Site-Specific Nutrient Management

For Nutrient Management Planning To Improve Crop Production, Environmental Quality, and Economic Return

Presentation Script: Nitrogen - Chapter 2

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Nitrogen Management

Slide 1.

This module will cover the most important concepts of nitrogen management in agronomic systems for profitable and environmentally safe crop production. Since it is impossible to go through specific situations for all regions of the U.S., general concepts regarding nitrogen management will be presented. Even though these principles apply for most regions, viewers are encouraged to review locally developed nitrogen use recommendations.

Slide 2.

Nitrogen is an essential nutrient for crop growth and production. It is part of every cell, a component of amino acids and nucleic acids, and especially, it is a major constituent of chlorophyll. When a plant is nitrogen deficient, it normally shows symptoms like chlorosis or yellowing, mainly in older leaves since it is a mobile nutrient in the plant. In corn, if the deficiency is severe, it is common to observe an inverted V-shaped necrosis in the plant lower leaves starting at the leaf tip. Not only is crop productivity affected by nitrogen supply, but also crop quality. For example, the protein content of wheat is highly affected by nitrogen availability. Also, nitrogen nutrition interacts with other nutrients in the soil-plant system.

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Several chemical, physical, and biological processes are involved and interrelated in the soil system. This is known as the soil nitrogen cycle. Processes in the nitrogen cycle include: mineralization, conversion of organic to inorganic forms of nitrogen; nitrification, transformation of ammonium to nitrate (the most important source of nitrogen for plants); and immobilization, the inverse process by which inorganic nitrogen is converted to organic nitrogen by microorganisms. Nitrogen can be gained in the system with biological fixation by plant-microbe associations and free nitrogen-fixing organisms, or by nitrogen additions as synthetic fertilizers or organic sources such as manure. In addition, nitrogen can be lost by crop harvest; leaching of nitrate from the soil profile; denitrification, microbial conversion of nitrate to nitrogen gases; volatilization, ammonia loss from the soil surface; or erosion, soil loss with water runoff.

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This diagram shows the nitrogen cycle in agricultural systems. As can be seen, a number of processes take place simultaneously in the plant-soil system, and are very interrelated. Optimal management of nitrogen for crop production is influenced by processes in the nitrogen cycle, and the processes are responsible for how nitrogen flows through agroecosystems, maintains the supply of crop available nitrogen, or influences losses to air and water resources.

Slide 5.

Nitrogen fertilization rate is an important management decision regarding potential to achieve optimum crop yield, influence on environmental issues, and return maximum economic profitability. This figure is an example of nitrogen fertilization response in corn. It depicts a low corn grain yield when no nitrogen is applied, and a large increase in yield with nitrogen application. The challenge is to identify application rates that allow for maximum economic net return without over- or under-fertilization for different conditions. The blue points indicate the economic optimum nitrogen rate, which is the rate that results in the maximum economic return to nitrogen. Due to the need to pay for the fertilizer input, recommended rates are less than the rate to produce the agronomic maximum yield (indicated by the vertical lines). One can also see the influence of the prior crop on crop response to nitrogen and yield.

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Using extra nitrogen fertilizer as a risk management approach is no longer a safe or cheap “insurance” from the economic point of view; certainly not as it once was due to the increased cost of nitrogen fertilizers. Also, applying “more than enough nitrogen” is not environmentally friendly and, therefore, must be avoided. High nitrogen fertilizer costs, uncertainty about crop prices, and environmental impacts should encourage growers to critically determine nitrogen application rates.

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This figure shows how nitrate-nitrogen loss in subsurface tile flow increases as nitrogen application rates increase and then accelerates as rate increases beyond optimum nitrogen application. This concept applies for all crops fertilized with nitrogen and most production scenarios, which highlights the importance of accurately determining the optimum nitrogen rate to maximize profitability and minimize environmental impacts within specific crops and production systems. In spite of much research, this is much easier to say than actually achieve in production fields due to the numerous and unpredictable factors that affect the optimum nitrogen rate and the crop response to applied nitrogen.

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The common nitrogen rate recommendation system used in cereal crops for many years in the Midwest USA and other regions was a yield-goal based factor. This approach uses expected crop yield as the criterion for determining nitrogen rates; the higher the expected crop yield the greater is the nitrogen requirement, and presumably the recommended nitrogen rate. This yield-goal recommendation approach, or modification of the approach, is useful in some crops and regions, such as corn in Nebraska or wheat in several states. In most of the Midwest USA, however, research with corn has identified a poor correlation between individual site-year crop yield and the economic optimum nitrogen rate, and that the economic optimum nitrogen rate does not change with yield level.

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The figure shows an example of this issue for corn in Iowa, but similar results can be found for other regions and crops. As can be seen, there is no relationship between the optimum nitrogen rate and the corn grain yield indicating that yield goals should not be used to define nitrogen rates for corn. Therefore, some university nitrogen recommendation systems have moved away from yield-based systems to nitrogen response data-driven recommendations that are sensitive to nitrogen and grain prices. In the Midwest USA this approach is called MRTN or Maximum Return To Nitrogen. Economic-based approaches are not new; however, this particular approach links documented yield responses to nitrogen rate from recent research trials directly with the relative economics of grain price and nitrogen cost.

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In some situations, soil sampling can be useful to diagnose nitrogen fertilization needs for crops. There are two general soil nitrogen test sampling approaches used and both are based on soil nitrate: preplant sampling and in-season sampling. Preplant soil sampling is based on determination of the profile soil nitrate-nitrogen amount. In humid regions, leaching and denitrification typically cause soil profile nitrate levels to change rapidly and therefore be unreliable as an adjustment to application rates for subsequent crops. However, it is most reliable and useful in dry climates and areas with wintertime frozen soils. When preplant soil sampling is used, the amount of nitrate-nitrogen is subtracted from the general recommended rate to arrive at the amount of fertilizer nitrogen to apply as illustrated in the figure. On the other hand, the objective of in-season sampling is to develop an index of nitrogen availability that integrates residual inorganic-nitrogen and springtime mineralized nitrogen up to the sampling time. Soil samples are collected prior to the maximum crop nitrogen uptake period; this allows for time to make needed nitrogen applications. For example, the nitrate-nitrogen concentration determined in soil samples collected in corn at the six-leaf stage, or in winter cereals at tillering, has been related through research with crop yields and economic optimum nitrogen rate.

Slide 11.

Plant nitrogen sufficiency and stress sensing is a relatively new approach to determine crop nitrogen status and manage in-season fertilizer applications. The concept is to use the plant to assess the supply of plant-available soil nitrogen, and show potential deficiency through reduced plant growth and coloration. Instead of a soil test, the plant is the integrator of soil nitrogen supply with plant need. Chlorophyll meter and crop canopy sensor readings produce values or readings that by themself do not adequately determine nitrogen sufficiency/stress. When readings are compared (normalized) with readings from an adequately nitrogen fertilized reference area (non-nitrogen stressed), then the crop nitrogen status can be determined relative to non-nitrogen stressed crop. The figure shows a conceptual relationship between normalized chlorophyll meter or canopy sensor values and rate differential from the economic optimum nitrogen rate. Information like this, or other calibrated algorithms, can be used to decide how much nitrogen (if any) is necessary to apply based on chlorophyll meter or canopy sensor determinations.

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Recognition of within-field variability in soil properties, crop yield, crop nutrient need, and nutrient supply by site-specific nutrient management is gaining popularity as technologies advance. Whole fields can be divided into management units where the fertilizer application may differ using some form of field diagnostic, such as intensive soil sampling, soil and crop remote sensing, aerial images, canopy sensing, or yield mapping. Consistently poor crop performance in one part of the field may indicate (although not always) greater potential for nitrogen loss if nitrogen is applied uniformly across the field. Variation in soil organic matter and soil texture can be important influences on nitrogen management. Soil maps, bare soil images, grid soil sampling and/or mapping of electrical conductivity may indicate this type of variation. Field history can also be used to account for old barnyard sites, past manure management and sections of the field which may have been broken from natural grassland later than other areas. Together, this information can be used to develop zone specific nutrient application strategies. However, the magnitude of the variation or lack of predictability or repeatability in nitrogen rate need may not justify varying nitrogen rates. This type of nitrogen management is still evolving.

Slide 13.

Timing nitrogen fertilizer applications to provide a plant-available supply of nutrients when the crop needs them is the desired goal. Because nitrogen fertilizers are subject to transformation in the soil, application timing can play a critical role in optimizing crop response and high use efficiency. Producers in certain geographic areas, such as the upper Midwest and Great Plains often apply nitrogen fertilizer for corn as anhydrous ammonia in the fall. The disadvantage of fall application is increased risk of loss before crop uptake the next summer. Nitrification of ammonium nitrogen will be slow if the soil temperature is low after application, with a suggested practice to not apply ammonia in the fall until soils cool to 50°F and continue to get colder. Fall-applied nitrogen may be nitrified before the crop is planted due to application when soil temperatures are relatively high, unexpected warming of the soil after application, periodic warming during the winter, and early warming of the soil in spring. This nitrate will be subject to leaching and denitrification with spring rains and waterlogged soils that occur before and after the crop is established. Use of a nitrification inhibitor with fall-applied ammonia can improve the effectiveness by slowing nitrification.

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Many studies show that spring applied nitrogen is more effective than fall application, especially when conditions favoring nitrogen loss develop. Fall application is only suggested for regions where winters have frozen soils, rainfall is low, and soils have good but not excessive internal drainage. Benefits from delayed, sidedress, and split nitrogen applications are greatest where there is a high risk of nitrogen loss between planting and crop use. In these cases, nitrogen use efficiency and crop yield can be increased and nitrate leaching reduced by applying a major part of the nitrogen in-season, at or near the time when crop nitrogen demand is high. Sidedress application also allows for use of in-season soil tests and plant nitrogen stress sensing to adjust nitrogen rates. Many producers are reluctant to apply nitrogen in-season as they may be busy with other operations, concerned about yield loss due to early nitrogen stress, or concerned that wet weather will prevent application. Delay in sidedress applications can reduce yield, but this can be avoided or minimized by applying a portion of the needed nitrogen before or at planting as a split application.

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Several organic and inorganic nitrogen sources can supply nitrogen required for optimum crop growth. Manure sources have characteristics that make nutrient management different and sometimes more complicated than fertilizer. These characteristics include a mix of organic and inorganic nitrogen forms, variation in nitrogen concentration and forms, handling as a liquid or solid, and relatively low nutrient concentration requiring large application volumes. Since manure nitrogen composition can vary significantly, sampling and laboratory analysis are always needed. Anhydrous ammonia is widely used for direct application because of its relative low cost and high nitrogen concentration. Many safety features must be considered when transporting and applying anhydrous ammonia, and strict safety procedures must be followed during handling. It can be applied preplant or sidedressed in row crops. Soil moisture content and soil physical conditions should be appropriate when anhydrous ammonia is applied in order to avoid volatile losses. Shallow placement may result in early season crop seedling or root damage from free ammonia. Proper depth and injection in good soil conditions helps avoid such problems. Addition of a nitrification inhibitor with late fall application may be beneficial to slow nitrification in the fall and early spring.

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Dry urea is widely used as a broadcast nitrogen product for many crops. It converts quickly to ammonium, especially in warm-moist soils. In no-till situations, ammonia volatilization from surface application may be a concern. Incorporation soon after application, or injection, places urea into the soil and avoids loss of ammonia. If surface application with no incorporation is planned, then urea can be treated with a urease inhibitor to slow urea conversion to ammonium. Urea-ammonium nitrate solution is widely used as a broadcast and injected product for many crops. It is popular because of the versatility as a liquid, as well as widespread availability and applicability. The nitrate portion is immediately subject to leaching and denitrification upon application. Urea-ammonium nitrate solution can also be banded on the soil surface by dribbling. Ammonium nitrate use has decreased due to regulations and safety issues. Both the ammonium and nitrate portions are immediately available for plant uptake. The nitrate portion is immediately subject to leaching and denitrification upon application. There is no volatile loss potential from surface application on most soils, with some on calcareous soils. There are also products that have varying chemical structures or are coated to slow the conversion to plant available inorganic N or control the available nitrogen release timing. These products have received the most use in specialty crops and turf.

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An important part of optimizing crop response to fertilization is ensuring proper nitrogen placement. Maximizing crop nitrogen uptake reduces the potential for nutrient loss, and placement can be a powerful management tool to help minimize nitrogen losses. Anhydrous ammonia must be injected into the soil, if it were surface applied the majority would simply go into the air. Urea and urea-ammonium nitrate solutions can be surface applied, but injection avoids potential volatile losses. Banding nitrogen beside and below seed placement at planting is a viable approach to have a high nitrogen starter available for early growth. Broadcast applications uniformly distribute nitrogen across the soil and are often applied preplant or prior to emergence. In conjunction with incorporation, applied nitrogen is mixed uniformly within the upper rooting zone. Irrigation systems, especially pivot and drip systems, can be fitted with equipment to apply nitrogen solutions with the irrigation water. This method has the advantage of avoiding a separate field operation to apply nitrogen and allows for multiple applications throughout the season to “spoon feed” the crop.

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There is no one nitrogen best management practice to achieve maximum economic return and limit nitrate loss to water systems However, when considering suites of practices to utilize, the right rate is an important place to begin. No matter the rate recommendation calculation used, rates should be based on research derived response to application rate and economic return to nitrogen application. Pre-plant soil sampling for residual nitrate-nitrogen is useful in dry areas, areas with frozen wintertime soils, and situations with large carryover nitrate. In-season soil nitrate sampling is used for adjusting sidedress application rates and where mineralization of organic nitrogen is uncertain. Plant sensing tools, like chlorophyll meters and canopy sensors, are used to access cereal crop nitrogen stress and adjust in-season nitrogen rates. Nitrogen rates should be specific for the crop rotation, be adjusted for prior crops, and account for plant-available nitrogen from manure applications.

Slide 19.

Many nitrogen sources can be used with little differences in efficiency if management, rate, and timing are correct for the source. Manure and other organic nitrogen sources should be analyzed for nitrogen content. Manure sources with high ammonium content should be managed similarly to ammonium-containing fertilizers. Manure sources with high organic matter may need to be applied well in advance of crop nitrogen need to allow for conversion to plant available nitrogen. Where nitrogen loss conditions are likely, controlled release fertilizers can delay available nitrogen release past times of loss potential. Nitrogen placement should be optimal for plant uptake and avoidance of volatile loss at and after application with manure and with urea containing fertilizers. Maximizing crop nitrogen uptake through proper fertilizer and manure placement also reduces potential for loss. Nitrogen placement is not as important as with nutrients that have limited movement in soil, as ammonium nitrogen is converted to nitrate and nitrate can move in the soil root zone and with water uptake by plants. However, in dry conditions, nitrogen placed within the root zone can enhance crop uptake.

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The ultimate goal of nitrogen management is to time nitrogen fertilizer and manure applications to supply available nitrogen that matches crop uptake needs while minimizing losses. In this sense, spring and sidedress applications are generally more effective than fall. Nitrification inhibitors can slow conversion of fall-applied anhydrous ammonia. However, they are most useful in northern geographic areas with cold wintertime conditions and frozen soils, rather than in areas with warm and open winter conditions. In-season nitrogen applications can avoid loss conditions that may occur before planting, and allow use of in-season soil nitrate testing and plant nitrogen stress sensing. Applying nitrogen with irrigation water can supply nitrogen during active crop uptake and supply small nitrogen amounts at multiple times. Yield penalties from late sidedress applications can be minimized or avoided by applying a portion of needed nitrogen at planting.

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Adequate nitrogen management in production agriculture is crucial for a number of reasons, especially to improve crop production and profitability. In conjunction, management options must consider ways to improve nitrogen use efficiency and off-field environmental impacts. Nitrogen management is more complex in humid regions than in drier areas due to excess soil moisture increasing likelihood of leaching and denitrification losses. The soil is an open system, which means losses occur, but management can help reduce those. Overall, management of nitrogen inputs should include several aspects, applying nitrogen at optimal economic rates, using application timings to minimize nitrogen losses, using diagnostic tools to adjust rates, using appropriate nitrogen sources and placement for the production system, and incorporating precision agriculture technologies as appropriate.