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The Yield Response to Nitrogen: Subjective Belief Bias in Nitrogen Management

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AGRICULTURAL SCIENTISTS and economists have long been interested in quantifying the optimal amount of nitrogen needed on an acre of corn. Notions of optimality are sometimes based on principles of cost and revenue, sometimes on yield targets, and other times on environmental concerns. Ask any producer, fertilizer retailer, or agronomist how much nitrogen a corn producer needs to apply and you will probably not be surprised to hear, repeatedly, "It depends." Even if the optimal amount of nitrogen can be computed for a single field, being right ex post hinges critically on weather and other factors. The nitrogen management decision is complicated because the yield response to nitrogen depends on a host of variables, most of which are uncertain when nitrogen is applied and beyond the control of the producer: rainfall amounts and timing, in-field nutrient availability, and growing conditions top the list.

Photo: USDA, ARS

Further complicating the nitrogen decision is a producer's beliefs about the underlying relationship between nitrogen and yields, and the roles played by external factors (e.g., weather). In 2014, we surveyed producers in Central Iowa to gain an understanding of the real-world decision processes used by farmers when making nitrogen decisions on their fields. The survey was designed to elicit individual producers' beliefs about how much nitrogen is needed on a specific field, the field's expected yields, and the expected impact on yields when lesser and greater amounts of nitrogen are applied.

An important contribution of this work is to compare farmers' underlying beliefs about the relationship between nitrogen and corn yields, these are subjective beliefs, with what agronomists have quantified as the actual relationship—this is the objective yield distribution and its response to varying amounts of nitrogen. Iowa State University researchers in the Department of Agronomy have maintained long-term trials of nitrogen and yield on several research farms located across the state (Sawyer et al. 2006). These trials occur on land of varying quality that experience variation in weather similar to the type of variation that would be experienced by producers

Inside this issue

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in our survey. At the research sites, variables such as soil fertility, planting date, hybrid, etc. are held constant in order to compare yields under different nitrogen rates and rotation. In order to properly condition our analysis, we asked producers to report on field specific measures including corn suitability rating (CSR), rotation, soil fertility, their nitrogen application plans and, importantly, their expected yield outcomes.

Figure 1 shows a histogram of actual yield outcomes for three different levels of nitrogen application (i.e., 0 lbs/acre, 120 lbs/acre and 240 lbs/acre) based on long-term nitrogen trials conducted by ISU agronomists.[1] Note that as more nitrogen is used, the probability of a high yield outcome increases. However, consistent with other studies, these data also show why nitrogen is considered a risk increasing input: the more nitrogen that is applied, the greater the variability in yield outcomes.

In helping producers make decisions about how much nitrogen to use, agronomists and other advisers often suggest using a metric such as the return to nitrogen: the expected increase in bushels produced when nitrogen application is increased. One example of this is the *Corn N Rate Calculator* (Sawyer et al. 2006), which calculates the maximum return to nitrogen (MRTN). The MRTN shows the nitrogen rate at which the return to nitrogen is maximized given user-supplied fertilizer costs and corn prices.

The expected marginal product of nitrogen can be constructed from both the subjective and objective data. Figure 2 shows the expected marginal product of nitrogen derived from both the actual or objective yield data (the downward sloping curve) and the surveyed farmers' subjective beliefs (the plotted points). Based on the objective trial data, the expected marginal product of nitrogen (the solid fitted curve) is positive and decreasing over most of the application range: as more nitrogen is added, the expected benefit in terms of yield increase is positive but declining. The broken lines above and below the fitted line frame a 95 percent confidence interval in this estimation. In contrast, the analysis from our survey finds that producers report an underlying belief that the yield response to nitrogen is substantially greater than indicated in N rate response research. Put another way, most producers, whether they considered their best performing field, an average field, or an underperforming field, mirror a belief that, in their fields, nitrogen application has a larger positive impact on corn yield than shown by the long-term nitrogen studies.[2]

continued on page 9

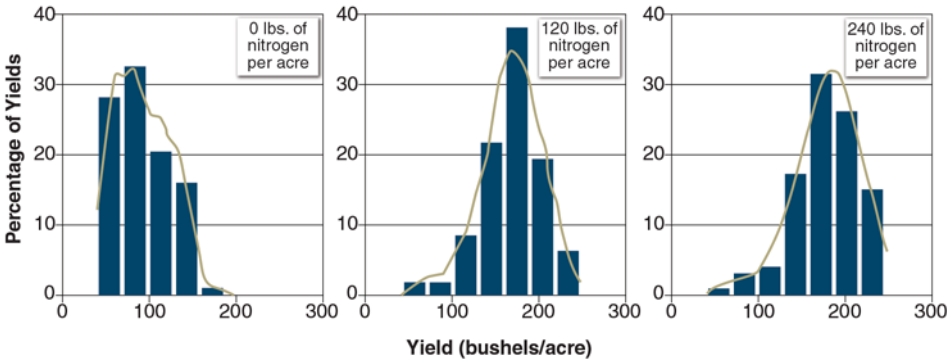

Figure 1. Corn yield outcomes at varying nitrogen application levels

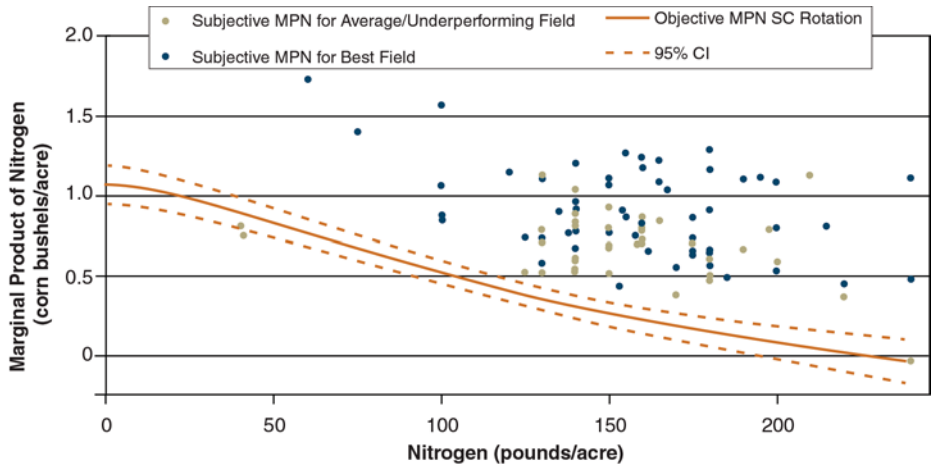

Figure 2. Comparison of the objective and subjective relationship between nitrogen and corn yields

[1]The trial data depicted here are from four research farms in Iowa from 1999–2013. Nitrogen application rates range from 0 to 240 lbs/acre in multiples of 40 or 60 lbs/acre of nitrogen; for brevity we show only three nitrogen rates here. In both the survey data and ISU field experiments, we do not control for the amount of nitrogen that exists in the soil pre-planting.

[2]The timing of this type of survey matters because producers' perceptions of the growing conditions and impact of nitrogen will change as weather uncertainty over the growing season is resolved. Our survey was conducted during mid-to-late June 2014. It is possible that the conditions observed at that time by producers did suggest the expected return to nitrogen would be different than the typical year.