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Management Practices to Maximize the Nutrient-Use Efficiency

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Introduction

The main strategy for increasing crop yields and sustaining them at a high level must include an integrated approach to the management of soil nutrients, along with other complementary measures. An integrated approach recognizes that soils are the storehouse of most of the plant nutrients essential for plant growth and that the way in which nutrients are managed will have a major impact on plant growth, soil fertility, and agricultural sustainability (Peter *et al*, 2000). Farmers, researchers, institutions, and government all have an important role to play in sustaining agricultural productivity. To better understand the processes at work in retaining soil fertility, the next chapter discusses the role of nutrients in creating an enabling environment for plants to grow. This paper gives some current management practices to maximize the nutrient use effeciency.

"Nutrient management is defined as the efficient use of all nutrient sources."

The primary challenges in sustaining soil fertility are to 1) Reduce nutrient losses, 2) Maintain or increase nutrient storage capacity, 3) Promote the recycling of plant nutrients. In addition, cultural practices that support the development of healthy, vigorous root systems result in efficient uptake and use of available nutrients. Many management practices help accomplish these goals, including establishing diverse *crop rotations*, growing *cover crops*, reducing *tillage*, managing & maintaining *crop residue*, handling *manure* as a valuable nutrient source, *composting* & using all available wastes, *liming* to maintain soil pH, applying supplemental *fertilizers*, and routine *soil testing*. These beneficial cultural practices have multiple effects on the soil fertility factors described above, which makes it important to integrate their use and examine their effects on the complete soil-crop system rather than just a single component of that system.

Crop rotations

Growing a variety of crops in sequence has many positive effects. In a diverse rotation, deep-rooted crops alternate with shallower, fibrous-rooted species to bring up nutrients from deeper in the soil. This captures nutrients that might otherwise be lost from the system. Growing legumes to fix atmospheric N reduces the need for purchased fertilizer and increases the supply of N stored in soil organic matter for future crops. Biologically-fixed N is used most efficiently in rotations where legumes are followed by crops with high N requirements. Rotating crops also increases soil biodiversity by supplying different residue types and food sources, reduces the buildup and carryover of soil-borne disease organisms, and creates growing conditions for healthy, well-developed crop root systems.

Cover crops

Growing cover crops can be viewed as an extension of crop rotation and provides many of the same benefits. Growing legume cover crops adds biologically-fixed N. The soil surface is covered for a longer period of time during the year, so nutrient losses from runoff and erosion are reduced. This longer period of plant growth substantially increases the capture of solar energy and the amount of plant biomass produced, which in turn increases organic matter additions to the soil. This organic matter is a pool of stored energy in the soil, in addition to a nutrient storage pool, and is the food and energy source for soil organisms. If you look at a farming system as an '*ecosystem*', and measure the health or productivity of that ecosystem by its harvest of solar energy, then cover crops increase the health of farming systems by increasing the flow of energy and productive capacity through them.

The extended growth period obtained with cover crops also extends the duration of root activity and the ability of root-exuded compounds to release insoluble soil nutrients. A winter cover crop traps excess soluble nutrients not used by the previous crop, prevents them from leaching, and stores them for release during the next growing season. Cover crops can also suppress weeds which otherwise would compete with crops for nutrients.

Soil & water conservation practices

Soil erosion removes topsoil, which is the richest layer of soil in both organic matter and nutrient value. Implementing soil & water conservation measures that restrict runoff and erosion reduces nutrient losses and sustains soil productivity. Tillage practices and crop residue cover, along with soil topography, structure, and drainage are major factors in soil erosion. Surface residue reduces erosion by restricting water movement across the soil and tillage practices determine the amount of crop residue left on the surface. Reduced tillage or no-till maximize residue coverage. Water moves rapidly and is more erosive on steep slopes, so reducing tillage, maintaining surface residue, and planting on contour strips across the slope are recommended conservation practices. As discussed above, rotations and cover crops also reduce erosion. Soils with stable aggregates are less erosive than those with poor structure and organic matter helps bind soil particles together into aggregates. Tillage breaks down soil aggregates and also increases soil aeration, which accelerates organic matter decomposition. Well-drained soils with rapid water infiltration are less subject to erosion, because water moves rapidly through them and does not build up to the point where it moves across the surface. Drainage improvements on poorly drained soils reduce erosion. Improving drainage also decreases N losses from de-nitrification, which can be substantial on waterlogged soils, by increasing aeration.

Manure management

Returning manure to crop fields recycles a large portion of the plant nutrients removed in harvested crops. On farms where livestock are fed large amounts of off-farm purchased feeds, manure applied to crop fields is a substantial source of nutrient inputs to the whole farming system. However, just as nutrients can be lost from the soil, nutrient losses from manure during storage, handling, and application are both economically wasteful and a potential environmental problem. Soluble nutrients readily leach from manure, especially when it is unprotected from rainfall during storage. Nitrogen is also readily lost through volatilization of ammonia, both during storage and when manure is not incorporated soon after field application. Nutrient losses from manure also occur when it is applied at excessive rates. Analyze manure for its nutrient content and adjust application rates based on crop needs and soil tests. In addition to nutrient value, manure adds organic matter to the soil and provides benefits such as increased CEC for nutrient retention.

Compost and other soil amendments

In addition to manure, organic amendments such as bio-solids (sewage sludge), food processing wastes, animal byproducts, yard wastes, seaweed, and many types of composted materials are nutrient sources for farm fields. Bio-solids contain most plant nutrients, and are much 'cleaner' than they were twenty years ago, but regulations for farm application must be followed to prevent excessive trace metal accumulation. Composting is a decomposition process similar to the natural organic matter breakdown that occurs in soil. Composting stabilizes organic wastes and the nutrients they contain, reduces their bulk, and makes transportation and field application of many waste products more feasible. On-farm composting of manure and other wastes also facilitates their handling. Most organic materials can be composted, nearly all organic materials contain plant nutrient elements, and recycling all available wastes through soil-crop systems by either composting or direct field application should be encouraged. These practices build up soil organic matter and provide a long-term, slow-release nutrient source.

Inorganic byproducts also can be recycled through the soil and supply plant nutrients. Available materials vary by region, but rock powder from quarries, gypsum from high-sulfur coal scrubbers, and waste lime from water treatment plants are among the waste products that have been beneficially used. When considering the agricultural use of any byproduct, a thorough chemical analysis and review of possible regulations should be done to avoid soil contamination problems. Even seemingly benign byproducts should be analyzed and field-tested on a trial basis before using them on a large acreage.

Soil acidity and liming

Soil pH has strong effects on the availability of most nutrients. This is because pH affects both the chemical forms and solubility of nutrient elements. Trace metals such as Fe, Zn, and Mn are more available at lower pH than most nutrients, whereas Mg and Mo are more available at higher pH than many other nutrients. The ideal soil pH for most crops is slightly acid, about 6.3-6.8, because in that range there is well-balanced availability for all nutrients. This pH range is also optimum for an active and diverse soil microbial population. Some crops grow better at higher or lower soil pH than 6.3-6.8, usually because of specific nutrient requirements. Blueberries grow best around pH 4.5-4.8 and are Fe deficient when the pH is much over 5. Most crops suffer from Al, Fe, or Mn toxicity when soil pH is that low. Legumes do best at a higher pH than most other crops, due to the high requirement for Mo by N-fixing bacteria.

Limestone is the most commonly used material to increase soil pH. Liming also supplies Ca and dolomite lime supplies Mg as well. Liming rates depend upon the buffering capacity of a soil in addition to the measured pH. Buffering capacity, or ability to maintain pH within a given range, is related to CEC and increases as clay and/or organic matter content of the soil increases. The lime requirement to raise soil pH the same amount is much larger for fine-textured, high organic matter soils than for coarse-textured, sandier soils. Low soil pH is a more common problem than a pH that is too high, but reducing pH may be necessary for acid-loving plants. Elemental S is the most commonly used material to lower soil pH.

Fertilizer applications

Many materials can be applied to soil as sources of plant nutrients, but the term '*fertilizer*' is usually used to refer to relatively soluble nutrient sources with a high-analysis or concentration. Commercially available fertilizers supply essential elements in a variety of chemical forms, but most are relatively simple inorganic salts. Advantages of commercial fertilizers are their high water solubility, immediate availability to plants, and the accuracy with which specific nutrient amounts can be applied. Because they are relatively homogeneous compounds of fixed and known composition, it is very easy to calculate precise application rates. This is in contrast to organic nutrient sources which have variable composition, variable nutrient availability, and patterns of nutrient release that are greatly affected by temperature, moisture, and other conditions that alter biological activity.

The solubility of commercial fertilizers can also be a problem, because soluble nutrients leach when applied in excess or when large rains occur soon after fertilizer application. Increasing soil cation exchange capacity by increasing organic matter reduces the leaching potential of some nutrients. Management practices that synchronize nutrient availability with crop demand and uptake also minimize leaching. Both application timing and the amount of fertilizer are important. Splitting fertilizer applications into several smaller applications rather than a single, large application is especially important on sandy, well-drained soils. Excess nutrient applications can be eliminated or at least significantly reduced by soil testing on a regular basis, setting realistic yield goals and fertilizing accordingly, accounting for all nutrient sources such as manure, legumes, and other amendments, and using plant tissue analysis as a monitoring tool for the fertilizer program.

Biological and chemical approaches to soil fertility and nutrient management

The goals of effective nutrient management are to provide adequate plant nutrients for optimum growth and high-quality harvested products, while at the same time restricting nutrient movement out of the plant root zone and into the off-farm environment.

Biological processes in the soil control nutrient cycling and influence many other aspects of soil fertility. Knowledge of these important processes helps farmers make informed management decisions about their crop and livestock systems. How these decisions affect soil biology, especially microbial activity, root growth, and soil organic matter are key factors in efficient nutrient management. Managing soil organic matter and biological nutrient flows is complex because crop residues, manures, composts, and other organic nutrient sources are variable in composition, release nutrients in different ways, and their nutrient cycling is strongly affected by environmental conditions.

Chemical processes in the soil, to a large extent, control mineral solubility, cation exchange, solution pH, and binding to soil particle surfaces. Knowledge of soil chemistry makes it possible to formulate fertilizers that supply readily-available plant nutrients. Management of inorganic nutrient sources is simpler than organic nutrient sources, because of their known and uniform composition and the predictability of their chemical reactions.

Chemical and biological processes and their effects on plant nutrients cannot be clearly separated, however, since inorganic nutrients can quickly be incorporated into biological cycles. Chemical fertilizers should also be used only after accounting for all organic nutrient sources to avoid overloading the system and losing soluble nutrients. When used to supplement biological nutrient sources, they can help make more efficient use of other available plant-growth resources, such as water and sunlight, and work together with biological processes for a productive agriculture and healthy environment. Hence balanced use of organic, inorganic and biofertilizers is essential to maintain a good soil physical and chemical environment and also serve as energy source for the soil microbial biomass (Gopalasundaram et al., 2012).

Conclusion

At present, the environmental drawbacks of heavy fertilizer use are confined to some developed countries and a few regions in developing countries. Appropriate and responsible application of fertilizers will help to maintain yields and minimize pollution. By contrast, levels of fertilizer use in most developing countries are so low that there is little likelihood of major environmental problems from their application. In fact, greater application of organic and inorganic fertilizers in these areas could benefit the environment and increase yields. Success will ultimately depend on how well these complex actions and socioeconomic factors can increase crop yields in a sustainable manner and improve the food security of millions of smallholder farmers currently struggling with declining soil fertility and poor management of plant nutrients.

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