Site-Specific Nutrient Management

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

Presentation Script: Overview - Chapter 1

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Overview

Slide 1.

This module will provide an overview of important concepts for soil fertility, plant nutrition, and nutrient management in agronomic systems for profitable and environmentally safe crop production. General concepts and some management practices will be presented. Even though these principles apply for most regions of the U.S., viewers are encouraged to review locally developed information and nutrient management recommendations.

Slide 2.

Understanding the principles of soil fertility is vital to efficient nutrient management, crop production, as well as environmental protection. There are seventeen chemical elements known to be essential for plant growth, and fourteen of these elements come from the soil. Each essential plant nutrient is needed in different amounts by the plant, varies in mobility within the plant, and varies in concentration in harvested crop components. For nutrient management, it is useful to know the relative amount of each nutrient that is needed for optimum economic yield and the relationship to amounts removed with crop harvest. It is also useful to know the nutrient transformations that occur within the soil and the potential mobility that might affect water quality.

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Three elements, carbon, hydrogen, and oxygen, are non-mineral nutrients because they are derived from air and water, rather than from soil. Although they represent approximately 95% of plant biomass, they are generally given little attention in plant nutrition because they are always in sufficient supply. However, other factors such as soil management, soil properties, soil quality, and the soil physical and chemical environment can influence the availability and crop growth response. The fourteen mineral nutrients are classified as either macronutrients, secondary nutrients, or micronutrients based on their plant requirements and relative fertilization need. There are six macronutrients: nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. Nitrogen, phosphorus, and potassium are often classified as ‘primary’ macronutrients, because their deficiencies are more common than the ‘secondary’ nutrients, calcium, magnesium, and sulfur. The micronutrients include boron, chlorine, copper, iron, manganese, molybdenum, nickel, and zinc. Most of the macronutrients represent 0.1 - 5%, or 100-5000 parts per million, of dry plant tissue, whereas the micronutrients generally comprise less than 0.025%, or 250 ppm, of dry plant tissue.

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To be classified as essential, the element needs to meet the following criteria: the plant cannot complete its life cycle without it, the element's function cannot be replaced by another element, and the element is directly involved in the plant's growth and reproduction.

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Each nutrient cannot be taken up by plants in its elemental form, but instead is taken up in an 'ionic' or charged form, with the exception of boron that can be also absorbed as boric acid which is uncharged. Knowing the form of a nutrient the plant absorbs helps us to better understand what controls the cycling, plant availability, and movement of that nutrient in soil and environment. In addition, understanding nutrient functions and mobility within the plant are useful in diagnosing nutrient deficiencies. Nutrient uptake by roots is dependent on root growth, the ability to absorb nutrients, and the nutrient concentration at the root surface. Roots come directly in contact with some nutrients (called root interception) as they grow; however, this only accounts for a very low percentage of the total amount of nutrients taken up by plants. Water moves toward and into the root as the plant uses water, or transpires. This process, called mass flow, accounts for a substantial amount of nutrient movement toward the plant root, especially for the mobile nutrients such as nitrate. Specifically, mass flow has been found to account for about 80% of N movement into the root system of a plant, yet only 5% of the more immobile phosphorus. Diffusion is the process where nutrients move from an area of high concentration to an area of low concentration. Diffusion accounts for the remainder of nutrient movement to plant roots. By fertilizing near the plant root, the plant is less dependent on exchange processes and diffusion to take up nutrients, especially phosphorus. The nutrients that are most dependent on diffusion to move them toward a plant root are relatively immobile (such as phosphorus and potassium), have relatively low solution concentrations, and yet are needed in large amounts by the plant.

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This table shows the chemical form in which every essential nutrient is taken up by plants. Some are taken up as negatively charged anions and some as positively cations.

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All nutrients move relatively easily from the root to the growing portion of the plant. Interestingly, some nutrients can also move from older tissue to newer tissue if there is a deficiency of that nutrient. Knowing which nutrients are mobile within the plant is very useful in diagnosing plant nutrient deficiencies because if only the lower leaves are affected, then a mobile nutrient is most likely the cause. Conversely, if only the upper leaves show the deficiency, then the plant is likely deficient in an immobile or less able to move, nutrient, because that nutrient cannot move from older to newer tissue. The table lists the six nutrients considered mobile and the eight nutrients considered immobile. Sulfur is generally considered immobile, but severe deficiency can affect the entire plant.

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Nutrient uptake does not always coincide with plant growth or the most critical need. For example, when corn growth represents 50% of its total mature biomass, the plant has accumulated approximately 100% of the total potassium, 60% of the nitrogen, and 55% of the phosphorus as shown in the figure. Phosphorus, for example, is critical for early plant growth due to cell division and multiplication at a time when the amount absorbed is very small. Therefore, supplying sufficient phosphorus early in a crop’s growing season is likely more important than during the middle of the growing season. However, late in the growing season, nutrients accumulate in the grain rather than in the leaves or stalk. Therefore, mid-season nutrient application may increase both quality and grain yield if other plant requirements are met, such as water. For example, nitrogen topdressed at tillering has been found to increase both yield and protein of winter wheat, especially at low soil nitrogen levels. Therefore, it is important to understand nutrient needs and timing of nutrient uptake for each crop that you’re working with. The principal goal of adequately managing nutrient application timing is to coordinate available nutrient supply in the soil with crop uptake requirements, and thus increase nutrient use efficiency and profitability, and reduce potential losses.

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This figure shows that yield can be severely affected when one or more plant nutrients are deficient, and when the nutrient deficiency is corrected, yield increases rapidly (Zone A) until the critical range of plant nutrient concentration is reached and yield is maximized. Nutrient sufficiency occurs over a wide soil concentration or nutrient application range, where yield is unaffected (Zone C). Increases in nutrient concentrations (by fertilizer application) above the critical range indicate that the plant is absorbing nutrients above that needed for maximum yield, commonly called luxury consumption, or if not taken-up by plants, excess plant available nutrients can contribute to environmental degradation. Elements absorbed in excessive quantities can reduce plant yield directly through toxicity or indirectly by reducing concentrations of other nutrients below their critical ranges (Zone D). The minimum amount of fertilizer required to maximize crop yield is called the agronomic optimum rate and it is located within Zone C. Even though the exact relationship between crop yield and nutrient rate will vary, the general shape of this relationship is relatively consistent for many crops and nutrients.

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Adequate nutrient supply, from the soil or applied nutrient, is vital to soil fertility and crop production. A limited supply of one of the essential nutrients can limit crop yield, although other factors such as another nutrient, light, heat, or water can also limit yield. The concept that a certain sufficiency level of a nutrient will limit plant growth or yield to a certain level is known as the law of the minimum. On the other hand, insufficient supply of multiple nutrients can interact to magnify reduction of yield. Therefore, how different nutrients behave according to these principles influences the degree and type of interactions between nutrients, and interactions with various growth factors. Although nitrogen is usually the first limiting nutrient for non-legume crops, without adequate supply of other nutrients, nitrogen nutrition can suffer. For example, increased nitrogen uptake and utilization with adequate potassium means improved nitrogen use efficiency and higher yields. The Figure shows how corn yield and nitrogen use efficiency were increased by fertilizer potassium application to a deficient soil, resulting in improved economic and environmental benefits.

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Nutrient diagnostic methods are tools for determining plant nutrient needs. They can include soil testing, plant analysis, crop canopy sensing, etc. The development of a diagnostic method for a given nutrient has historically involved four steps: first, selecting a soil/plant extractant or methodology to measure any crop characteristic related to plant nutrition need or response to application, second, correlation of test results with crop yield, amount of nutrient taken up by plants, and/or some other desirable crop characteristic, third, field calibrating the test result in terms of the amount of nutrient to apply to optimize yield or any other desirable crop characteristic for different soil-test results, and fourth, developing sufficiency interpretations. Fertilizer recommendations are then based on interpretation of test results from calibrated methods and fertilizer response trials.

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A combination of correlation and calibration research is necessary to gather information needed to answer nutrient application questions. Correlation is a relationship between the amount of nutrient extracted from soil or plant tissue by a laboratory test and nutrient uptake by plants and/or crop yield in the field. If such a relationship cannot be established, the analytical procedure has little or no usefulness. Sometimes the relationship can be established for only one nutrient and one crop, and on a particular soil type. This is a limitation that the producer or crop advisor must know and recognize, and the soil test should only be used for those specific conditions. For example, useful correlations have been established between the Bray-1 phosphorus test and percent of maximum yield for different crops in many states. These correlations help determine when soil test phosphorus is adequate for maximum yields and when no response from additional fertilizer is expected. Different crops such as wheat, corn, and soybean vary in their response to the amount of phosphorus in the soil as shown in this figure. Yields of both corn and soybean change rapidly with small differences in soil test phosphorus. Winter wheat requires higher levels of soil phosphorus to attain maximum yields. Because of crop differences, soil test correlation research must be conducted with different crops and across varying soil and climatic conditions.

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Calibration establishes the relationship between a given soil/plant test level and the yield response from an addition of the fertilizer nutrient to the soil. The figure represents a general example of this relationship. From crop yield responses, one can determine the amount of fertilizer needed over a range of test levels for many soils where a given crop is grown.

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After field correlation, experiments have been conducted, soil test levels of a given nutrient can be placed into categories related to the magnitude and probability of yield response. These categories give quick insight to fertilizer decisions. Their general meaning is given in this table in terms of the probability of a yield increase due to fertilizer application. This explanation illustrates much of the basic science behind using correlation-calibration to develop fertilizer recommendations, especially for nutrients considered immobile in the soil (such as phosphorus and potassium).

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Nutrient management involves managing all crop fertility inputs and other production practices to achieve efficient crop growth and water quality protection. Nutrient management plans for site-specific situations should minimize undesired environmental effects while optimizing whole-farm profits and production. Nutrient management planning involves several steps. Obtain accurate soil information for each field or management unit within a field. This could be use of existing NRCS approved soil maps and/or site-specific information layers such as fertility and yield maps. Soil samples should be obtained, handled, and analyzed according to state recognized soil fertility sampling and analytical procedures. Estimate realistic crop yield potential based on soil productivity or yield mapping, crop rotation and intended management. It is impossible to foretell growing seasons, but average yields over last four to six years should provide a reasonable estimate. It is important to be realistic. Calculate plant nutrient applications required. Nutrient recommendations and harvest removal information for common crops are available from the NRCS, local Extension offices, and University soil fertility publications and web sites. It is important to distinguish between nutrient recommendations for specific situations, crop uptake or use by the growing crop, and crop removal which is the physical removal of nutrients from the field with harvesting. Determine the plant-available nutrients in any livestock manure or other by-product amendments for estimating application rates. Account for any applicable residual nutrient contributions from fertilizer or manures applied in previous seasons, or previous legume crop effects on soil nitrogen supply.

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Also, determine need for purchase of off-farm nutrients, such as fertilizer or manure. If necessary, use an applicable environmental risk assessment tool, for example the phosphorus index, to determine the potential for offsite movement of nutrients on a field-by-field basis. The phosphorus index incorporates several site specific soil conditions and conservation practices to determine the probability of phosphorus movement in the landscape; such as soil test phosphorus level, soil permeability, field slope, manure and fertilizer applications, rainfall, and distance to surface water. Apply animal manures and commercial fertilizers to supply nutrients when needed using practices that ensure high use efficiency. Allocate nutrients in accordance with the 4R concept of right source, right rate, right timing, and right placement to improve site specific nutrient management and nutrient use efficiency. Keep records of nutrient sources, application dates, rates, and methods. Remember that nutrient management plans need to be accurate, understandable, and defendable. And, they need to be updated so they are current and most useful.