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# Variable-rate N Management: One Option For Better Profits

Also increases N-use efficiency and minimizes potential environmental consequences.

***Summary:*** *Variable-rate nitrogen (N) management seemingly has many positive attributes, but is only slowly being adopted by producers. The primary reason at this time is probably the lack of a consistently adequate economic incentive unless high-value crops are involved. Several commercial products and approaches are available to help producers evaluate the technologies. These include components that might be used to assess N needs, make variable-rate N recommendations, and/or variably apply products for individuals who would like to build their own management programs. Others include commercial services that provide a comprehensive package of activities for producers who are not prepared to handle the intimidation component of new technologies or find it more convenient and less risky to hire others to provide the services. Users of the technologies have multiple options in terms of which inputs to the N recommendation process might logically include a spatial component and which do not.*

Deciding where and how much N to variably apply is probably the biggest challenge facing producers. If they are confined to using a soil-based N management strategy, producers either have to plan for an average year or perhaps try to compensate for moderately extreme conditions. If water availability is the limiting factor, it is probably best to plan for an average year because more favorable water conditions for the crop will also result in additional mineralization. For crops like corn, sorghum, and wheat, a late-season N stress will reduce grain protein content considerably more than it will yield.

There probably isn't a right or a wrong way to make variable-rate N fertilizer recommendations because so much depends on the local situation, information available, and availability of someone with Geographic Information System (GIS) skills to analyze and help integrate the information.

### Considerations to make

*Yield goal.* A uniform yield goal for the field is commonly used and probably is the least appropriate considering the sophistication and capabilities of variable-rate fertilizer application equipment. Yield maps from previous years can provide useful information related to yield stability. Maps with four to six yield categories are usually appropriate depending on the size of the field. If a management zone approach is used for soil sampling and making nutrient applications, then it may be convenient to develop a yield map with the same number of categories. An image taken during grain fill can be used to characterize the spatial variability that will likely occur in yield. Using this approach, someone would need to provide the yield goal for the field so that relative yield for each segment or area can be calculated and the yield redistributed to generate a proxy yield map.

Another strategy being tested for estimating yield potential of corn is based on crop vigor at about the V8 growth stage. Crop normalized difference vegetation index (NDVI) values, along with growing degree days (GDD), are used to predict yield from which a fertilizer N recommendation is derived. This latter strategy seems to work for wheat in Oklahoma where winterkill can be an issue, but with corn the strategy needs additional evaluation in that corn yields are not usually related to plant population as much as they are to water status and climatic conditions later in the growing season. The applicability of this approach in corn is questionable because climatic records clearly illustrate that the difference between average and exceptional corn yields is having favorable light and temperature conditions during the grain filling period.

*Residual N.* Responsible N management practices do not usually result in excessive residual N levels in the root zone at the end of the growing season. As such, residual soil N may be one of those inputs that is appropriately represented by an average for the field or that is proportioned according to soil color or other physical attributes. If management zones are delineated and soil samples are available for other purposes, then it might be appropriate to analyze soil samples at that level of resolution. Grid sampling for residual N is on the decline because of the cost and marginal value of the data. As such, many producers fi nd it difficult to justify sampling at greater than the management zone level. This partially explains why the interest in real-time nitrate monitoring is waning. Current technologies for on-the-go assessment of residual N are limited to electrical conductivity (i.e., Soil Doctor or Veris) and experimental techniques using a nitrate electrode.

*N mineralization.* Organic matter is a source of N that keeps giving over time as crop residues and manure decompose. This process (mineralization) is regulated by temperature, moisture conditions, and the availability of an energy source for the soil micro-organisms (i.e., carbon in crop residues and manure). A rule of thumb suggests that the N credit given for mineralization should be 20 to 40 lbs/A/yr for each one percent organic matter in the soil. The spatial variability of soil organic matter within a field and the cost of acquiring the information will dictate whether N mineralization is considered a spatial or uniform input. Sometimes remote sensing is used to generate a proxy map of soil organic matter content from which a map of estimated potential mineralization is generated.

*Bare soil imagery.* Aerial photographs provide an inexpensive way to assess the extent of spatial availability in N mineralization within a field. Patterns in soil brightness in images can be readily calibrated to generate a map of soil organic matter or potential N mineralization. Incorporating this information into a variable-rate fertilizer N recommendation should be an easy and inexpensive task in that the same map can be used from year to year.

*Vegetation imagery.* Aerial photographs of living vegetation have adequate spatial resolution to compare with patterns of soil color and soil types. However, the spatial resolution of many sources of satellite images is probably at the extremes for being useful. Remote sensing specialists recommend that users should strive to have 2.5 pixels (picture elements) per width of the application or harvesting equipment. This translates into about three row-widths for eightrow equipment or about five rowwidths for 12-row equipment. Resampling images using GIS tools to increase pixel size (e.g., adjusting the pixel size to a common scale) so that images can be more readily compared with yield maps is quite acceptable. However, resampling a course-resolution color image (e.g., Landsat satellite images) doesn't really gain anything unless it is merged with a higher resolution image (e.g., black and white image) to proportionately scale the color of the larger pixels into smaller ones to generate a map with finer resolution.

*Variable rate has made it possible to address spatial aspects of N and P availability in the soil.*

*Nitrate in irrigation water.* Irrigation of corn usually occurs predominantly during the last half of the growing season. N uptake is usually about 60 percent complete at the time of tasseling and 90 percent complete three weeks later. Therefore, timing can be an issue when considering an N credit for nitrate in irrigation water. A general guideline is that each acre-inch of irrigation contains 0.227 lb N per 1.0 ppm $NO_3$-N in water. As such, an acre-inch of irrigation water containing 30 ppm $NO_3$-N supplies nearly 7 lbs/A of N to the crop. Considering that evapotranspiration for corn is 0.35 inch/day during July and August, and if all of the water is supplied by irrigation, then 30 ppm nitrate-N water carries about half of the maximum daily N uptake for corn. In comparison, precipitation in the Midwest usually contains <1.0 ppm N (the fi rst tenth inch may contain 3 to 4 ppm N but shortly thereafter the N concentration usually declines to <0.1 ppm).

*Soil-based N management.* Much of the information that goes into a soil-based variable-rate N management scheme does not change very much over time (e.g., pH, organic matter content, mineralization, electrical conductivity, drainage, etc.) The parts that change are residual soil inorganic N (nitrate source) and biomass production/yield (N sink or removal in grain). The extent to which either of these considerations can be justified as having a spatial component depends on the producer and situation. Herein lies the value of yield maps or vegetation images over several years. Areas of a fi eld that have relatively stable yields over time should serve as the base when making variable rate N management decisions. These parts of the field are less likely to be affected by excess precipitation, nitrate leaching, and drought, none of which can be predicted when N applications are made. Producers perpetually fear that their fields, or parts of fields, might come up short of N if an exceptional year evolves (ideal growing conditions with high N uptake or excess precipitation that results in N losses). In reality, Mother Nature tends to take care of herself in that fertile areas that are subject to nitrate leaching and denitrification will also have a higher potential for N mineralization. Regions of the U.S. where fertilizer N recommendations are not based on the level of production (yield goal) have fewer opportunities for variable rate N management unless they have considerable spatial variability in other N sources (i.e., mineralization, manure).

*Sharing technologies.* Some innovative producers have integrated band application of nutrients and reduced-till into a concept called "strip tillage." The goal is to place liquid starter fertilizer and most of the annual N application (usually anhydrous ammonia) about 6 to 8 inches directly below the row where the next crop will be planted. Variable-rate technologies have made it possible to address the spatial aspects of N and P availability in the soil. Ammonium polyphosphate (10-34-0) is being injected to spatially address crop P needs (Capstan or Exactrix technologies) and then variable rate N is applied to complement the N in the 10-34-0. An example in 2004 from Nebraska is where a producer used imagery (bare soil and vegetation) and yield maps to delineate management zones.

*Plant-based N management.* Producers should not rely solely on a plant-based N management strategy for corn production. This is because several key physiological processes are initiated in plants before leaf color and plant vigor become reliable indicators of relative nutrient status or yield potential. Discussion of by-plant fertilization is in its infancy and largely driven by technologies that are capable of monitoring the biomass and chlorophyll status of individual plants and then fertilizing accordingly. The reality is that individual plants share both above- and below-ground environments with their neighbors. The appropriateness of applying N fertilizer to plants based on their potential to produce grain is not in question because the scale of management will ultimately be driven by profitability and the ease of implementing the technologies. For the time being, the greatest potential for in-season N management lies with the introduction of several new active crop canopy sensors (GreenSeeker and Crop Circle) that can be used to assess relative crop vigor. The unique feature of active sensors is that they work equally well any time of the day and do not necessarily need to involve the generation of a recommendation map (i.e., all operational aspects are transparent to operators other than some safety checks).

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