IPNI
Plant Nutrition TODAY
Better Crops, Better Environment...through Science

From Scientific Staff of the
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WILL BIOTECHNOLOGY REPLACE NITROGEN FERTILIZER?

Research in molecular biology has put highly desirable and widely adopted traits for herbicide and pest resistance into crop plants. It is expected that the science will soon impact the rate of progress in yield improvement, and that genetically modified plants may show increased stress tolerance and nutrient use efficiency. What is the likelihood of being able to replace N fertilizer altogether?

Plants of the legume family have always been able to make their own N. A complex symbiosis with rhizobial bacteria lets them make the ammonium they need for protein synthesis directly from the N gas abundant in the air. They fix N using the nitrogenase enzyme of the bacteria. It costs the plant something for energy, but perennial species like alfalfa are efficient enough at it that they rarely respond to N fertilizer. Transferring the trait to non-legume crops would be a major challenge. The most important grain crops of the world—the cereals…corn, wheat, and rice—are all non-legumes. They take most, if not all, of their N from the soil. They generally do not produce high yields without N fertilizer.

Research on the genetic control of the legume symbiosis has led to identification of the plant genes that trigger the formation of nodules. A breakthrough was reported in the summer of 2006. Dr. Giles Oldroyd, a scientist working at the John Innes Centre (JIC) in Britain, said: "The fact that we can induce the formation of nodules in the plant in the absence of the bacteria is an important first step in transferring this process to non-legumes…. However, we still have a lot of work before we can generate nodulation in non-legumes."

Considering that both the plant and the bacteria need to take many more steps after nodulation in order to begin the process of effectively taking N from the air, it is clear that the science behind the transfer of the process to non-legumes is in its infancy. The genome (DNA sequence) of the rhizobial bacteria that fix N in alfalfa was published in 2001. At least 100 scientific studies since then have cited the article—which shows that research is active. However, owing to the complexity of the processes involved, much remains to be discovered.

The Brazilian Agricultural Research Corporation announced in December 2006 that it has finished mapping and sequencing the genome of another bacterium that works as a natural fertilizer. *Gluconacetobacter diazotrophicus* is found in sugarcane, sweet potatoes, and pineapples. As an endophyte—living between the cells of the roots of its host—its association is not as intimate as that of the rhizobia that invade the root cells of a legume to form nodules. However, this organism is responsible for the low N requirements of sugarcane and contributes to the high energy efficiency of the Brazilian ethanol industry.

Genetic improvement has contributed to steady yield gains in North American corn production. Since 1940, yields have been on an increasing trend, growing by about 1.8 bushels per acre each year. Some anticipate that genetic engineering will almost double the rate of yield improvement. The past increase in yields has been accompanied by improved N use efficiency. Biotechnology is reducing the amount of N fertilizer used to grow a bushel of corn, because yields are increasing faster than rates applied.

Sunlight, water, and nutrients remain the major factors limiting crop yields. Biotechnology has potential to improve the efficiency by which plants utilize all three. But growing global demand for food, fuel, fiber, and feed ensures that plant nutrient inputs will continue to play an important role for the foreseeable future.

—TWB—

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Abbreviations in this article: N = nitrogen; DNA = deoxyribonucleic acid.

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NUTRIENT STRATIFICATION AND NO-TILL – IS IT A PROBLEM?

Farmers have adopted conservation tillage practices at a very high rate across the northern Great Plains, a practice we are thankful for each spring when the wind blows. However, a common question asked about no-till seeding systems is whether there is any nutrient stratification due to a lack of soil mixing, and if this stratification is a problem for crop access to soil nutrients?

Nutrient mobility in the soil plays a big role in evaluating stratification. Those nutrients that end up in a chemical form which is mobile, like nitrate and sulfate, generally are less stratified. The less mobile nutrients, like P and K, bind to soil and are primarily found in the surface 6 inches, regardless of tillage practices.

Phosphorus and K have been found to accumulate near the soil surface to a greater degree after 10 years of no-till than with conventional till. In research trials where both P and K were measured, they generally were found to be at a higher concentration in the surface 2 to 3 inches relative to conventional till. In fact, some studies found that the P and K accumulated at the same depth, which also happened to be the depth that the fertilizer had been banded – an interesting finding and confirmation about the low movement of these nutrients.

However, the next important question was this: Did stratification impact nutrient uptake? Studies in northern Alberta and central Montana both reported that when nutrients were stratified in the no-till soil, this did not impact the uptake of the nutrient by the next crop in rotation. In fact, in one instance P uptake was actually improved in the no-till plots. This is good news for those folks who are concerned about the change in soil nutrients with no-till.

Why would stratification of nutrients in no-till fields not impact crop uptake? There are a few factors we need to consider when asking this question. First of all, many research projects have reported that the surface soil moisture in no-till fields is higher than tilled fields. As a result, we would expect more roots to grow in this surface region, one which is also rich in nutrients. Secondly, many of our prairie soils are high in K, and some have residual P from years of application in the seed row. As a result, many of these soils will not show a high response to applied fertilizer P or K. In fact, many farmers are applying P at a rate which replaces what they remove on an annual basis, and rely on the residual nutrients from these bands to support crops for several years to come.

Nutrient stratification is an issue to monitor, but not one to worry about at this time. The results from these three research trials in Alberta and Montana indicate that we do have nutrient stratification occurring in our no-till fields. However, the two that measured crop uptake indicate that this is not a problem to date, but one we continue to closely monitor.

—AMJ—

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Abbreviations in this article: P = phosphorus; K = potassium.

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WHICH NUTRIENT SOURCE IS BETTER?

There is a lot of confusion over organic and commercially produced fertilizers. Every fertilizer, whether it is called organic or not, is a chemical fertilizer that supplies nutrients for plant growth. Manures, composts, and mulches all break down in the soil to release the same nutrients as commercial fertilizers.

One of the biggest differences between commercial and organic nutrient sources is that organics usually must first be decomposed by soil microorganisms before their nutrients are available to plant roots. The speed of this breakdown process is often difficult to predict…and it can range from weeks, to months, or years for the nutrients to be released. Frequently, these nutrients are still being released from the organic fertilizers long after the crop has been harvested or become dormant.

With commercially produced fertilizers, the nutrients are rapidly available to nourish the plants. It is usually easier to manage these nutrient sources since their composition is consistent and their behavior is well understood.

The composition of organic nutrient sources, such as manure or compost, reflects whatever was present in the animal feed, the bedding, or the starting compost material. This commonly results in the organic material containing an imbalance in the ratio of essential plant nutrients. For example, long-term use of manures often results in a buildup of soil P because crops typically require all the N in manure while not requiring all of the P.

The nutrient content of commercially produced fertilizers is carefully controlled and blended to meet the needs of each specific crop and field. A soil that already contains an adequate supply of any nutrient may not receive additional application of that fertilizer for a season…thereby avoiding unnecessary and wasteful inputs.

Farmers may be reluctant to fully utilize manures due to their bulky nature and low nutrient concentration. For example, to supply N to a typical corn crop using commercial fertilizer urea, a farmer might apply 430 **pounds** of material per acre. Using dairy manure, a farmer would need to apply up to 40 **tons** of manure per acre to provide the same amount of available N. The labor and energy costs associated with applying that much material are not small!

Clearly, organic nutrient sources may be excellent materials for crop production and should always be used appropriately, but there is no need for confusion over the superiority of any source. All nutrient sources…. organic or commercially-produced…can play an important role in sustaining healthy food production.

—RLM—

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Abbreviations in this article: N = nitrogen; P = phosphorus.

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2006 CORN AND SOYBEAN NUTRIENT HARVEST IN THE NORTHCENTRAL U.S.

In 2006, Iowa had the highest average corn yields of the six states of IPNI's Northcentral U.S. Region: Iowa, Illinois, Indiana, Minnesota, South Dakota, and Wisconsin. State average corn yields in 2006 ranged from 97 to 166 bu/A. Average P removal rates were 34 to 70 lb P_2O_5/A and quantities of K removed were 29 to 50 lb K_2O/A. In 2006, the majority of the states showed decreased corn yields and quantities of nutrients removed. Only two states, Illinois and Indiana, were up from last year. Nationally, the U.S. average corn yield in 2006 was 149.1 bu/A, up 0.7% from 2005.

Corn: Average state yield per acre, state average P and K removal per acre, and yield and removal percent change from 2005.

State	2006 avg. yield, bu/A	2006 avg. removal, lb/A		Change in yield and removal from 2005, %
		P_2O_5	K_2O	
IA	166.0	62	50	-4.0
IL	163.0	70	46	14.0
IN	157.0	58	42	1.9
MN	161.0	55	31	-7.5
SD	97.0	34	29	-18.5
WI	143.0	54	41	-3.4

Sources: USDA National Agricultural Statistics Service and state Extension publications.

Soybean yields in 2006 ranged from 34 to 50.5 bu/A, with Iowa again having the highest average yield. Quantities of P removed by soybean harvest ranged from 26 to 41 lb P_2O_5/A. Potassium removal was 44 to 76 lb K_2O/A. Like corn, Illinois and Indiana were the only states to see increases. Indiana's corn and soybean yield increases were similar, but in Illinois, corn yield increases far outpaced those of soybeans. U.S. soybean yields averaged 42.7 bu/A, down 0.7% from 2005.

Soybean: Average state yield per acre, state average P and K removal per acre, and yield and removal percent change from 2005.

State	2006 avg. yield, bu/A	2006 avg. removal, lb/A		Change in yield and removal from 2005, %
		P_2O_5	K_2O	
IA	50.5	40	76	-3.8
IL	48.0	41	62	3.2
IN	50.0	40	70	2.0
MN	44.0	36	44	-2.2
SD	34.0	26	48	-2.9
WI	44.0	39	44	0.0

Sources: USDA National Agricultural Statistics Service and state Extension publications.

Nutrient management will need to be adjusted for 2006 production levels and nutrient removal rates. Recalculating historical average yields and re-evaluating soil sampling schedules may be in order. In addition, growers should consider sampling corn and soybean grain for nutrient content to gain insight into nutrient removal rates occurring in their local area and under their management practices and environmental conditions.

—TSM—

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Abbreviations: P = phosphorus; K = potassium; lb = pounds; A = acre; bu = bushel

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MANAGEMENT TOOLS OPTIMIZE CORN RESPONSE TO SPRING-APPLIED NITROGEN

Genetic improvements have helped raise the yield potential of corn across the U.S. It is the proper management of all agronomic inputs, however, that enables farmers to capture higher yields, which are necessary for profitable production. Tools are available to determine the appropriate N rate for individual fields and sub-field management zones. Among the most reliable resources which farmers depend on are results from local, replicated university N rate research trials. In the absence of local university research data, on-farm replicated tests can be quite helpful as a guide in choosing N rates for specific soils, environmental conditions, and adapted corn hybrids.

The most successful corn growers and crop advisers always consider N credits for recent past and current manure applications, and they also factor-in N credits for any rotational legume crops (or cover crops) in their N rate decisions. With increased energy costs—-which directly impact N costs—proper N credits from these sources can really help improve the bottom-line.

Other tools that can be used to estimate either the residual or current soil nitrate-N supply, to help adjust the total N rate applied, include: 1) spring preplant soil nitrate-N test (often helpful where manure has been applied); 2) late spring soil nitrate-N test (after the crop has been planted); and 3) pre-sidedress soil nitrate N test (before the second N application). These have proven helpful, especially in less humid and lower rainfall production regions. They may also be reliable in other regions where research has calibrated the measured nitrate-N and meaningful interpretations have been developed. Demands for labor and time have sometimes prevented the wide-spread adoption of these tools.

Agronomic scientists have made valiant efforts to develop soil tests which estimate the potentially-available N provided by release of inorganic N from soil organic matter (mineralization). Some of these tests have met with moderate success, primarily in geographic areas where they were developed. Use beyond the locally-calibrated geography has frequently proven less successful. For example, one of the more recent soil N mineralization tests – the "Illinois N test" (also referred to as the amino-sugar N test) — has not worked well in a number of other states where it has been tested, according to a paper presented at the 2006 North Central Extension-Industry Soil Fertility Conference in Des Moines, Iowa.

Skilled agronomists often use in-season plant tissue testing, in combination with soil testing, to refine and verify adequate plant N nutrition. Newer technologies that are also being utilized and improved through local calibration include: 1) remote sensing of color and biomass (by satellite or airplane, calibrated to N nutrition); 2) on-the-go sensing (as equipment moves over the field during vegetative growth); and 3) hand-held chlorophyll meter (for leaf greenness estimation, related to N nutrition). In some countries, where there is considerable knowledge about adapted varieties or hybrids, simple calibrated color charts are used to determine if crop N levels are sufficient (e.g. rice in southeast Asia).

Additives like urease or nitrification inhibitors can help control or maintain the specific form of N in the source used, and may enhance crop N recovery. Slow- or controlled-release N sources may also have a place on some farms and fields, depending on the N loss mechanisms involved.

Although every tool can not be used on every field, we have the capability of using many different tools to refine spring-applied N management for corn in 2007 — for economic benefit and improved environmental stewardship. What will you add to your plan to improve N management in corn fields this year?

—CSS—

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ENHANCED EFFICIENCY FERTILIZERS

The idea of improving the efficiency of applied crop nutrients is not new. For example, one slow release N product (urea formaldehyde) was patented in Europe in 1924, with production in the U.S. beginning in the 1950s. Enhanced efficiency (EE) fertilizer materials have long been used in specialty applications such as turf and ornamentals. However, because of increased fuel and fertilizer costs and improvement in manufacturing technology, there is a growing interest and usage of these materials in production agriculture.

The American Association of Plant Food Control Officials has described EE fertilizer as "fertilizer products with characteristics that minimize the potential of nutrient losses to the environment, as compared to 'reference soluble' products." This description says nothing about agronomic effectiveness, but we can generally assume that in most cases agronomic effectiveness and reduced environmental impacts go hand-in-hand. Notice too that the description is not nutrient specific…in other words, it is not restricted to N fertilizers. Nevertheless, most EE technologies are applied to N.

Commercially available EE N fertilizers generally fall into one of three categories: 1) Synthetic organic compounds containing N, e.g., urea-aldehyde condensation products (urea-formaldehyde [UF] reaction products, IBDU), triazines, etc.; 2) Physical coating or barrier around soluble N fertilizer, such as SCU, PCU, and combination products; 3) Stabilized materials, such as nitrification and urease inhibitors.

The mechanisms controlling release of N from these materials is variable…differing among sources. For example, with UF products temperature is the major factor controlling N release because it is a biological (microbial) breakdown. On the other hand, release of N from IBDU involves chemical decomposition and is thus less temperature-dependent.

Several EE N fertilizers involve applying technology to commonly available soluble products. One example is the coated urea products. Polymer-coated urea products have made significant inroads in production agriculture over the past few years. An important aim of these materials is to match the kinetics of N release with the kinetics of crop uptake. Another example is the treatment of urea or UAN with urease and/or nitrification inhibitors. These materials have been shown to reduce the loss of N through volatilization or leaching where potential for loss is high. A complete coverage of EE fertilizer materials is far beyond the scope of this brief article. More information on these products is available through extension and industry professionals, and in published literature. Nonetheless, a few brief summary statements can be made concerning the suitability and advantages of these materials. EE fertilizer materials are best suited for: • Traditional applications, e.g., turf, ornamentals, nurseries, etc.; • High value crop production; • In crops with shallow root systems; • Where potential for N loss is large, e.g., surface application, sandy soil, high rainfall, etc.; • Environmentally sensitive circumstances.

Where used appropriately, these materials can aid in the accomplishment of our primary objective…to get more of the applied nutrient into the plant. It follows then that they have the potential to reduce loss of nutrients to the environment. Other potential benefits include reduced application frequency, more uniform plant growth, and improved yields. It's important to understand that EE fertilizer materials are tools, not "magic bullets". **And, as with any tool, we must understand where it fits and how to use it to best serve its purpose.**

—WMS—

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Abbreviations in this article: N = nitrogen; IBDU = isobutylidene diurea; SCU = sulfur-coated urea; PCU = polymer-coated urea.