Soil Fertility Considerations for Continuous No-till Crop Production

Mark Alley
W. G. Wysor Professor Emeritus
Dept. of Crop and Soil Environmental Sciences
Virginia Tech
Blacksburg, VA 24061

Introduction

Adequate availability of essential plant nutrients is required for efficient and sustainable crop production in all tillage systems. No-till production systems have several unique considerations for providing crop nutrients because the soil is not being mixed with tillage, residues remain on the soil surface, and organic matter levels in the soil surface are increasing. Understanding these unique features of continuous no-till production systems enables growers and advisers to develop efficient and sustainable fertilizer programs. The overall objectives of the fertility program are to insure that (1) crop yields are not limited by nutrient availability; (2) crop yields are sustained through the replacement of nutrients removed in harvests; and (3) nutrient losses to the environment are minimized. These objectives are met though a consistent soil testing program that measures soil pH levels, available phosphorus and potassium and soil organic matter levels, and applications of needed lime and fertilizers that are optimized for rate, placement and timing.

Soil Acidity

Soil acidity level (soil pH) affects the availability of all plant nutrients, soil micro and macro organism activities, plant root growth directly if soil acidity levels are exceptionally low, and the mineralization of manures and soil organic matter. Soil pH levels between 6.0 and 6.5 optimize the availability of residual and applied phosphorus (P), potassium (K), the secondary nutrients calcium, magnesium and sulfur, and micro nutrients such as zinc, molybdenum and boron, while creating a favorable environment for soil microbial activity.

There is no reason to “guess” about soil pH levels and lime needs. A soil sample from the depth that lime can be mixed will clearly show lime needs. In preparing to initiate a continuous no-till system, acid soils should be limed to create optimum soil pH levels throughout the soil surface layer prior to deleting tillage. While we can neutralize soil acidity through surface applications of lime, (think about continuous forages and pastures), lime moves slowly through soil, and mixing the lime with tillage will eliminate the adverse affects of acid soil on crop growth.

After the continuous no-till system is begun, soil acidity can be neutralized over the long term with surface applications of lime because the vast majority of soil acidity in crop production will occur in the surface few inches. For example, manure and fertilizers are going to be surfaced applied, or injected in the surface 3 to 4 inches of soil, naturally acidic rainfall enters the soil through the surface, and decomposition of crop residues occurs in the surface of the no-till system. Once the continuous no-till system has been initiated, soil samples should be collected regularly, i.e. 2 to 3 years, from the surface 3 to 4 inches of soil in order to monitor soil pH levels and apply appropriate lime to maintain the soil pH. Separate soil samples can be taken from deeper depths, but if the soil pH levels is optimized prior to beginning continuous no-till, we can expect soil pH levels to acidify from the surface downward, and surface applications of lime will maintain optimum soil pH levels.

High quality dolomitic limestone should be used for maintaining soil pH, and such applications supply plant calcium and magnesium needs. Agricultural limestone in Virginia must have a minimum calcium carbonate equivalence of 85% and must have a particle size distribution of 90% passing a 20 mesh sieve, 50% passing a 60 mesh sieve, and 30% passing a 100 mesh sieve. The smaller particles sizes, i.e. passing a 100 mesh sieve, react rapidly with soil acidity (2 weeks) while the larger particles provide residual acid neutralizing capacity for 2 to 3 years depending on the application rate. In continuous no-till systems, we may expect that lime applications could be more frequent but at lower rates than in tilled systems, as soil acidity development is greatest in the soil surface of continuous no-till programs, and that acidity should be neutralized before it becomes detrimental to plant growth.

Nitrogen, Phosphorus and Potassium (The Macro Nutrients)

Nitrogen (N), P and K are macro nutrients because of the amounts needed by plants and the fact that these are generally the most widely deficient nutrients in soils used for growing crops. Phosphorus and K needs are determined by soil testing and because these nutrients are held by soils, fertilizer applications can be made at various times in the crop production system. As with soil pH, surface soil levels of P and K should be raised to levels that do not limit plant growth prior to beginning continuous no-till. With this situation, band and broadcast applications of fertilizers and manures can maintain residual soil fertility so that P and K do not limit crop yields, even though we can expect to see build up or stratification of these nutrients in the surface soil layers with increased years of continuous no-till. Availability of these stratified nutrients does not seem to be a problem in most soils as surface soil organic matter increases allow better root development and moisture holding capacity in the surface soil horizon. As with soil acidity, soil samples taken to a depth of 3 to 4 inches enables growers to monitor P and K fertility levels. Sometimes it is also useful to take soil samples to a 6 to 8 inch depth and separate into a surface 3 to 4 inch deep sample and a 3-6 or 4-8 inch deep sample to see how fertility levels are changing below the surface with increasing years in continuous no-till.

Developing an efficient (high yields, least cost per bu or ton, environmentally sensitive) N fertilization program requires an understanding of the N cycle in soil and accounts for inputs and outputs from all possible sources. Nitrogen in soil is very mobile as it is not held by mineral soil particles. Nitrogen in the nitrate form will move with soil water, can be transformed into gaseous compounds by microbes, or incorporated into the bodies of soil microbes or taken up by plants. Sources of N for crop plants include availability of N from legumes in the crop rotation, manures, cover crops, crop residues, mineralization of soil organic matter and fertilizers. All of these sources must be considered in developing field and season specific N fertilizer rates. Weather conditions must also be considered as cool temperatures and/or dry soil conditions will reduce N mineralization from organic sources (manures, crop residues, soil organic matter), and wet conditions can lead to leaching and/or denitrification losses. The determination of an optimum rate, time, and placement of N fertilizer requires consideration of all the factors mentioned as they relate to the time of N need for each specific crop. Experienced growers and advisers many times make these considerations without thinking, but development of a process to consider all factors for each field and season can increase efficiency.

The factors outlined in the preceding paragraph are not unique to continuous no-till crop production systems and must be considered for all crop production. The unique aspects of continuous no-till include increasing organic matter in soil surfaces, more crop residues on the soil surface, and more surface applications of fertilizers and manures in continuous no-till as compared to tilled systems. Increasing soil organic matter will lead to increased cycling of N from the soil organic matter since soil organic matter contains on average 5% N. While this will not change N recommendations in the initial years of no-till, changes can be expected as continuous no-till increases to 5, 10 and 15 years. More crop residues on the soil surface can result in higher N fertilizer requirements for the initial years of continuous no-till if the residues are high carbon to nitrogen materials such as rye straw. Microbes that decompose the residue require N and many times 15 to 20 lbs N/acre extra are required for the first several years as soil organic matter levels build. However, if legume cover crops such as vetch or clovers are used, extra N fertilizer is not needed because the legumes contain adequate N for the microbes decomposing the residues.

Increased efficiency of applied N fertilizers and manures for corn production can many times be observed with injection of the fertilizer or manure below the surface residues. Placing the fertilizer or manure below the residue surface decreases the potential for volatilization and runoff losses, minimizes the interaction of microbes in the surface residue with the fertilizer, and places the fertilizer closer to the plant root zone in the case of starter band and injected side-dress applications. Starter band placement of N and needed P for corn production in no-till systems has been shown to be almost always beneficial to increasing growth of corn seedlings, and to be the most efficient way to supply early season N. Split side-dress N applications completes an efficient N fertilization program for corn. However, the cost in terms of equipment and speed of application for band placements must always be considered.

The most widely used sources of N fertilizer in Virginia are currently urea ammonium nitrate (UAN) solution and dry granular urea. Both are excellent fertilizer sources but the urea component of these fertilizers can be subject to significant volatilization losses with surface applications if certain climatic conditions (warm, slightly moist soil surface, windy) occur during the first few weeks after application. If rainfall occurs shortly after application, the urea is washed into the soil and little if any loss occurs. Fertilizer additives known as urease inhibitors that can reduce volatilization losses from urea are available, but will be profitable to use only if the climatic conditions for volatilization losses occur.

Calcium, Magnesium and Sulfur (The Secondary Nutrients)

Calcium (Ca), magnesium (Mg) and sulfur (S) are considered secondary nutrients only because deficiencies of these nutrients are less wide spread than are deficiencies of N, P, and K. Calcium, Mg and S are required by plants in similar amounts to the macronutrients, and lack of any of these nutrients will decrease crop yields and reduce the efficiency of use of other nutrients.

Calcium and Mg are generally supplied in more than adequate amounts by dolomitic lime applications to our agricultural soils. Routine soils tests measure the levels of these nutrients in soil because Ca and Mg are both held by the soil clay and organic matter particles, and changes are easily monitored by tracking soil test results over years.

Sulfur differs from Ca and Mg in that it is not bound as tightly in soil as Ca and Mg, and is cycling in soils in much lower amounts than Ca and Mg. Sulfur is required for protein synthesis in plants and deficiencies result in lower yields, less efficient use of applied N fertilizer, and lower protein contents of forages and grains. Sulfur in soil occurs in soil organic matter and crop residues, and is released for plant uptake as organic materials decompose (mineralize). Another major source of S for crops has been through deposition from the atmosphere. However, as our nation has reduced S emissions from coal burning power plants and other industries, our fields are receiving significantly less S deposition, and more S deficiencies are being observed. Sulfur fertilizers have been routinely applied for many years on coastal plain soils in eastern VA where soil organic matter contents are low and the sandy soil textures are prone to leaching of sulfate S during the winter months. Sulfur deficiencies have not been widely observed on the soils in western VA that have higher soil organic matter contents, more frequent manure applications and the soils have silt and clay textures that are not as susceptible to leaching.

Soil tests for S are not as well calibrated as tests for P, K, Ca, and Mg, and thus should be used only as indicators that soil S levels might be moving toward a deficient situation. Plant tissue analysis is an excellent tool to use to determine if adequate S is available for plants. Tissue samples can be collected during early growth of corn, forages and small grains to detect low S levels while there is time to apply S before yield losses occur. Sampling instructions and critical levels of S in tissue are available from VA Cooperative Extension as well as numerous private labs that do S determinations in plant tissue.

Applications of sulfate-S fertilizers, i.e. ammonium sulfate, calcium sulfate, potassium magnesium sulfate, or magnesium sulfate, will correct S deficiencies as all of these fertilizers are water soluble and the sulfur is in the sulfate form which is the form taken up by plants. Elemental S is not readily available to plants as it must be transformed in soil from the elemental form to the sulfate form. While elemental S can be used to build overall soil S levels, availability is in terms of several weeks to months or more, and thus should not be used to correct an immediate S deficiency. There are no differences in application methods for no-till systems for S as the sulfate sources are water soluble and do not volatilize. Surface applications will quickly move into the soil with rainfall and be plant available.

Micronutrients

Micronutrients are essential plant nutrients that are required by plants in only small amounts. Concentrations of these nutrients in plant tissue will be in parts per million (ppm) while the macronutrients occur in plants in percents. For example, adequate zinc (Zn) concentrations in corn plant tissue will be 30 to 40 ppm with a critical level of 20 ppm, while N and K concentrations in corn tissue will be 3 to 5% (one percent equals 10,000 ppm). However, the micronutrients are essential and if plants do have adequate micronutrient availability, yields are reduced.

Fortunately, micronutrient deficiencies are not widespread, but boron (B) is recommended routinely for alfalfa as legume requirements for B are high, and B fertilization is not costly compared to the value of the crop. Zinc (Zn) is also widely used in corn production as reduced Zn availability in soil is associated with very high soil P levels and high pH (6.5 or above). Very high soil P levels occur on many of our soils that have received manure applications for extended periods.

There are no major differences in managing micronutrients for continuous no-till crop production systems versus tilled production systems. Soil tests for micronutrients are not as precise as tests for P and K, and thus should only be used as broad indicators of micronutrient availability to crops. Tissue tests are more reliable indicators and should be used to monitor the micronutrient levels in plants. Starter-band applications of Zn in corn production systems are more efficient than broadcast applications, while foliar applications of micronutrients are generally best for correcting in-season deficiencies.

Summary

Adequate plant nutrient availability is essential to an efficient and sustainable crop production program. Fields should receive adequate lime, P and K prior to beginning continuous no-till. Nutrient availability for high, sustained yields can be maintained in continuous no-till production systems through surface application of nutrients. Careful monitoring of soil pH and residual soil nutrient status with high quality (representative) soil samples taken from the surface 3 to 4 inches enables growers to make proper and timely lime, P and K applications.

Nitrogen requirements can be met in continuous no-till with surface applications, but considerations must be made for levels and types of surface residues, as well as the potential for volatilization losses of some widely used N fertilizers under certain climatic conditions. Injection of N fertilizers and manures below surface residues in no-till can reduce potential losses and increase N use efficiency. However, all costs must be considered.

Secondary and micronutrients are essential nutrients that must be considered in the crop production program. Tissue analysis of plants is the most exact way to monitor S and micronutrient nutrient needs, and should be used on a routine basis to determine if deficiencies exist, or if the fertilizer program is meeting crop needs.

Continuous no-till properly managed by maintaining surface residues and using cover crops is a production system that reduces soil erosion, and can increase yields and enhance soil quality with reduced expenses for tillage. Evaluation of nutrient needs can be done with soil and plant tissue testing on a regular basis and maintaining fertilizer and manure application records. Comparing application records with changes in soil test levels for nutrients such as P, K, Ca, and Mg as well as comparing plant issue levels of S and micronutrients provides a good picture of the success or need to adjust a lime and fertilizer program.