Temporal Variability of Crop Response to Fertilizer

By Robert Mullen, Greg LaBarge, and Keith Diedrick

Owing to the weather, crops respond differently to fertilizers from one year to the next. Weather controls processes of nutrient supply and loss from the soil, and crop nutrient demand. Improvement of nutrient use efficiency requires systems that take into account the influence of weather on these processes.

Visual response of corn to N at the Northwest Research Station near Custar, Ohio, in July 2008. Plot at left received 240 lb N/A, plot at right received no N.

Managing nutrient inputs for crop production can be a difficult activity when one considers all of the factors affecting nutrient supply from the soil and nutrient demand of the crop. Most agronomists can easily discern spatial patterns in these factors across a landscape, but addressing the issue of temporal fluctuations is a challenge. The goal of this article is to provide some insight into how temporal fluctuations occur from the perspective of nutrient supply and demand.

For soil-mobile nutrients like N, what dictates how much will be required? The factors that control crop response to N can be grouped into three categories: 1) from the supply side, how much N will the soil render plant-available (mineralization), 2) how much will be lost (leaching, denitrification), and 3) from the demand side, how much corn could be produced. While these are easily identified factors, they are quite difficult to quantify or predict precisely.

Mineralization rate is a function of the type of organic matter and the environmental conditions that persist throughout the growing season. Warm, moist conditions are likely to release more N than cool, dry soil conditions. The amount of N lost by denitrification and/or leaching is a function of precipitation patterns, soil drainage, air temperature, and availability of mineralizable carbon. Attainable yield within a growing season is a function of emergence, competition, and the presence or absence of stress. What is the one constant across the supply side of nutrients from soil, and subsequent demand of nutrients by plants? Variability in weather.

Ohio State University has been conducting a study evaluating corn grain yield response to sidedress urea-ammonium nitrate (UAN) in a corn/soybean rotation since 1998. The study evaluates corn response across five N rates: 40, 60, 120, 180, and 200 lb/A prior to 2006 and 0, 60, 120, 180, and 200 lb/A since. Each year, N response is modeled using a quadratic-plateau regression equation that allows us to determine the agronomic optimum N rate (AONR). The AONR is the lowest rate of N that provides maximum grain yield.

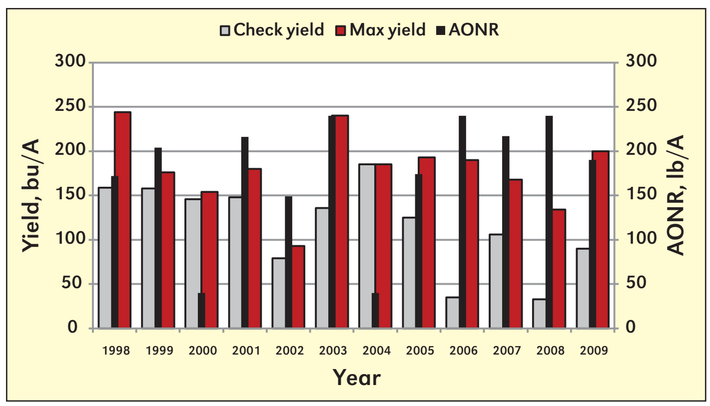

Figure 1. Maximum and check grain yields at the Northwest Research Station near Hoytville, Ohio, and the corresponding agronomic optimum N rates (AONR) necessary to achieve those yield levels for corn following soybean, 1998-2009.

As illustrated in **Figure 1**, the maximum attainable yield changes every year as does the amount of fertilizer N required for achieving that yield. Temporal fluctuations result in different optimum N rates at the same experimental location within the same rotation.

Traditional N recommendations have been based upon yield potential with the assumption that higher achievable yields require additional N to achieve those yields. We have learned that higher achievable yields do not necessarily translate into higher N needs (Sawyer et al., 2006).

Why do we frequently find no direct relationship between yield and optimum N rates in fields typical of the U.S. Corn

Abbreviations and notes: N = nitrogen; K = potassium.

Belt? Mineralization of soil organic matter has the capacity to supply a large amount of N, precluding the need for supplemental fertilizer N. Additionally, if the loss potential of the growing environment is low, less fertilizer N would be required. Thus, from the supply side, the soil itself may supply enough to satisfy most of the plant's N needs, and the N supplied is less likely to be lost. Plant demand may also be low if corn productivity was adversely affected by the presence of some stress (most likely related to weather).

Foliar application of a Mn solution by Keith Diedrick at the Northwest Research Station in Ohio.

Taking 2004 and 2005 from **Figure 1** to illustrate the concept of temporal variability in fertilizer N requirement, notice that the attainable yield is similar between years (~190 bu/A), but the amount of fertilizer N required to achieve that yield level is completely different. What was different was the yield with a lower rate of N fertilization. The check treatment (treatment actually received 40 lb N/A with the starter) yielded 190 and 125 bu/A in 2004 and 2005, respectively. The decreased N requirement in 2004 was unlikely the result of lower loss potential, as the amount of rainfall that fell between May 1 and August 1 was 5 in. higher than in 2005. Thus, it would appear that much more N was mineralized in 2004 than in 2005.

While N fertilization lends itself quite well to a discussion on temporal variability, soil-immobile nutrients may also be influenced. Micronutrient nutrition provides another opportunity to discuss temporal trends in nutrient supply and demand.

Take manganese (Mn) nutrition of soybean as an example. Multiple fields in north-central Ohio can exhibit Mn deficiency symptoms, but it does not occur every year. In fact, sometimes it is not visible for much of the growing season and then suddenly it becomes visible in pockets across the field. Research at Ohio State University has demonstrated that response to foliar Mn can be agronomically and economically important, but it does depend upon the year **(Figure 2)**.

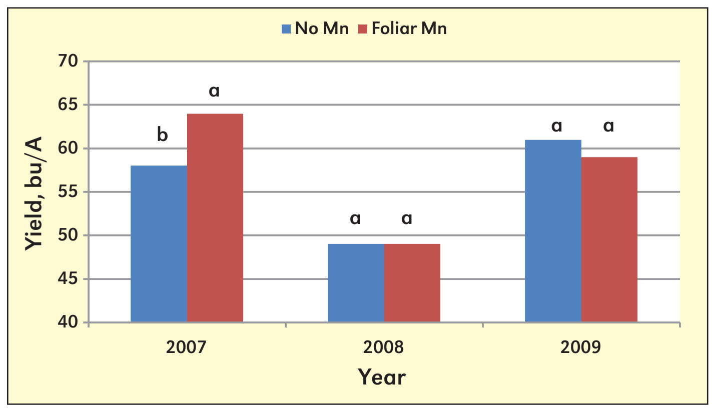

Figure 2. Response of soybeans to foliar-applied Mn at the Northwest Research Station near Hoytville, Ohio, 2007-2009. Bars with different letters above them differ significantly at the 0.05 probability level.

When soils dry, available Mn is oxidized to form manganese oxide, an insoluble compound. Thus, Mn is rendered unavailable to the plant. Application of foliar Mn under these conditions can result in positive agronomic and economic benefits (2007 season in **Figure 2**). Severe drought stress observed in 2008 likely precluded the need for Mn as a result of decreased yield potential (decreased demand). Lack of drought stress in 2009 resulted in adequate Mn availability from the soil and thus no response to a foliar application (increased supply).

Other nutrients can be subject to a similar phenomenon. Potassium stress is more prevalent in dry years in the eastern Corn Belt, especially on soils derived from 2:1 clays that can occlude K as soils dry. Conversely, in years with wetting/drying cycles, crop response to applied K may be smaller and less likely if soils release adequate K for crop nutritional demands.

Temporal variability in nutrient need is strongly affected by weather and its impact on soil nutrient supply and plant nutrient demand. These temporal trends elucidate the need for tools to monitor plant nutrient demand and soil nutrient supply simultaneously. Plant tissue analysis, in-season soil sampling, and the use of newer technologies (remote sensing) will likely play increasingly larger roles in making nutrient decisions. BC

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