NITROGEN AND PHOSPHORUS: MECHANISMS OF LOSS FROM THE SOIL SYSTEM AND EFFECTS TO SLOW THOSE LOSSES AND INCREASE PLANT AVAILABILITY

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Nutrient management issues associated with production agriculture are becoming more of a concern and a focal point of discussion. Management considerations are no longer focused on just meeting yield goals or improved crop performance, but now include questions on how their use on agriculture lands impacts surface water, watersheds, soil quality, long-term health benefits and economic viability for the producer.

It has been estimated that 30 to 40 % of production inputs are associated with purchasing and applying commercial fertilizers. Inputs of commercial fertilizer are essential to meeting food requirements of our nation and the global community whose population continues to increase at an alarming rate. Few people would also argue that every individual should have access to safe, nutritious foods in feeding the people who inhabit the world now and in the foreseeable future. Without the availability of this precious resource of fertilizers the demand for raising the needed amount of food simply cannot happen. Many involved in global markets also recognize the relationship between global food security and the availability of inorganic fertilizer related to a countries food production goals and that countries sustainability.

However, the question has been asked and continues: Can we as a responsible community involved in production agriculture and specifically soil fertility do a better job at developing fertilizers products that improve the efficiency of those nutrients needed for sustainability of our population as well as address concerns for the environment and the far reaching impacts of our soil fertility recommendations.

Health productive soils have biological and chemical processes occurring simultaneously that decrease the efficiency of N and P fertilizers. This paper makes an attempt to address some of these issues and makes a case for the need to improve fertilizer applications by considering the use of Enhanced Efficiency Fertilizers.

Phosphorus: Phosphorus is essential and plays a critical role in all crops. Phosphorus influences photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement, and other plant processes including the hastening of maturity that may very well improve water use efficiency. Plants must have adequate P applied at the right time and the right form in order to complete production cycles without limiting yield potential. Finally and maybe the most critical, is that higher fertilizer phosphorus (P) prices are likely to continue, which is one reason why improved P efficiency is critical in obtaining higher crop yields, sustained profitability and improved environmental stewardship. If we are able to move more P into a plant with less being unaccounted for then we can improve phosphorus utilization and efficiency (Figure 1).

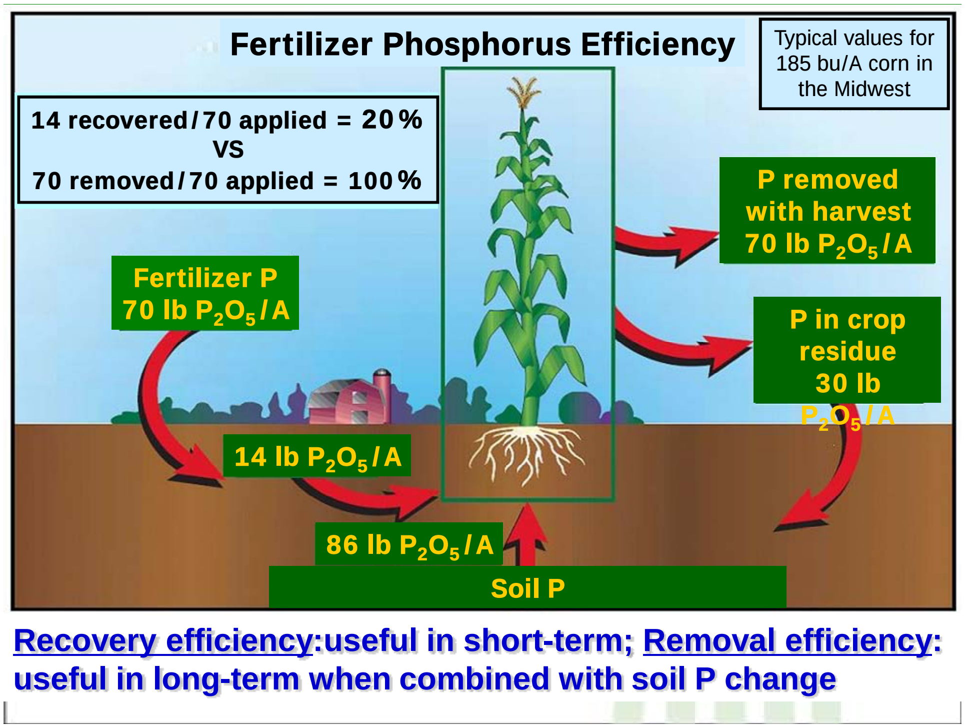

Figure 1: Fertilizer Phosphorus Efficiency in Soils--IPNI

Phosphorus is present in the soil in both the organic and inorganic form and is absorbed by the plant from P within the soil solution. The most common form of plant available P is inorganic (ortho-phosphate). Organic matter will also mineralize P similar to N and provide available P from background levels of organic matter as well as from the breakdown of manure and compost. It should be noted that many of our western soils with high P concentrations are a direct result of copious amounts of manure being applied. Immobilization or precipitation of fertilizer P also occurs reducing the concentration of inorganic P into soil solution. Phosphorus can be lost from the soil through erosion as well as crop removal. Phosphorus is also lost from some fields through soil solution and subsequent losses from a field in runoff. Reducing these losses or management of P fertilizer is a part of stewardship that each crop advisor, researcher and grower should both recognize and manage for improvements.

With all of these losses of P as factors to consider, the greatest loss in P efficiency is the fixation of P by antagonistic cations. Rapid reaction of applied P fertilizers with antagonistic soil cations of calcium (Ca), magnesium (Mg) in alkaline soils to form Ca and Mg phosphates and aluminum (Al), iron (Fe), oxides in acid environments to form Al and Fe phosphates. It has been estimated that there are over thirty phosphate combinations that are involved in this process known as P-fixation. This phenomenon is a worldwide concern that keeps efficiency of applied P fertilizers at relatively low levels and increases production costs. The efficiency of applied P fertilizer and initial year's recovery has been estimated at between 5 to 25 percent of the applied P the year of application. Increased crop production inputs and an environmental awareness of the fate of applied P fertilizers have increased the need for improved P efficiency (Figure 2).

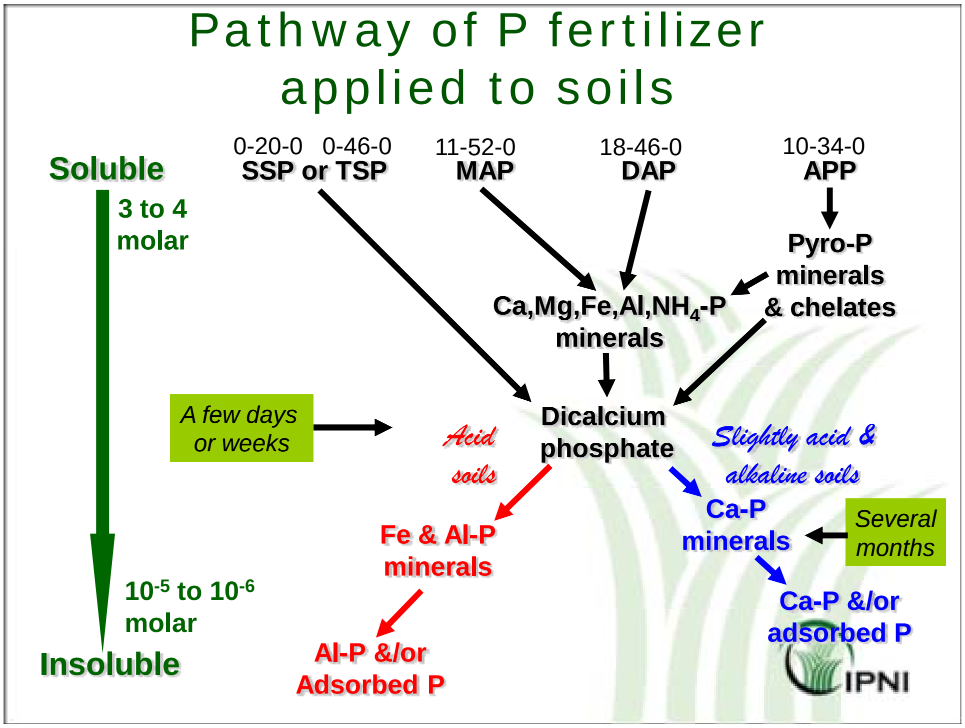

Figure 2: Pathway of P fertilizer applied to soils and precipitates formed--IPNI

Research has demonstrated management tools such as banding or direct seed applications as well as enhanced N and P formulations can in many cropping systems improve yields and nutrient use efficiency. Most of these techniques have been understood and demonstrated for many years and may also increase the efficiency of applied P fertilizer. Although P availability is considered to be near its maximum level at a near neutral pH (pH range 6.8 to 7.2) soils, there continues to be appreciable amounts of P fixation taking place. These efforts will continue, but there appears to be an improved chemistry that impacts the reactions of precipitates at a reactionary scale. This is surrounding the Phosphate granule or within the band itself. AVAIL appears to be just that.

AVAIL Mode of Action—AVAIL is a complex organic acid of maleic-itaconic acid copolymers and a patented family of dicarboxylic acid products. It is designed to sequester antagonistic metals (Al, Fe, Ca, Mg etc) in the soil around the fertilizer granule to reduce the tie-up of P and keep it in a plant-available form through most of the growing season of many annual crops. AVAIL is distributed world-wide by Specialty Fertilizer Products. Third party research trials including many western based University, Governmental and grower demonstrations have indicated wide consistency in improving P use efficiency that would be measured as either: improved yield, quality, tissue P concentration or improved soil P availability within the growing season. The Polymer is impregnated on to a wide array of dry granule P fertilizer or also formulated to be included in liquid formulations like ammonium polyphosphates or ortho-based liquid formulations that can be used in starter formulations. Data sets also include the applicability of applying AVAIL through drip or under some fertigation systems.

Mechanisms that Cause Soil N Losses and Decrease Nutrient Use Efficiency- Improving nitrogen use efficiency in crop production has been and is a goal of agronomists and crop producers since the beginning of commercial fertilizer use. Use efficiency can range widely but is seldom greater than 65-70% of applied N in the first year after application. Nitrogen carryover is possible but many factors influence the amount and the availability to the following crop.

Nitrogen loss mechanisms include ammonia volatilization from ammonia injection or from urea, leaching of nitrate and denitrification (figure 3). The magnitude of losses can be modified by method of N application. Subsurface banding, surface banding, mechanical incorporation into the soil and rain or irrigation shortly after application all lower N losses. Heavy soil surface residues tend to increase ammonia volatilization losses by preventing applied N from coming into contact with the soil and by their content of urease enzyme which mediates urea hydrolysis. Heavy residues also contribute to microbial immobilization of applied N in the decompositon of organic residues. The process of nitrification produces the nitrate anion which can move with water in the soil and depending on soil texture may move beyond the reach of plant roots. Nitrate-N is used as a terminal electron acceptor in place or oxygen by bacteria in water-logged soils leading to further N losses as elemental $N_2$and nitrous oxide (NO). Slowed nitrification in the soil can modify the rate and magnitude of both leaching and denitrification.

The fertilizer and chemical industries have sought to develop additives or coatings which can change the speed or outcome of these soil reactions. Classes of compounds include slow solubility compounds, plastic coatings, nitrification inhibitors, urease inhibitors and combinations of urease inhibiton and nitrification suppression materials which affects ammonia volatilization, the rate of nitrification and denitrification.

NutriSphere-N Mode of Action- A nitrogen fertilizer additive patented by Speciality Fertilizer Products, Inc., Nutrisphere-N, has been shown in laboratory and extensive field reseach to affect soil N reactions, decreasing the concerns associated with weather and management by increasing yield and improving N use efficiency over a wide range of environmental conditions. Nutrisphere-N™ [butenediodic methylenesuccinic acid] is a complex organic acid with a large negative charge (1800 meq 100 g^{-1}). When impregnanted on an N fertilizer like urea, Nutrisphere-N™ on the fertilizer granule remains in microenvironment with the dissolved urea influencing N conversion processes. In the soil the high negative charge density of Nutrisphere-N sequesters nickel essential for bacterial production of the metalloenzyme urease. Without the urease enzyme the hydrolysis of urea into ammonium ceases. Since this mechanism is the primary pathway for conversion of urea N in the soil, the efficacy of urea plus Nutrisphere-N would be less sensitive to environmental or management conditions.

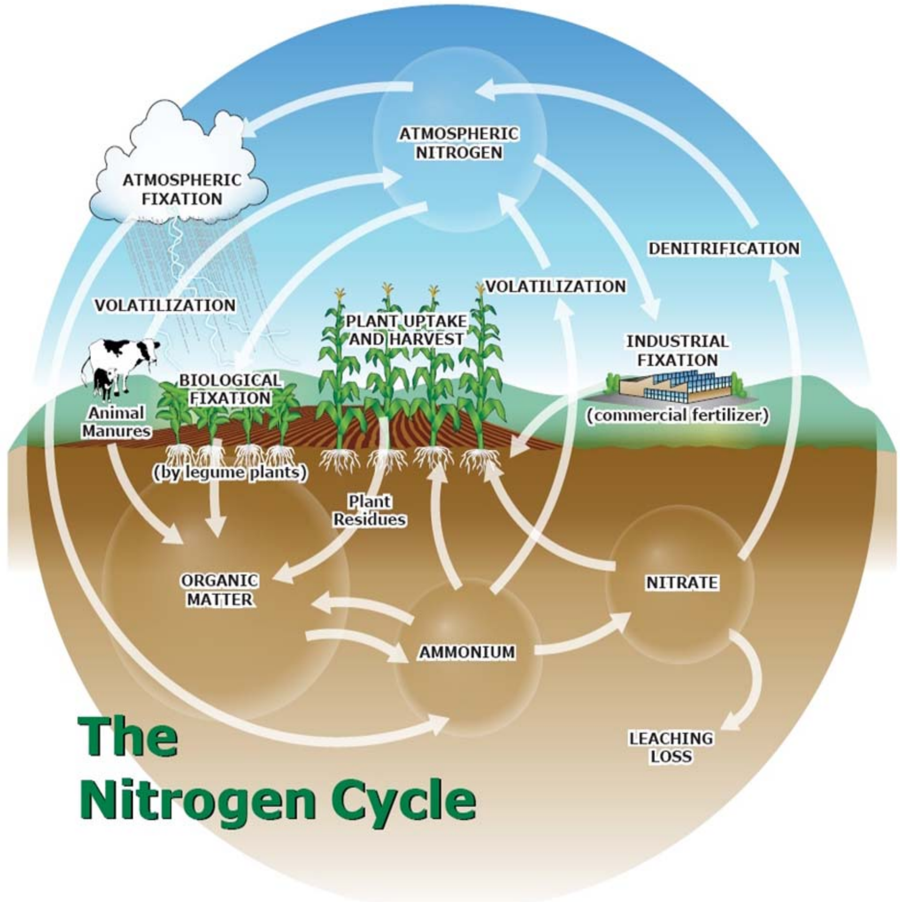

Figure 3. The Nitrogen Cycle-IPNI

Soil nitrogen in the ammonium form is subject to soil bacteria that will reduce it to the nitrate form of nitrogen. *Nitrosomonas* and *Nitrobacter* bacteria which are responsible for the nitrification of ammonium in the soil require Cu and Fe. NutriSphere-N complexes with the Cu and Fe in the microenvironment near treated urea to inhibit the bacteria and slow the nitrification process. Keeping the nitrogen in the ammonium form longer in the soil increases the efficiency of the nitrogen by keeping it in a form that is less susceptible to leaching.

This paper will discuss and compare commercially available Enhanced Efficiency Products that increase the efficiency of nitrogen and phosphorus fertilizers. The J.R. Simplot Company and its distributors are focused on AVAIL^{TM} for improvements of phosphorus and NutriSphere-N^{TM} for improvements of nitrogen fertilizers. Both of these materials are registered trademarks of the Specialty Fertilizer Company of Leawood, KS. Additional information on the AVAIL and NutriSphere-N technologies can be found at www.simplot.com/agricultural/plant/products.cfm .

PROCEEDINGS

OF THE

WESTERN NUTRIENT

MANAGEMENT CONFERENCE

Volume 9

MARCH 3-4, 2011
RENO, NEVADA

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