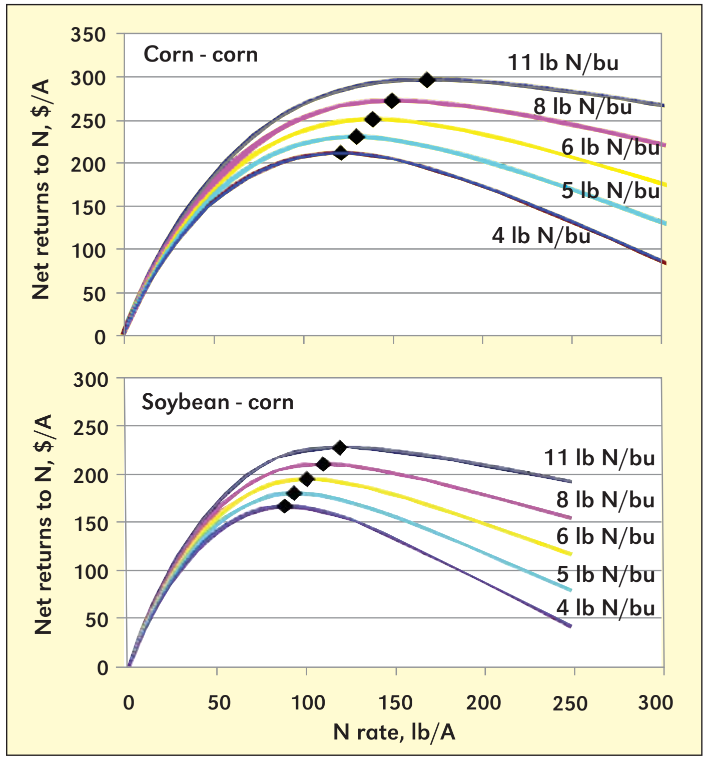

Figure 1. Returns to fertilizer N application as affected by N rate and the price of fertilizer N compared with grain. Black diamonds indicate each economically optimal N rate (EONR).

Table 1. Corn yield, fertilizer N use efficiency, and percent of applied N recovered when N was applied at the economically optimal N rate (EONR).

	Corn-corn n = 12	Soybean-corn n = 16
Yield, bu/A	237	231
EONR, lb/A	155	110
N uptake, grain	152	143
N uptake, stover	82	80
Grain:fertilizer NUE, lb/lb	85	115
Recovery efficiency, %	67	76

An overall measure of N use efficiency is the amount of grain produced per unit of N applied. This averaged 1.5 and 2.1 bu grain per lb N applied for CC and CS, respectively **(Table 1)**. The Nebraska average is about 1.1 bu of grain per lb of N applied. Therefore, N use efficiency at EONR was much higher in these high yield situations than is commonly achieved in Nebraska.

One component of N use efficiency is crop recovery of applied N (i.e. the difference in plant N uptake with and without N applied, divided by the N application rate). Mean fertilizer N recovery in above-ground biomass at EONR was 67% for CC and 76% for CS **(Table 1)**. This is almost double the national mean recovery efficiency for corn, which is about 40%. There was a linear decline in recovery efficiency of 0.2% per lb/A of N for application rates in excess of EONR.

High recovery efficiency implies little loss of applied N,

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur.

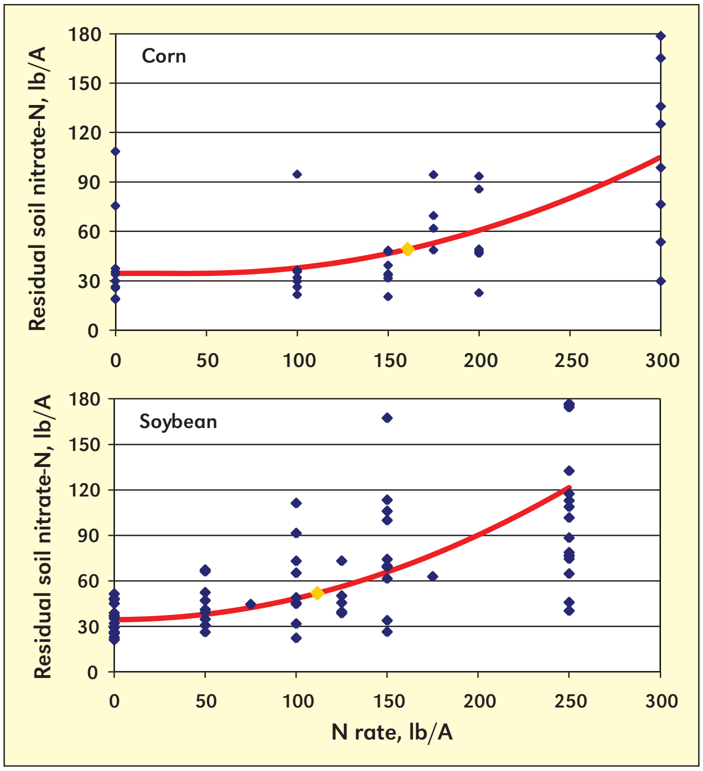

Figure 2. Effect of N rate on residual soil nitrate-N to a 4-ft depth following harvest. The gold points on the lines indicate the EONR when 8 lb N equals the value of 1 bu of corn.

and little residual soil nitrate-N remaining after harvest. Residual soil nitrate-N may be of value to a subsequent cereal crop if not lost to leaching or denitrification, but will be of little or no value to a subsequent legume crop. Mean post-harvest residual soil nitrate-N at EONR was 49 lb/A (sampled to 48 in., analyzed using water extraction and cadmium reduction) and just 14 lb/A more than with no N applied **(Figure 2)**. Residual soil nitrate-N increased greatly with N rates in excess of EONR.

Another component of N use efficiency is the conversion of plant N to grain N, or physiological efficiency. This is a function of N harvest index and grain N concentration. Grain contained 64% of the plant N. The average grain protein level at EONR was above 8%, as indicated by a grain N concentration of 1.3%, an increase from 7% protein with no N applied. Mean physiological efficiency at EONR was approximately 42 lb of grain per lb of N.

The results demonstrate the potential to achieve high N use efficiency by corn in high yield situations, compared with typical efficiencies, provided N was applied near EONR. Calculation of EONR in Nebraska considers corn yield history, previous crop, residual soil nitrate-N, and soil organic matter. Efficiency was greater with corn following soybean compared

Irrigated corn trial sites were established across Nebraska to evaluate crop response to split-applied N.

with continuous corn. Several factors contributed to high fertilizer N recovery: no fall N application; split application of N; avoiding sites prone to water-logging and leaching to minimize nitrate-N losses; crop management to have a healthy crop with a vigorous root system efficient in both nutrient uptake and conversion of nutrients and carbohydrates to grain; and irrigation management to avoid leaching and denitrification losses and to avoid crop stress. High yield corn responses to applied P, K, and S were also determined with the results reported in an *Agronomy Journal* 2010 paper. Changes to the Nebraska fertilizer recommendations for corn resulting from this research have been incorporated into several decision tools including: an on-line tool for determination of fertilizer rates (http://soiltest.unl.edu); an N rate calculator (http://cropwatch.unl.edu/web/soils/resources); the Manure Management Planner (http://cropwatch.unl.edu/web/soils/resources); and the Maize-N model (http://www.hybridmaize.unl.edu/maizeN.shtml). BC

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