Optimal Rates for Corn Nitrogen Depend More on Weather than Price

By Bill Deen, Ken Janovicek, John Lauzon, and Tom Bruulsema

Corn yield response to N fertilizer varies from year-to-year owing to weather. Optimal N rates depend on the yield response, and also vary with the price ratio between fertilizer and corn. In a trial in Elora, Ontario, optimal N rates over six years varied more than three times as much due to differences in weather as compared to differences in price ratio. While small profit gains can be achieved by adjusting N rates for price ratio, there is much more potential profitability and environmental benefit to be gained in better adapting N management to weather.

Over the past decade, the price of corn has fluctuated considerably. From 2011 to 2013 Ontario farmers received some of the highest prices ever, while market forces during 2014 and 2015 eroded prices to their lowest levels in five years. This decline has led many producers to reconsider N application rates. The economically optimal N rate (EONR) depends on the ratio between N and corn prices. A falling corn price reduces optimal rates of N, but the producer often lacks information to answer the question, "by how much?" In this study, we used data from two sources, the Ontario Corn N Database, and a long-term N trial, to quantify relationships of EONR to prices, and to compare to weather effects on EONR.

The Ontario Corn N Database includes data on grain yield response to fertilizer N from field experiments conducted from 1962 to 2013. An earlier version was described by Janovicek and Stewart (2004). The database was queried to generate a subset of 213 trials conducted between 1990 and 2013—with previous crops of soybean, dry edible bean, forage grasses (no legumes) and small grains (mostly winter wheat), not following cover crops (including red clover)—a minimum of four N rates, and non-N limited grain yield of at least 110 bu/A. To characterize yield response to N rate, data from the Ontario Corn N Database was fitted with a quadratic plateau response model.

A long-term N trial with continuous corn was established at Elora, ON in 2009. The soil at the experimental site is a Guelph loam with pH 7.7, silt 48%, clay 20%, and soil organic matter 4.5%. Over the six years of the trial, agronomic management factors were held constant, except that fall chisel plowing was re-

Abbreviations and notes: N = nitrogen; $ = Canadian dollar. IPNI Project # IPNI-2008-CAN-ON29

Excellent growing conditions in 2013 led to high yields and high optimal N rates.

Table 1. Average farm-level prices paid and received in Ontario, Canada.

	2009	2010	2011	2012	2013	2014
Fertilizer N price, $/lb	0.79	0.51	0.60	0.74	0.67	0.62
Corn price, $/bu	4.14	5.26	6.16	6.61	5.89	4.67
Price ratio, lb corn/lb N	10.7	5.5	5.4	6.3	6.3	7.4

Source: McEwan (2015) and Kumuduni (2015).

Table 2. Economically optimal N rate decreases as price ratios increase. The changes are small except when fertilizers become extremely expensive relative to corn.

	Low-yielding trials[2] 110-160 bu/A		High-yielding trials[2] > 160 bu/A	
Price ratio[1], lb corn per lb of N	Optimal rate, b/A	Yield, bu/A	Optimal rate, lb/A	Yield, bu/A
4.5	120	138	149	185
5.4	116	137	144	185
6.7	110	136	137	184
10.7	91	134	119	182
13.7	79	131	108	179

[1] Mean price ratio in Ontario from 2009-2014 was 6.7; annual means varied from 5.4 to 10.7.
[2] n = 113 and 100 response trials for low and high yield groups, respectively, in the Ontario Corn N Database.

Table 3. Profit gain comparing scenarios for N rates.

	2009	2010	2011	2012	2013	2014
Rate scenario comparison	- - - - - - - - Profit gain, $/A - - - - - - - -					
Actual versus average price ratio[1]	1.94	0.27	0.25	0.03	0.02	0.08
Actual EONR versus 150 lb N/A[2]	6.70	8.94	8.82	8.71	59.29	26.90

[1] Actual ratio for each year from Table 1 as compared to the average ratio of 6.7 for the period.
[2] 150 lb N/A is the rate recommended by the Ontario Corn N Calculator for the average yield attained.

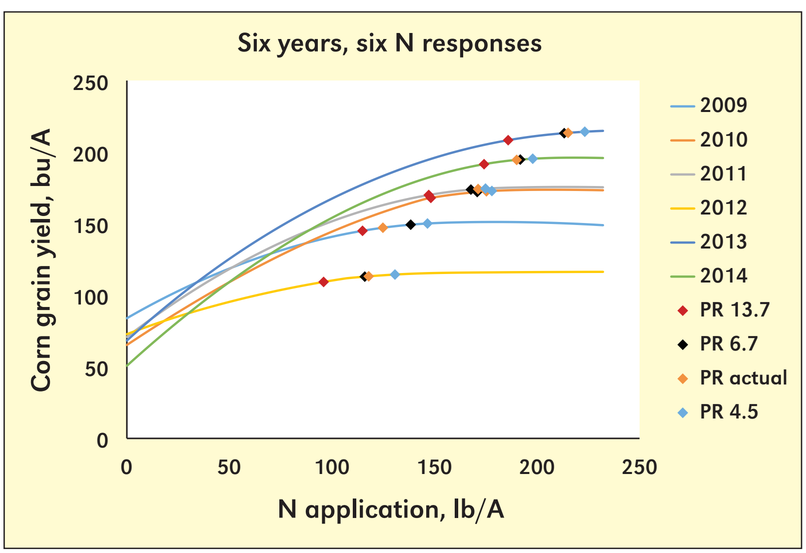

Figure 1. Curves indicate fitted corn grain yield response to applied N at Elora, Ontario. Points indicate the economically optimal N rates for price ratios (PR) varying from 4.5 to 13.7 lb corn per lb of N.

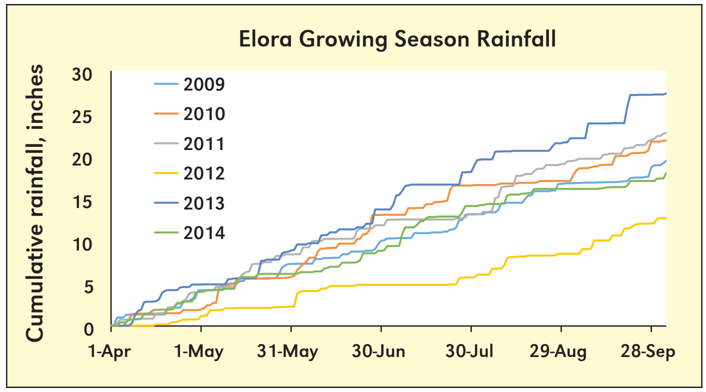

Figure 2. Rainfall accumulation differences during the growing season explained much of the variation in yield and optimal N rate.

placed by fall moldboard plowing from the fall of 2010. The hybrid for the first five years was Pioneer 38B14, and was changed to Dekalb DKC39-97 in 2014. Weather was the major factor that varied among years. At planting, all plots received 27 lb N/A as a starter. Each year, additional rate treatments were applied for total annual N rates of 27, 52, 78, 129, 195, and 232 lb/A. These rates were applied across four treatments involving preplant and sidedress timings, and histories of different N rates applied to the previous corn crop. Responses were averaged over timing and history. With four replications, each year's response curve was supported by a total of 160 data points. Curves were fit using the Crop Nutrient Response Tool V4.5 (Bruulsema, 2015), which uses an R^2-weighted mean of five response functions, providing precision for detailed comparisons of scenarios for profitability.

Price ratio (PR) was defined as the cost of fertilizer divided by the cost of grain. Economically optimal N rates were defined as the rate at which the last increment of added N generated a yield response equal in value to that of the added N.

Results

Price ratios varied considerably among years (**Table 1**), even when based on annual average prices. The average N price divided by the average corn price for 2009 to 2014 produced a price ratio of 6.7 lb of corn per lb of N. Considering that within each year, some producers may pay more for fertilizer and receive less for their corn than others, the scenarios shown in **Table 2** were extended to include a wider range of price ratios, based on half the reported variation in fertilizer prices, and assuming ±10% variation in corn prices. The changes in optimal N rates, relative to a price ratio of 6.7, were largest when price ratios increased to the high end of the range (levels which occurred only in 2009). Changes were similar for both the low and high yielding subgroups of trials. A reduction in EONR corresponds with a reduction in corn yield. Producers reducing rates in response to high fertilizer prices and low corn prices may see yield reductions of 3 to 5%, across the range of price ratios shown in **Table 2**.

In the Elora field trial, yield responses to N varied widely among years (**Figure 1**). Yield varied by 100 bu/A in response to water availability each year (**Figure 2**). The driest year, 2012, produced the lowest yields and showed the lowest optimal N rates. The highest yielding year, 2013, had unusually high rainfall in late June and early July. Even though it followed the drought year, it also showed the highest optimal N rates.

Optimal N rates varied from 118 to 215 lb N/A over the six years (**Figure 1**). This year-to-year variation was more than three times greater than the average range of rates arising from adjusting for the extremes of price ratio within a year. Since these year-to-year differences depend on weather, they are difficult to predict. Nevertheless, some of the yield variation could have been predicted by mid-June each year by simply looking at rainfall data as in **Figure 2**. Modeling tools could also make predictions of N mineralization and losses by that time. Producers are able to apply N at growth stages even beyond mid-June. These data point to a large potential opportunity to improve optimal rate prediction by using tools to incorporate measured and forecast weather data into mid-season N application decisions.

The economic value of a scenario in which actual EONR is implemented, as compared to a recommendation of 150 lb N/A derived from the Ontario Corn N Calculator, is shown in **Table 3**. These values for potential profit were calculated from the response functions shown in **Figure 1** and the prices shown in **Table 1**. The potential profit gain from addressing year-to-year variability greatly exceeds the profit that can be expected by making adjustments each year for actual price ratios.

The benefits of addressing weather-related variability in N response increase further when environmental impacts are also considered. Measurements of soil nitrate and long-term effects on soil organic N will be reported in future articles. Nitrous oxide emissions have been monitored for two years and are reported in Roy et al. (2014). Matching the N applied to year-specific crop N demand has large potential to reduce surplus N available for losses. BC

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IPNI Crop Nutrient Deficiency Photo Contest—The Rules for 2015

The International Plant Nutrition Institute (IPNI) is continuing its sponsorship of its plant nutrient deficiency photo contest during 2015 to encourage field observation and increase understanding of crop nutrient deficiencies. To get up-to-date, here is our list of rules for this year's contest:

1. In addition to the four nutrient categories (N, P, K and Other Nutrients - secondary and micronutrients), our **Feature Crop** category for 2015 is focused on **Root and Tuber Crops** (e.g., Potato, Sweet Potato, Cassava, Carrot, Beets, etc.)

2. Our list of prizes is as follows:
- US$300 First Prize and US$200 Second Prize for Best Feature Crop Photo.
- US$150 First Prize Awards and US$100 Second Prize Awards within each of the N, P, K and Other Nutrient categories
- In addition, all winners will receive the most recent copy of our USB Image Collection. For details on the collection please see http://ipni.info/nutrientimagecollection

3. Specific supporting information is required for all entries, including:
- The entrant's name, affiliation and contact information.
- The crop and growth stage, location and date of the photo.
- Supporting and verification information related to plant tissue analysis, soil test, management factors and additional details that may be related to the deficiency.

4. Photos and supporting information can be submitted until **Wednesday, December 9, 2015 5pm EST** and winners will be announced in early 2016. Winners will be notified and results will be posted at www.ipni.net.