BETTER CROPS
WITH PLANT FOOD

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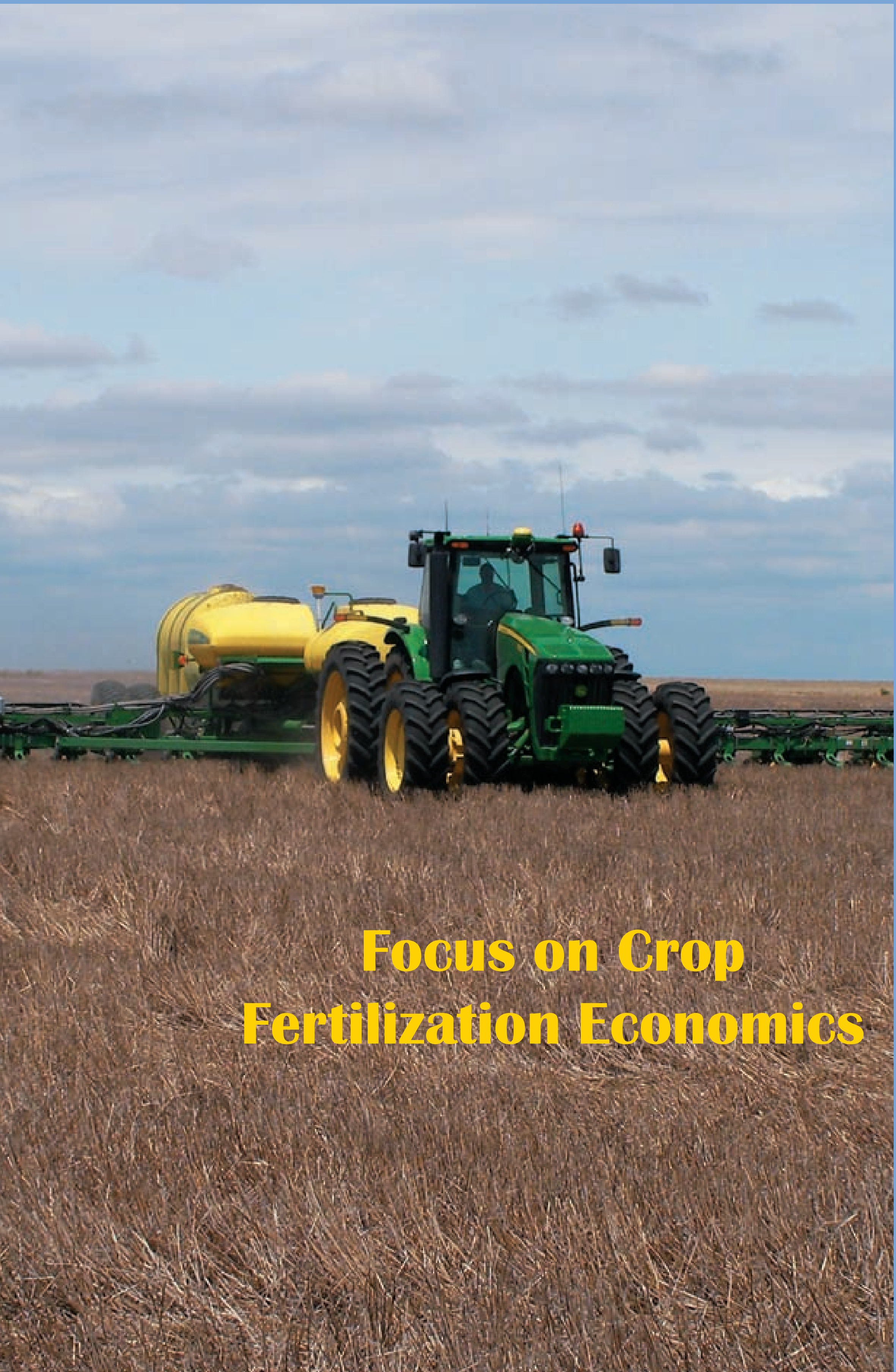

Focus on Crop Fertilization Economics

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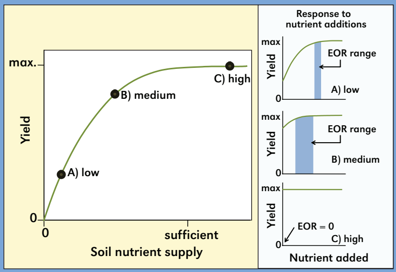

Nutrient Management within a Wheat-Maize Rotation

Corn Fertilizer Decisions in a High-Priced Market

Also:

Balanced Fertility Still Pays in Irrigated Corn

...and much more

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Vol. XCII (92) 2008, No. 3

Our cover: Planting at Kastens Inc. Farms, north central Kansas.
Photo by Dietrich Kastens
Editor: Donald L. Armstrong
Assistant Editor: Katherine P. Griffin
Circulation Manager: Carol Mees
Design: Kathy Hefner

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Fundamentals of Fertilizer Economics Emphasized

Record high fertilizer prices are causing many producers to ask: "Can I afford to fertilize?" And, record high crop prices beg the question: "Can I afford not to fertilize?" Answers to such questions are complex and should be based on an understanding of sound economics and associated risks. Fertilizer prices are not expected to decrease in the near future because the supply/demand market is so tight. Current fertilizer prices are related to increased demand caused by an increasing global need for more food and a more diverse diet, escalating energy prices, rising transportation costs, a weak U.S. dollar, and increased crop production required to produce biofuels. Fertilizer is a world market commodity subject to global market forces, volatility, and risks.

Growing a crop always carries some risks…some related to weather and some to the market…but with today's input prices the investment in a crop is greater than ever before and so is the risk. But, similar to any investment, increasing risk also provides the potential for higher returns, particularly with recent strong crop prices, which are not expected to decline substantially in the near future. The world's grain stocks to use ratio is at its lowest level in the last 35 years and consumption has exceeded grain and oilseed production in 8 of the last 9 years.

Farmers cannot afford to use nutrients inefficiently. They must do all in their power to manage fertilizers properly to minimize risk and to maximize potential returns. The risk of applying too little fertilizer and producing a sub-optimal crop and not capitalizing on high crop prices or the risk of applying too much fertilizer and incurring unnecessary costs must both be considered. This issue of *Better Crops with Plant Food* will review some of the basics of fertilizer economics in North America and around the world and will reinforce some of the principles of fertilizer management designed to help ensure nutrient use is efficient and also effective in accomplishing the multiple objectives of crop system management. BC

NORTH AMERICA

Principles of Allocating Funds across Nutrients

By T. Scott Murrell and Tom W. Bruulsema

When funds are limited, farmers and advisers should be familiar with the basic principles of crop response. This article discusses general concepts that guide fertilizer investment decisions for one or two nutrients.

The situation: A farmer does not have enough money to purchase all of the supplemental nutrients needed by crops on the farm. He or she asks for guidance on how best to spend the money that is available. The challenge is to combine nutrients to reap the maximum possible benefit from their application, recognizing that when all needed nutrients cannot be purchased, overall production and profit will be compromised.

Allocating Funds to One Nutrient

Let's first consider the case where one nutrient is needed, but the total recommended quantity cannot be afforded. To reduce the total fertilizer bill, we need to allocate fertilizer to where it is needed most in the field. Areas of greatest need are those where crop responses are expected to be the largest. **Figure 1** demonstrates the concept. In this figure, the large curve on the left is a conceptual model of crop response to soil nutrient supply. As the soil supply of a nutrient increases, crop yield increases until the soil becomes sufficient. Beyond this sufficient level, yield does not increase.

Next we examine how a crop is expected to respond to nutrient additions for each of the three soil nutrient supplies. These three expected responses are shown on the right side of the figure.

The top graph (A) shows that when a soil has a low supply of a nutrient, the yield attained with no additional supplement (where the curve intersects the vertical axis) is low (the same as point A on the larger graph to the left). However, adding more of the nutrient results in a large crop response. Because the response is so great, the short-term economically optimum rate (EOR) does not change much as prices vary, shown in the shaded area under the curve.

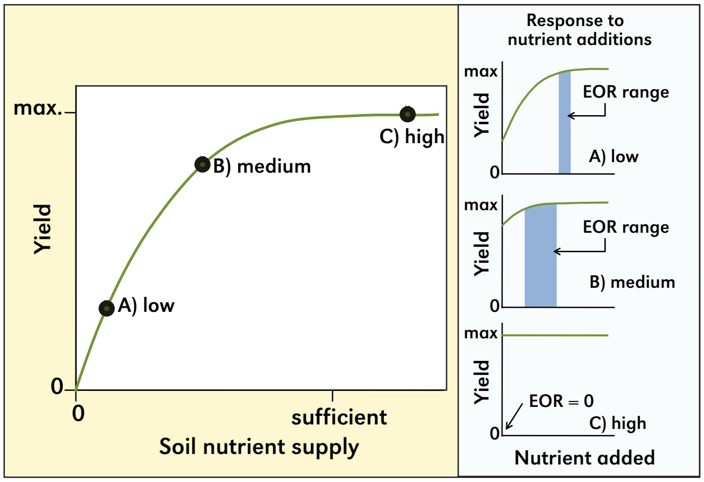

Figure 1. A conceptual model of crop response to soil nutrient supply. Also shown are model crop responses to nutrient additions for A) low, B) medium, and C) high soil nutrient supplies. The shaded areas below the curves in A) and B) show the range in short-tem economically optimum rates (EOR) based on various crop and nutrient prices.

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; EOR = economically optimum rate.

In the second case (B), where the nutrient level in the soil is at a medium level, the yield without a supplemental application is higher, reflecting the greater soil supply (the same as point B on the larger graph to the left). As a supplement of the nutrient is added, the crop still responds, but not as much as where soil supplies are lower. Most of the response occurs with the first few increments of nutrient added. The more subdued response leads to a greater sensitivity of the EOR to fluctuating prices (the shaded region under the curve). When the nutrient price is higher relative to the crop price, only lower rates are justified. However, when nutrient price is lower relative to the crop price, higher rates are needed.

The third and final graph (C) demonstrates that when the soil already has an adequate supply of the nutrient, further additions do not increase yield. In this case, the EOR is zero, regardless of economic conditions.

The concepts of crop response to a single nutrient result in the following guidance:

- Allocate much of the nutrient to more responsive areas. More responsive areas are not very sensitive to price fluctuations. Examples of more responsive areas are:
  - o P and K: areas with low soil test levels
  - o N: areas that are coarser textured and/or have low organic matter contents
  - o N: areas where corn has not been planted after a legume crop
- Apply some of the nutrient to less responsive areas as well. Most of the crop response occurs with the first few units of added nutrient. Reductions are economically justified when nutrient prices are more expensive relative to crop prices. Examples of less responsive areas include:
  - o P and K: areas with medium soil test levels
  - o N: finer-textured soils and/or areas with higher organic matter contents
  - o N: areas where corn is planted after a legume crop

Allocating Funds across Two or More Nutrients

When more than one nutrient needs to be supplemented to a crop, the nutrients can interact to produce greater crop response than any particular nutrient applied alone. A conceptual example of how two nutrients interact is provided in **Figure 2**. The levels of each nutrient are represented by the two axes, with greater nutrient levels to either the right or toward the top. The curves shown on the graph represent single yield levels, labeled low, medium, or high. They are akin to contours on a map. Looking at one curve demonstrates that there are several combinations of nutrient 1 and nutrient 2 that can result in a single yield level. Although not shown because of complexity, the concept extends to interactions of three or more nutrients.

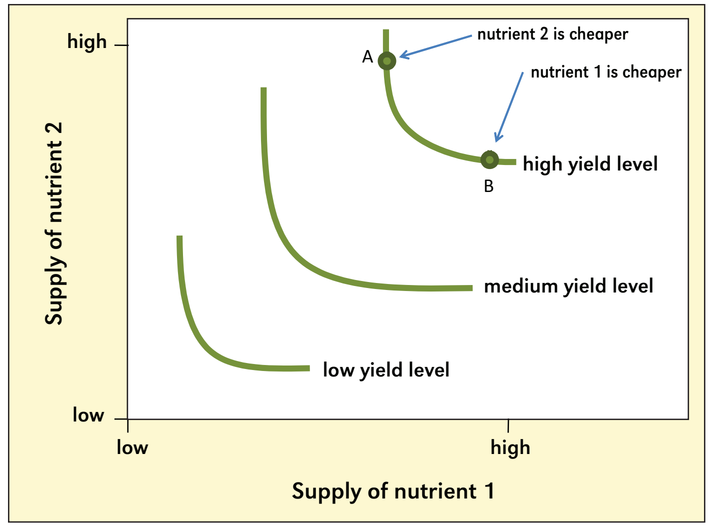

Figure 2. A conceptual model of the interaction of two nutrients on crop yield. Each curve represents a single yield level, indicated as low, medium, or high (adapted from Figure 2-4 on p. 99 in Black, 1993). The axis shows how various combinations of each nutrient can produce the same yield (one curve) or different yields (moving from one curve to another). Points in upper right show that A) higher levels of nutrient 2 compared to nutrient 1 are justified when an increment of nutrient 2 is cheaper, and B) higher levels of nutrient 1 compared to nutrient 2 are justified when an increment of nutrient 1 is cheaper.

Corn planters for conservation tillage provide the choice of placing fertilizer with or beside the seed, supporting soil-test-based decisions.

Each curve has three parts: 1) the vertical part, which reflects the yield level attained from higher levels of nutrient 2 but lower levels of nutrient 1; the horizontal part, which shows the yield level possible with higher levels of nutrient 1 but lower levels of nutrient 2; and 3) the curved portion (the elbow) which represents the same yield level derived from more balanced levels of both nutrients.

Because there are several combinations of both nutrients that can produce the same yield, there is some flexibility in how we combine the nutrients to attain a given yield, based upon nutrient price. In the upper right of **Figure 2**, we see that both nutrients must be present at higher levels to attain high yield. However, there is flexibility in the latter units added. Point A is the case where adding a unit of nutrient 2 is cheaper than adding a unit of nutrient 1. In such a case, the desired high yield can by achieved if the last few units of added nutrients are allocated more toward nutrient 2 than nutrient 1. In other words, we add more of the less expensive nutrient. Conversely, if a unit of nutrient 1 were cheaper (point B), then more of it should be added instead.

Figure 2 also provides insight into how university recommendations may need to be adjusted when considering nutrient interactions. First, we need to recognize that university recommendations are generally based upon experiments that change the level of only one nutrient, while keeping the levels

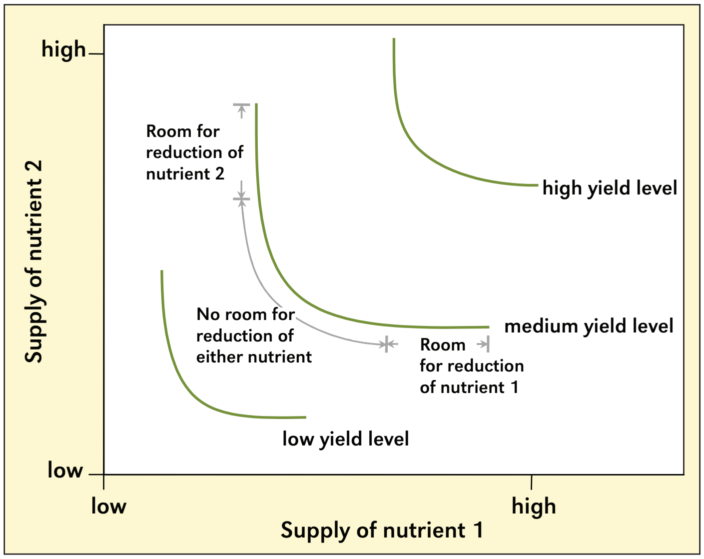

Figure 3. The conceptual model described in Figure 2 with risk assessments imposed.

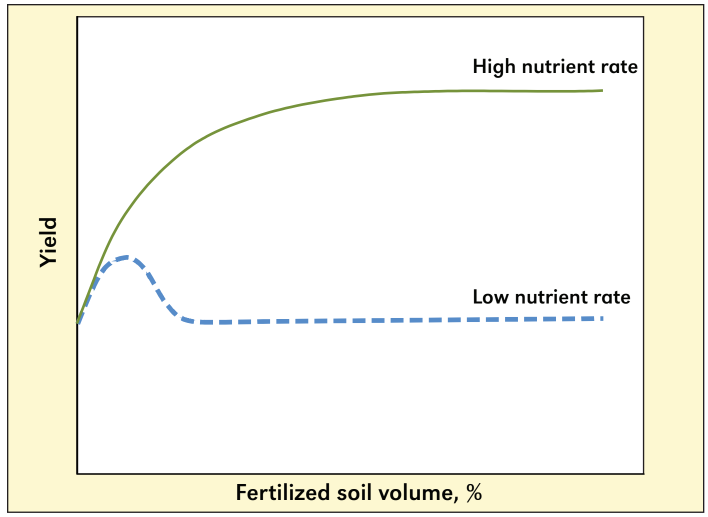

Figure 4. A conceptual model of the interaction of nutrient rate with placement upon crop yield (adapted from Anghinoni and Barber, 1980).

of all other nutrients non-limiting. For instance, if nutrient 1 were the focus of such research, the resulting recommended supply would likely be that associated with point A, since the level of nutrient 2 is non-limiting there. However, if a decision is made to reduce the level of nutrient 2 because of economics, the recommended amount of nutrient 1 becomes too low to attain high yield. So we see that it can actually take more than the recommended rate of a nutrient when other nutrients are limiting. This result demonstrates that while nutrients can interact in beneficial ways, they can also interact in detrimental ways when they become limiting.

How much, if any, yield reduction occurs by reducing the supply of nutrient 1 or nutrient 2 depends upon where you start on a particular yield curve. If we reduce the supply of nutrient 2 when it is high on the vertical part of the yield curve, no significant yield reduction will occur until we start to move toward the elbow. The same holds true for nutrient 1 if we are far to the right on the horizontal part of the yield curve. The more horizontal or more vertical parts of a yield curve therefore convey some concept of risk management, as shown in **Figure 3**. At higher than needed levels, there is room for error in the management of either nutrient and for the uncertainty involved in predicting nutrient needs for any one growing season. However, when the levels of both are more balanced (the elbow region), reducing one or both nutrients necessarily results in lower yield.

The concepts of nutrient interactions lead to the following guidance:

- Examine rates of nutrients typically used. Cut back on any that are in excess of crop need.
- When considering cutting back on the last few units of more than one nutrient, cut back on the nutrients that are more expensive per unit
- If you have to cut back on one or more needed nutrients that have higher per unit costs, add as much of the less expensive nutrients as you can. The required rate of those less expensive nutrients may become higher than typically recommended if the reductions in other nutrients adversely affect yield.
- Try to apply at least some of all nutrients that are in short supply in the soil to make use of the positive interactive effects

P and K Placement Depends on Rate

Although not a formal part of the theory of allocating funds across nutrients, the way in which nutrient rate and placement are interrelated is important to consider when reducing rates. The concept of how these two factors interact is shown in **Figure 4**. The two curves in this figure show how yield responds to the percent of the potential rooting volume fertilized with a nutrient. The assumption is that the soil itself does not contain a sufficient level of the nutrient, so a crop response is expected. The lower dotted line shows that response to a low rate of a nutrient is maximized when a relatively low volume of soil is fertilized. Conversely, when a higher rate is applied, crop response is maximized when a greater volume of soil is fertilized. The crop response to the lower rate confined to a smaller volume of soil is less than that associated with a higher rate distributed over a greater volume of soil.

The practical implications of this theory are as follows:

- If only a low rate of a needed nutrient can be afforded, consider banding it and placing it strategically. Roots should be able to intercept it early in their development, but the nutrient should be placed far enough from the seed to minimize any possibilities of damage.
- If a higher nutrient rate can be applied, consider banding part of it strategically and broadcasting and incorporating the rest to fertilize a greater soil volume. BC

Dr. Murrell (smurrell@ipni.net) is IPNI Northcentral Region Director, located at West Lafayette, Indiana. Dr. Bruulsema is IPNI Northeast Region Director, located at Guelph, Ontario.

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Balanced Fertility Still Pays in Irrigated Corn

By Mike Stewart, Steve Phillips, Terry Kastens, and Dietrich Kastens

Just a few years ago we were asking questions about the value and economics of fertilization (Stewart, 1999). Today we are asking similar questions, but for much different reasons. Not that long ago we were facing depressed crop prices that caused many to question whether cutting fertilizer rates was advisable. However, over the past year or two grain prices have reached dizzying heights, and fertilizer and other input prices have followed. Although circumstances are dramatically different, the questions being asked are similar, viz.: "Should I reduce fertilizer rates in response to the current price environment?" Thus, it is time again for a review of the role of nutrient inputs in crop production systems, particularly irrigated corn in this instance.

Fertilizer N prices have changed dramatically over the past few years (**Figure 1**). As prices have escalated, questions about application rates have followed. Agricultural economists at Kansas State University (KSU) have developed an Excel spreadsheet crop budget tool (Dhuyvetter et al., 2006) where, based on crop and fertilizer prices, optimal (profit maximizing) fertilizer N and irrigation levels can be determined for corn, soybean, wheat, sorghum, sunflower, and alfalfa. This tool is particularly useful to evaluate the relative impact of changes in N price across grain prices.

Figure 2 shows an example for irrigated corn production (250 bu/A yield goal) using default values in the program and varying corn and N fertilizer prices across a wide and relevant range. This evaluation reveals some key points. As crop price increases, the impact of increasing N fertilizer price on optimal rate of application diminishes, as evidenced by the convergence of the lines in **Figure 2** from left to right. In other words, N price does impact optimal rate of application, but that impact is diminished with increased grain price. Indeed, there is little difference in predicted optimal N application rate at \$3.50/bu corn and \$0.25/lb N compared to \$5.50 corn and \$0.75 N…the difference is only 14 lb N/A. Granted, the outlay and risk involved in today's environment is significantly higher than a few years ago, but the most profit producing N rate has not changed much.

The importance of balancing N with other nutrient inputs is often emphasized. One of the best ways to ensure the production of optimal yields and efficient use of N and other fertilizer inputs is through complete and balanced fertilization. Results from a recent high-yield irrigated corn study (Gordon, 2005) in north central Kansas have demonstrated how balance among N, P, K, and S can impact yield (**Figure 3**). Nitrogen was kept at a constant and non-limiting level (300 lb/A) as P, K, and S were added. Notice the "stair-step" effect as a more complete nutrient input program was put into place. Using the response data from this example, and assuming that N cost is \$0.60/lb, P_2O_5 is \$0.90/lb, K_2O is \$0.50/lb, S is \$0.80/lb, and corn price is \$5.50/bu, a very simple analysis of return on fertilizer investment shows that N alone returned \$211/A while the complete treatment (N+P+K+S) returned \$533/A. Thus, even in a relatively recent price scenario, balanced fertility still has the potential to pay handsomely.

The addition of P, K, and S in the previous example obviously impacted how much of the applied N was utilized to produce yield. **Figure 4** shows how improving nutrient balance impacted apparent N fertilizer recovery efficiency. Recovery efficiency for the fertilizer treatments in this example was determined by estimating how much N was taken-up by the crop over the zero N control, assuming N uptake of 1.4 lb N/bu grain produced, then dividing that by 300 (lb N fertilizer applied). While this is a crude estimation, it nevertheless serves a

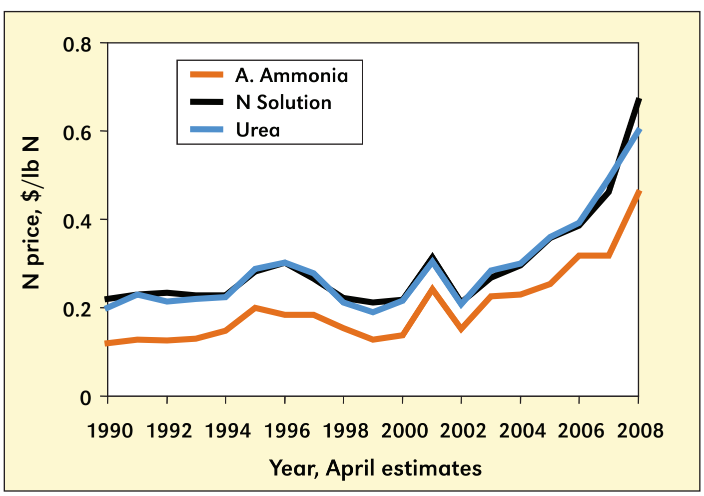

Figure 1. Price per pound of N for major fertilizer materials, April estimates, 1990-2008. (Source: USDA/ERS, 2008.)

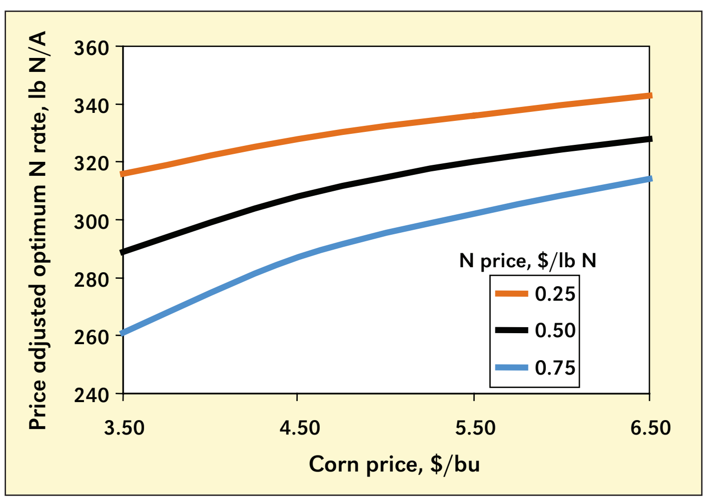

Figure 2. Estimated impact of corn and N fertilizer price on optimal rate of N application for irrigated corn. Assumes 250 bu/A yield goal, 2% organic matter, and 20 lb NO_3-N/A. (Source: derived from Dhuyvetter et al., 2006.)

Abbreviations and notes for this article: N= nitrogen; P = phosphorus; K = potassium; S = sulfur.

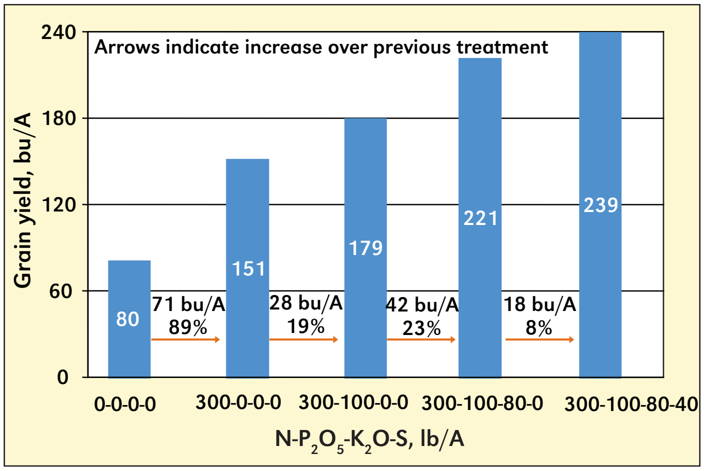

Figure 3. The impact of fertility treatments on irrigated corn yield in north central Kansas, Carr sandy loam, 2-year average (Gordon, 2005).

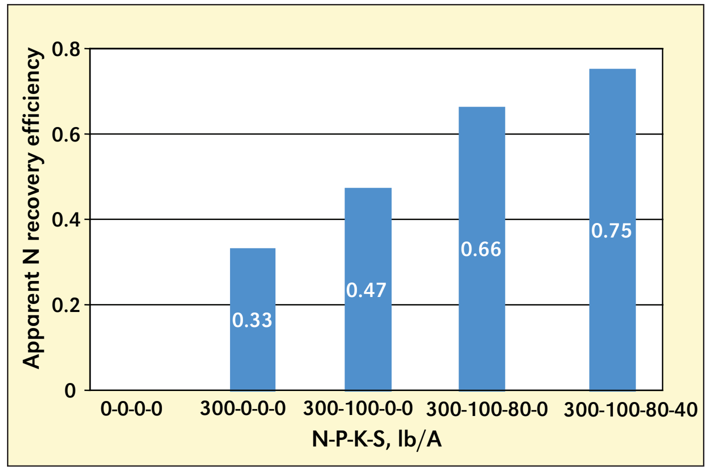

Figure 4. The impact of improving fertility balance on apparent N recovery efficiency in irrigated corn production in north central Kansas; Carr sandy loam, 2-year average, assumes 1.4 lb N uptake per bu (after Gordon, 2005).

purpose. Notice that, compared to N alone, the complete program improved apparent N use efficiency by over two-fold, from 0.33 to 0.75. This is equivalent to more than doubling the "bang for the N buck" by simply attending to other nutrient needs.

The north central Kansas irrigated corn example discussed above is from a single location and is used to demonstrate how crop nutrition can impact production and returns in the current environment. Therefore, one should not necessarily use the fertilizer rates in this example to guide decisions in other production environments. Nutrient application decisions should, as always, be based on information such as realistic yield goals, soil test results, plant analysis, cropping history and nutrient budgets, and experience. Tools such as the previously discussed KSU crop budget calculator can be useful as well. Along with establishing the right rate and balance of nutrients, it is important to consider other fertilizer best management practices that take into account right timing, placement, and source. Furthermore, the adoption of appropriate site-specific management tools is another option that is increasingly feasible as production systems evolve and adapt to meet greater demands and challenges. BC

Dr. Stewart (e-mail: mstewart@ipni.net) is IPNI Southern and Central Great Plains Region Director, located at San Antonio, Texas. Dr. Phillips is IPNI Southeast USA Director, located at Owens Cross Roads, Alabama. Dr. Kastens is Extension Agricultural Economist, Farm Management, at Kansas State University. Dietrich Kastens is a farmer located at Herndon, Kansas.

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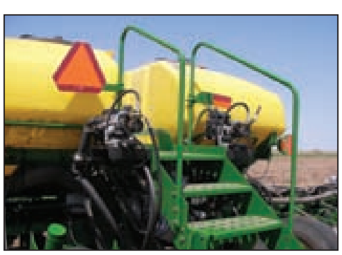
More about Our Cover....

Kastens Inc. Farms in Rawlins County, Kansas, uses a 24-row planter for corn and grain sorghum. Liquid N (32-0-0) and liquid P_2O_5 (10-34-0) are variable-rate applied. Prescription maps are generated in the office and then imported into a controller that accomplishes the rate changes, product application documentation, and section control functions. "We carry 850 gal. of 10-34-0 and 1,300 gal. of 32-0-0 in the field...They are blended into a common product that is delivered through single disk openers set 4 in. off row and 2 in. deep," explains Dietrich Kastens.



On the Kastens Farms' planter, two diaphragm pumps (one for 10-34-0 and one for 32-0-0) are hydraulically controlled.

Two-product variable rate application and section control is handled by AgLeader Insight in the tractor cab.

High Fertilizer Prices: What Can Be Done?

By José Espinosa and Juan Pablo García

In tropical areas of the Andean countries, Central America, and Mexico, thousands of hectares are cultivated with corn and rice, but low average yields are common. Production of corn grain is utilized to satisfy dietary needs of the population, but there is also an increasing demand for corn grain to be used as animal feed. From the standpoint of human and animal feed, this crop is strategic for all the countries in the region. During the last few years, global market conditions and low yields made corn production unattractive because corn grain could be imported at cheaper price than the grain produced locally. Conditions were more or less similar for rice in many countries of the region.

Unforeseen conditions in the global market have substantially increased international corn and rice prices and grain production has become profitable and essential for each country. However, the substantial increase in prices of fertilizer and other agricultural inputs has added pressure to agricultural production, causing questions and reservations of farmers and technicians regarding fertilizer management.

Corn and rice production in the region have faced several limitations over the last decades which explain the low productivity. Perhaps the more important limitation was the lack of incentive to produce which in turn depressed local markets and provided little motivation to develop and adopt technology.

Fertilizer recommendations used in the different corn producing areas of the region do not satisfy the nutrient needs of high yielding corn required to satisfy the public demand and to allow farmers to transform grain production in a profitable activity. Most of these recommendations are based on soil test calibration work conducted many years ago with different corn germplasm and in different growing conditions. In many cases, only one fertilizer recommendation is used for extensive areas of production, assuming that nutrient need is constant in time and space. Experience indicates that in general, corn and rice growers of the region don't use soil testing.

The lack of technology and the need to improve grain production in the region called for a new dynamic approach which quickly generates the information required to design fertilizer recommendations and nutrient management schemes to take advantage of the potential of the new corn hybrids and rice varieties developed for the tropics.

In the tropics, yield potential and nutrient needs differ among agro-ecological zones. This situation results in different growing conditions with different attainable yields which require different nutrient recommendations. The magnitude of the yield goal determines the total nutrient requirement. In 2006, a project to test a site-specific nutrient management approach (SSNM)…based on the omission plot technique (Witt, et al., 2006)…was initiated in the region. The goal was to study the influence of local agro-ecological conditions on nutrient requirements as a tool to develop fertilizer recommendations for achieving high sustainable yields in the particular conditions of tropical America. Projects were initiated in Colombia and Ecuador and later expanded to Mexico, Honduras, and El Salvador.

SSNM is an approach based on the plant that utilizes the omission plot technique to determine the yield obtained with only the soil reserves (omission plots) compared to the attainable yield obtained when nutrients are not limiting. The attainable yield becomes the yield goal for the next growing season. The N fertilizer requirement is then calculated from the yield difference between the complete plot and the N omission plot assuming an N agronomic efficiency (NAE) of 25 to 35 for corn and 18 to 25 for rice (AE = kg of grain/kg N).

Nitrogen omission plot beside a P omission plot at Santander, Colombia.

Requirements for P and K are calculated based on yield goal, grain yield response to the nutrient, and nutrient removal. The recommended rate of fertilizer is tested and refined the following year along with other management practices which can improve fertilizer use efficiency. However, the rate can be used by farmers in the surrounding fields as the first approach to evaluate a recommendation which is based on a yield goal attainable for the site. This is a sound approach to cope with high fertilizer prices and to make grain production profitable in areas where soil testing is not used regularly (Dobermann et al., 2005).

Example for Colombia

Here is an example of the approach tested in Colombia. **Table 1** shows average yields of -N, -P, and -K omission plots, the complete treatment, and the farmer treatment for 2006 and 2007 at three sites in Colombia with different yield potential. This situation is common in the tropics where microclimates can markedly influence yield potentials. The Espinal site is located at the bottom of the Valley of the Magdalena River and is characterized for having high day and night temperatures which restrict yield accumulation. The other two sites (Antioquia and Bugalagrande) are at higher altitude and have cooler nights, conditions which allow greater yield potentials. The

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium.

average yields of the two growing seasons (2006 and 2007) at the complete NPK plots define attainable yield, which is then set as the yield goal for the next cropping season. This is a reasonable yield target because it reflects the effect of climate in yield accumulation. Yield goal also defines the magnitude of nutrient requirements. **Table 1** shows the calculated nutrient requirements to reach attainable yields at the different sites.

Farmers in the region are enjoying higher grain prices, but they also face a substantial increment in the prices of fertilizers and other agricultural inputs. Only high sustainable yields will allow farmers to take advantage of the situation and make grain production a profitable activity. **Table 2** shows a comparison of the cost and income of the attainable yield and the yield obtained with the farmer practice. Once an attainable yield goal is determined by field experimentation, the magnitude of the nutrient requirement and the fertilizer recommendation can be set. This recommendation can be refined over the years to make more efficient use of agricultural inputs.

The problems that corn cultivation has faced in tropical Latin America during the past decades have prevented the

Table 1. Grain yield in the omission plots and the complete treatment and calculated nutrient requirements for three sites located at different ecosystems in Colombia (2-year averages).

Treatments	Yield, t/ha	Yield increase, t/ha $R_X - R_0$
Espinal		
-N	1.6	4.8
-P	5.3	1.1
-K	5.8	0.6
NPK	6.4	
Farmer	4.8	
Yield goal = 6.4 t/ha		
Fertilizer recommendation (kg/ha) to reach yield goal = 160 N-56 P_2O_5-48 K_2O		
Antioquia		
-N	3.2	4.9
-P	6.3	1.8
-K	7.3	0.8
NPK	8.1	
Farmer	4.9	
Yield goal = 8.1 t/ha		
Fertilizer recommendation (kg/ha) to reach yield goal = 163 N-92 P_2O_5-64 K_2O		
Bugalagrande		
-N	3.7	5.7
-P	7.8	1.6
-K	8.7	0.7
NPK	9.4	
Farmer	6.9	
Yield goal = 9.4 t ha-1		
Fertilizer recommendation (kg/ha) to reach yield goal = 190 N-81 P_2O_5-56 K_2O		

NAE = 30; PAE = 45; KAE = 15 (elemental basis)
R_X = yield of the complete treatment;
R_0 = yield of omission plot
P and K rates were calculated using the same procedure (R_X-R_0). There are exceptions when calculated P_2O_5 is lower then 25 kg/ha and K_2O is lower than 30...not the case here.

Table 2. Comparison of cost and income of attainable yield and yield obtained with farmer practice at three sites located at different ecosystems in Colombia (2-year averages).

Fertilizer recommendation, kg/ha	Fertilizer type	Fertilizer amount, kg/ha	Fertilizer cost[1], US$/ha	Other input costs[2], US$/ha	Corn yield, t/ha	Grain price, US$/t	Total income, US$/ha	Net income, US$/ha
Espinal								
Farmer practice								
N = 90	Urea	153	90					
P_2O_5 = 50	DAP	109	144					
K_2O = 70	KCl	117	87					
			321	1,300	4.8	470	2,256	635
SSNM								
N = 160	Urea	300	177					
P_2O_5 = 56	DAP	121	161					
K_2O = 48	KCl	80	60					
			398	1,300	6.4	470	3,008	1310
Antioquia								
Farmer practice								
N = 120	Urea	218	128					
P_2O_5 = 50	DAP	109	144					
K_2O = 50	KCl	83	62					
			334	1,300	4.9	470	2,303	669
SSNM								
N = 163	Urea	276	162					
P_2O_5 = 92	DAP	200	265					
K_2O = 64	KCl	107	80					
			507	1,300	8.1	470	3,807	2,000
Bugalagrande								
Farmer practice								
N = 140	Urea	270	159					
P_2O_5 = 40	DAP	87	115					
K_2O = 90	KCl	150	112					
			386	1,600	6.9	470	3,243	1,257
SSNM								
N = 190	Urea	344	202					
P_2O_5 = 81	DAP	176	233					
K_2O = 56	KCl	93	70					
			505	1,600	9.4	470	4,418	2,313

[1]Assumed costs per metric ton of product, US$: urea = 588; DAP = 1,324; KCl = 748.
[2]Source: National Association of Cereal Growers (FENALCE), Colombia.

(Continued on page 10)

IPNI Crop Nutrient Deficiency Photo Contest—2008

While the classic symptoms of crop nutrient deficiencies are not as common in fields as they were in the past, they do still occur. To encourage field observation and increase understanding of crop nutrient deficiencies and other conditions, the International Plant Nutrition Institute (IPNI) is sponsoring a photo contest during 2008.

"We hope this competition will appeal to practitioners working in actual production fields," said IPNI President Dr. Terry Roberts. "Researchers working under controlled plot conditions are also welcome to submit entries. We encourage crop advisers, and others to photograph and document deficiencies in crops."

Some specific supporting information is required for all entries, including:

- The entrant's name, affiliation, and contact information.
- The crop and growth stage, location, and date of the photo.
- Supporting and verification information related to plant tissue analysis, soil test, management factors, and additional details that may be related to the deficiency.

There are four categories in the competition: Nitrogen (N), Phosphorus (P), Potassium (K), and Other. Entries are limited to one per category (one individual could have an entry in each of four categories). Cash prize awards are offered in each of the four categories as follows:

- First place = US$150
- Second place = US$75
- Third place = US$50

Photos and supporting information can be submitted until December 15, 2008 and winners will be announced in January of 2009. Winners will be notified and results will be posted at the website.

Entries are encouraged from all regions of the world. However, entries can only be submitted electronically as high resolution digital files to: **>www.ipni.net/photocontest<**.

For questions or additional information, please contact:

Mr. Gavin Sulewski, IPNI
Agronomic and Technical Support Specialist
102-411 Downey road
Saskatoon, SK S7N 4L8 Canada
Phone: 306-652-3536
E-mail: gsulewski@ipni.net

Shown at right are some photos as examples of deficiency symptoms. BC

Nitrogen deficiency in corn.

Phosphorus deficiency in cotton.

Potassium deficiency in soybeans.

Sulfur deficiency in canola.

High Fertilizer Prices…from page 9

development of local technology. The sudden increase in the international grain price represents both an opportunity and a challenge for local producers. Simple techniques like the omission plots can provide a robust way of generating solid information to develop site specific fertilizer recommendations which can be implemented and refined immediately. BC

Nitrogen omission plot beside the complete treatment at San Carlos, Ecuador.

Dr. Espinosa (e-mail: jespinosa@ipni.net) is Director, IPNI Northern Latin America Program, located at Quito, Ecuador. Ing. García (e-mail: jgarcia@fenalce.org) is Soils Research Coordinator, National Association of Cereal Growers (FENALCE), Colombia.

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Harmandeep Singh Khurana Joins Staff of IPNI as Deputy Director, India Program-West Zone

Dr. Khurana

Dr. Harmandeep Singh Khurana has joined the staff of IPNI as Deputy Director, India Program-West Zone, effective July 1, 2008. He will be working in coordination with Dr. K.N. Tiwari, Director of the IPNI India Program.

"Dr. Khurana has an outstanding record of academic achievement plus valuable experience as a researcher focused on understanding factors that influence plant nutrition, including soil fertility, fertilizer rates and application timing, and management systems to optimize nutrient uptake efficiency in cereal crops. With his post-doctoral responsibilities and previous work related to the rice crop in India, he is well-qualified for this new role," said IPNI President Dr. Terry L. Roberts. "His related skills in programming and statistics, laboratory procedures, and communications are unique."

In 2005, Dr. Khurana received his Ph.D. in Soils at Punjab Agricultural University (PAU), in Ludhiana, India. He earlier earned his Masters degree in 2001 and B.S. in 1999 at the same university. From 2006 until 2008, Dr. Khurana was Postdoctoral Associate, Soil Fertility and Plant Nutrition, in the Department of Crop and Soil Environmental Sciences at Virginia Tech, Blacksburg, Virginia. In that responsibility, he modified and tested a soil-water-plant-atmosphere simulation model related to site-specific management and analyzed the fate of excess N in soil and water.

Recently, he was involved in testing and improving the algorithm for an optical sensor to improve N use efficiency through understanding the complexity of factors that affect prediction of the genotypic yield performance of corn and wheat. During 2005 and 2006, Dr. Khurana was Assistant Professor, Soil Fertility and Plant Nutrition, at PAU, with 100% research responsibility.

Dr. Khurana has received numerous awards and recognition for academic and research achievements, including best all round postgraduate student of PAU Award in 2002 and All-India Best Ph.D. Thesis Presentation Award, Indian Society of Soil Science, 2005.

His publications include research, extension, and popular articles, proceedings papers, and abstracts. He has also prepared a considerable number of presentations and invited lectures.

Dr. Khurana is active in professional societies, including the American Society of Agronomy, Soil Science Society of America, Indian Society of Soil Science, Punjab Academy of Sciences, and "Global Response", an environmental and educational network. BC

Raúl E. Jaramillo Joins Staff of IPNI as Deputy Director, Northern Latin America

Raúl E. Jaramillo

Mr. Raúl E. Jaramillo joined the staff of IPNI as Deputy Director, Northern Latin America, effective June 1, 2008. He is based in the Quito, Ecuador, office of the Institute and will work in coordination with Dr. José Espinosa, Director of the IPNI Northern Latin America Program. That region now includes Mexico and the Central American and Caribbean countries, as well as Peru, Ecuador, Colombia, Venezuela, the Dominican Republic, and Puerto Rico.

"We are very glad to have Raúl Jaramillo joining in the important work of IPNI. While he is just completing his Ph.D. degree, he has a wealth of knowledge and experience in international settings that will serve well in this new role," stated IPNI President Dr. Terry L. Roberts. "His background in both soil science and plant nutrition will be a valuable asset." Mr. Jaramillo is expected to complete his Ph.D. program at the Pennsylvania State University in fall 2008.

A native of Quito, he completed undergraduate studies in Agronomy at the Central University in Quito in 1994. He then worked with the International Potato Center (CIP) in Quito as a research assistant in the breeding program for Late Blight resistance. In addition to plant selection, he took part in projects dealing with participatory research and integrated management of plant diseases.

In 1998, Mr. Jaramillo joined the Soil Sciences program at the Wageningen Agricultural University in Holland and received his M.Sc. degree with specialization in Land Use Evaluation in 2000. His thesis on the impact of insecticides was used as input information by the "Tradeoffs" projects, a joint venture of CIP, Wageningen University, and Montana State University, focused on the evaluation of economic tradeoffs between agriculture and the environment. After graduation, he worked for 2 more years with Tradeoffs and related projects in Ecuador on the study of land use effects on agricultural sustainability.

Mr. Jaramillo began his Ph.D. program in the Laboratory of Plant Nutrition at Penn State in 2002, under the supervision of Dr. Jonathan Lynch. He contributed in the analysis of plant and root traits involved in the acquisition of nutrients and water. He also investigated the distribution of phosphorus-deficient soils around the world and the interaction between increased carbon dioxide and soil type (soil fertility) in plant growth. BC

Nutrient Management within a Wheat-Maize Rotation System

By Hongting Wang, Ping He, Bin Wang, Pingping Zhao, and Hongmei Guo

Shanxi Province's maize and wheat rotation contributes greatly to national food security. This study examined the implications of inadequate or imbalanced fertilization within the two cycles of this crop rotation.

Maize and wheat are the two major crops in Shanxi Province located in north central China. The crop rotation of wheat and maize is a particularly dominant cropping system for Shanxi's southern regions – an area that occupies 720,000 ha. Nutrient management on farmland plays an important role in crop production and environmental protection. However, the fertilizer decision-making process for many farmers is limited due to little understanding of soil nutrient status. This lack of understanding can lead to excessive or insufficient use of mineral fertilizer.

To maintain the sustainability of agricultural development, it is necessary to explore the benefits of fertilizer application through an improved nutrient management system. This study was conducted at the monitored village of Nanma in Shanxi to develop such an approach within the wheat/maize cropping system.

The field experiment was established in October 2005. The site had a semi-arid, monsoonal climate with an average annual rainfall of 498 mm, an average temperature of 12.6 °C, and a frost-free period of about 195 days. Soil at the site was classified as a calcic cinnamon soil with loamy texture. Prior to the experiment, soil samples (0 to 20 cm) were collected to analyze residual soil nutrients after a previous soybean crop. Soil nutrients were determined according to procedures applied by the National Laboratory of Soil Testing and Fertilizer Recommendation (Jin and Zhang, 1996). The physical and chemical properties of the test soil are given in **Table 1**.

The experiment was designed in a randomized complete block with six treatments and four replicates. Treatments included a zero fertilizer check (CK), a soil test-based balanced "optimum" nutrient application (OPT), and a series of nutrient omission treatments including OPT-N, OPT-P, OPT-K, and OPT-Zn. Urea, single superphosphate, potassium chloride, and zinc sulfate were selected as fertilizer sources. In each rotation of wheat and maize, all P, K, and Zn fertilizer and 180 kg N/ha was applied on winter wheat, while only 195 kg N/ha was applied on summer maize to corresponding treatment at jointing stage. The complete fertilizer application scheme is outlined in **Table 2**. Crop planting and harvest details are given in **Table 3**. Irrigation, insect-control, inter-row tillage, and other management activities were conducted according to farmer practice. After each harvest, soil samples (0 to 20 cm) and plant samples were collected and analyzed for total N, P, and K. Plant samples were digested using wet oxidation with H_2SO_4 and H_2O_2. Total N was determined using the Kjeldahl method, P was determined by vanadomolybdate yellow color development, and K was analyzed by flame spectrophotometers (Analysis Approach of Soil Agro-chemical Analysis, 2000).

Crop yield results indicate large variation between treatments (**Table 4**). Balanced fertilization produced the highest yields, while treatments omitting N, or fertilizer altogether, were the least productive. Yields within N omission plots declined between the first and third crops indicating a significant decrease in soil N supply capacity. This effect is easily observed in the photos taken during the jointing stage of the first and third crops (see next page).

Yields from the fourth crop (maize) were obviously higher across all treatments compared to the first maize crop. Ample rains amounting to 273 mm, or 72% of the year's total, fell during the summer maize growing

Abbreviations and notes for this article: N= nitrogen; P = phosphorus; K = potassium; Zn = zinc; H_2SO_4 = sulfuric acid; H_2O_2 = hydrogen peroxide.

Table 1. Soil physical and chemical properties as tested in October 2005.

pH	OM, %	Ca	Mg	K	NH_4-N	P	S	B	Cu	Fe	Mn	Zn
		- -				mg/L			- -			
8.3	0.65	2,964	373	266	0.0	29	2.7	0.8	1.8	4.2	0.15	1.7
Critical value		401	122	78	50	12	12	0.20	1.0	1.0	5.0	2.0

Table 2. Fertilizer treatment design for wheat and maize in 2005-2007.

	Nutrient application, kg/ha			
Treatments	N	P_2O_5	K_2O	Zn
OPT	375[1]	150	200	15
OPT-N	0	150	200	15
OPT-P	375[1]	0	200	15
OPT-K	375[1]	150	0	15
OPT-Zn	375[1]	150	200	0
CK	0	0	0	0

[1]180 kg N/ha applied on wheat, and 195 kg N/ha applied on maize.

Table 3. Schedule of crop planting and harvests.

Year	Crop/ Variety	Seeding rate	Seeding date	Harvest date
2005/06	Wheat/ Jinmai 81	225 kg/ha	Oct. 12, 2005	June 15, 2006
2006	Maize/ Jindan 958	45,000 plants/ha	June 15, 2006	Oct. 10, 2006
2006/07	Wheat/ Jinmai 81	225 kg/ha	Oct. 10, 2006	June 12, 2007
2007	Maize/ Zhengdan 958	45,000 plants/ha	June 17, 2007	Oct. 16, 2007

Plot size was 5 m × 5.3 m, or 26.5 m^2.

Table 4. Yields of four successive crops of wheat and maize in 2005-2007.

Treatments	2005-2006				2006-2007			
	Wheat grain yield		Maize grain yield		Wheat grain yield		Maize grain yield	
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
OPT	7,307 a	100	6,073 a	100	7,792 a	100	8,033 a	100
OPT-N	5,192 c	71	3,814 c	63	3,596 c	46	5,561 b	69
OPT-P	6,824 b	93	5,503 b	91	6,354 b	82	7,887 a	98
OPT-K	6,804 b	93	5,755 b	95	7,450 a	96	7,898 a	98
OPT-Zn	7,020 ab	96	6,015 ab	99	7,525 a	97	7,568 a	94
CK	4,932 c	68	3,302 d	54	3,437 c	44	5,738 b	71

Treatments with the same letter do not differ at the α=0.05 level.

Table 5. Net returns of four successive crops in 2005-2007.

Treatments	2005-2006		2006-2007	
	Wheat profit	Maize profit	Wheat profit	Maize profit
	-------------------- US$/ha --------------------			
OPT	1,146 a	957 a	1,308 a	1,568 a
OPT-N	821 c	668 c	532 d	1,158b
OPT-P	1,158 a	857 b	1,117 b	1,537 a
OPT-K	1,149 a	902 b	1,340 a	1,540 a
OPT-Zn	1,095 a	947 ab	1,259 a	1,471 a
CK	986 b	578 d	716 c	1,195 b

Net return was calculated by differences between yield values and fertilizer costs only.
Treatments with the same letter do not differ at the α=0.05 level.

season. This timely rainfall increased the yield potential of all treatments including those showing an apparent decline in productivity (i.e., OPT-N, OPT-P, and CK). Yield differences between the OPT and OPT-K treatments were significant in the first two crops (first rotation), but not in the following two crops (second rotation). Yield differences between the OPT and OPT-Zn treatments were not significant in all crops.

Crop profitability mirrored the yield responses, with the OPT treatment being most remunerative (**Table 5**). Although profitability of OPT treatment sometimes was slightly lower than that of OPT-P treatment (first crop) or OPT-K treatment (third crop) in a single season, the profitability differences between treatments of OPT and OPT-P (first crop) or OPT and OPT-K (third crop) were not statistically significant, and profitability of OPT treatment was always the highest within the rotation of wheat and corn (data not shown). Profitability was consistently lowest in OPT-N or CK plots and returns from these two treatments, as well as the OPT-P treatment, appeared to decrease throughout the duration of the study. The difference in profits between the OPT and OPT-P treatment was significant for the second and third crops. Differences between the OPT and the OPT-K or OPT-Zn were not significant.

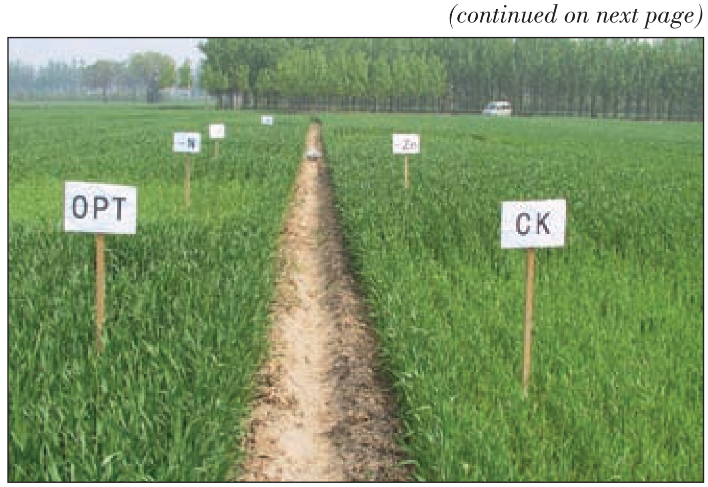
Nutrient uptake was almost always highest under the OPT applied in each cropping season (**Table 6**). Single crop nutrient use efficiency, especially N, was calculated throughout the study. Considering the first wheat/maize rotation, use efficiency of N, P, and K fertilizer was 39%, 14%, and 9%, respectively. The second rotation figures were 62%, 17%, and 21%, respectively.

Nutrient balances for N, P, and K were severely negative with omission of single nutrients, or all nutrients entirely (**Table 7**). The OPT treatment maintained a balance for N, generated a P surplus, but still resulted in a serious soil K deficit due to a significant increase in K uptake by crops. The K balance would be highly dependent upon the degree of crop residue recycling as a large portion of this K deficit could be eliminated given a continual recycling of straw materials. In this study, field management was conducted according to farmer practice, thus crop residue recycling was not considered.

In summary, balanced fertilization is essential for optimizing yields, increasing profits, and improving fertilizer use efficiency. This study outlines a rational fertilization strategy able to improve the economic outlook of this wheat-maize system. The above results from this study have several implications for nutrient management. 1) Balanced fertilization

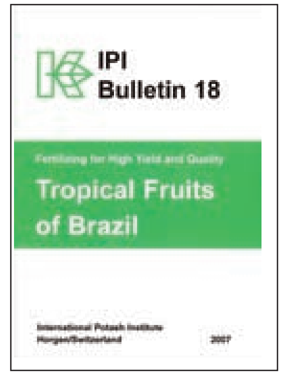
(continued on next page)

At jointing stage in the first crop (April 6, 2006), this photo shows dark green color in the OPT, OPT-P, OPT-K, and OPT-Zn plots, while wheat was pale green and grew slowly in the OPT-N and CK plots. These plots exhibited insufficient soil N supply capacity.



At jointing stage in the third crop (April 29, 2007), the plots show similar effects as in the first crop. However, N deficiency symptoms are more severe in the OPT-N and CK plots than in the OPT plot.

Tropical Fruits of Brazil
Publication Available from IPI



The International Potash Institute (IPI) has released a new 233-page bulletin titled *Fertilizing for High Yield and Quality: Tropical Fruits of Brazil.* It discusses the cultivation, mineral nutrition, and fertilization of 11 widely grown perennial, tropical fruits. Brazil is one of the world's major producers of tropical fruit. While much of the information and data is from Brazil, there are also cross references to production systems in other tropical climates…making the observations applicable to other parts of the world. The book is in English.

Content of the bulletin features 11 tropical fruits: acerola, banana, cashew, citrus, coconut, guava, mango, papaya, passion-fruit, pineapple, and soursop. Each chapter contains a brief overview of the geography of the area where the fruit is grown, the characteristics of the climate and soil, and recommendations for soil preparation and amelioration. The function of each nutrient for the given fruit is discussed, and a description of the visible symptoms caused by their deficiency provided. The authors emphasize fertilization practices for the various phases of plant development from nursery to production, with particular attention to irrigation (including fertigation).

The original version of the book (in Portuguese) was edited by Dr. Lindbergue Araújo Crisóstomo, EMBRAPA Center for Tropical Agro-Industry at Fortaleza (Brazil), together with Dr. Alexey Naumov, IPI Coordinator for Latin America and Associate Professor at the Faculty of Geography of Lomonosov Moscow State University (Russia). The English version is edited by A.E. Johnston of Rothamsted Research at Harpenden (United Kingdom).

The book (Bulletin No. 18: Tropical Fruits of Brazil) is available for purchase at US$14.00. To order a copy, look for "publications" at the IPI website: **>http://www.ipipotash.org/publications/detail.php?i=245<** BC

Nutrient Management…from page 13

is a very important measure to maintain the sustainability of agricultural development. 2) Nutrient application should pay attention to crop rotation and crop sequence. Thus, N should be applied within each non-legume cropping season, while P application in one cropping season may be enough to fulfill the requirements for the wheat and maize grown. 3) Best management practices for fertilizer should consider integration of fertilizer, water, and other cultivation practices. BC

Table 6. Responses of nutrient uptakes of four crops to successively fixed fertilization in the rotation of wheat and maize in 2005-2007.

	Nutrient uptake in 2005-2006, kg/ha						Nutrient uptake in 2006-2007, kg/ha					
	Wheat (first crop)			Maize (second crop)			Wheat (third crop)			Maize (fourth crop)		
Treatments	N	P	K	N	P	K	N	P	K	N	P	K
OPT	163	31	147	191	23	189	184	28	194	209	27	148
OPT-N	104	23	88	105	16	118	59	12	69	100	15	90
OPT-P	158	26	143	182	19	154	151	20	148	214	23	131
OPT-K	150	27	141	188	22	180	182	26	176	212	25	130
OPT-Zn	159	28	143	171	20	180	172	27	176	209	24	138
CK0	97	21	82	83	12	109	75	16	65	101	17	91
Efficiency[1], %	33	8	4	44			69	12	11	56		
Efficiency[2], %				39	14	9				62	17	21

Efficiency[1] denote the nutrient use efficiency of a single crop; Efficiency[2] denote the nutrient use efficiency of the wheat/maize rotation.

Table 7. Balance sheet of nutrients of four crops (two rotations) from 2005 to 2007.

	Nutrient uptake, kg/ha			Nutrient input, kg/ha			Balance, kg/ha		
Treatments	N	P	K	N	P	K	N	P	K
OPT	747	109	678	750	132	332	3	23	-346
OPT-N	368	66	364	0	132	332	-368	66	-32
OPT-P	705	89	576	750	0	332	45	-89	-244
OPT-K	732	101	627	750	132	0	18	31	-627
OPT-Zn	712	100	637	750	132	332	38	32	-305
CK0	357	66	346	0	0	0	-357	-66	-346

Dr. H. Wang, Mr. B. Wang, Ms. Zhao, and Ms. Guo are with the Soil and Fertilizer Institute, Shanxi Academy of Agricultural Science, 16 Nongke North Road, Taiyuan, 030031, China; e-mail: htwangwb@public.ty.sx.cn. Dr. He is Deputy Director, IPNI China Program, and Professor, Soil and Fertilizer Institute, Chinese Academy of Agricultural Science, 12 South Zhongguancun Street, Beijing 100081, China. E-mail: phe@ipni.net. IPNI Project #Shanxi-NMBF

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Soils Exhibit Featured at Smithsonian's National Museum of Natural History

From July 2008 to January 2010, the Smithsonian Museum of Natural History in Washington, DC, will showcase a new 5,000 sq. ft. exhibit called *Dig It! The Secrets of Soil*. The educational, interactive exhibition will help visitors discover the amazing connections between soils and everyday life and to think about this hidden world in a whole new way.

"This is one of the best opportunities we have to show the world how basic soils are to life," said Dr. Gary Peterson, President of the Soil Science Society of America (SSSA), the exhibition's founding sponsor. The Nutrients for Life Foundation of The Fertilizer Institute (TFI) is the lead sponsor of *Dig It!*, with additional support by several USDA agencies, including the Natural Resources Conservation Service (NRCS).

IPNI also provided financial support to the project, as well as technical guidance as various ideas were developed. "This is a rare opportunity to reach segments of the public who may have very little awareness or appreciation for the soil. The fertilizer industry has an important role in helping to bridge this need for greater understanding of one of our most precious resources," said IPNI President Dr. Terry L. Roberts.

IPNI President Dr. Terry L. Roberts attended the opening of the new exhibit.

IPNI Northeast Director Dr. Tom Bruulsema, center, provided technical guidance in cooperation with the design team for the Smithsonian Soils Exhibit and TFI staff members Kathy Mathers (left) and Bill Herz, right. "This was a great opportunity to work with artistic professionals in developing a means of communicating to the public the role of soils and plant nutrients in their lives," Dr. Bruulsema said.

The exhibit will explain differences among soil types, featuring soil samples from all states and territories of the USA and a world map of soils. After examining soil close up, exhibition visitors can step back and see the "big picture" with a world map and interactive stations that present the connection between soil and global systems. Models demonstrate the roles of soil around the house and the formation of soil in commercial and residential construction, dams, playing fields, neighborhoods, roads, and crop production. Visitors will learn about the role of soil as an ingredient in medicines, textiles, cosmetics, pottery, and numerous other products.

Following its showing at the National Museum of Natural History, plans call for the exhibit to travel to a number of museums across the country through 2013 under the auspices of the Smithsonian Institution Traveling Exhibition Service. Funding is being sought to support this effort. For more information about the traveling exhibition, visit: **>www.sites.si.edu/soils<**.

Additional information about *Dig It! The Secrets of Soil* is available at: **>http://forces.si.edu/soils<**. BC

International Plant Nutrition Colloquium Set for August 2009

The 16th International Plant Nutrition Colloquium (XVI IPNC) will take place August 26-30, 2009 at the Sacramento Convention Center in California, sponsored by the University of California-Davis (UC-Davis). Since its inception in 1950, the IPNC has grown to become one of the most important international meetings on fundamental and applied plant nutrition, from both an agricultural and environmental context.

The theme for the 2009 Colloquium, "Plant Nutrition for Sustainable Development and Global Health", aims to highlight the importance of plant nutrition as a foundation science with impact on all aspects of cropping system and environmental sustainability, human health, and well being. Dr. Patrick Brown of the UC-Davis Department of Plant Sciences serves as President of the IPNC. BC

Additional information is available at the website: http://ipnc.ucdavis.edu.

NORTH AMERICA

Corn Fertilizer Decisions in a High-Priced Market

By Tom W. Bruulsema and T. Scott Murrell

When prices are high for both fertilizers and corn, producers will be rewarded for spending more time on fertilizer decisions, using the tools developed by science to determine the right product, rate, timing, and placement.

Markets have taken the prices for corn and fertilizers to places they have never been. How does this influence management decisions for the right product, the right rate, the right timing, and the right placement?

Background

Price variations for the three main fertilizer ingredients from 1980 to 2000 are dwarfed by the increases since then (**Figure 1**), with the largest increase occurring between 2007 and 2008. Phosphate fertilizer prices shot up most dramatically in the past year.

Prices received for corn have varied more than prices paid for fertilizer (**Figure 2**), and have increased rapidly from a low level in 2005. The average price producers will receive for the 2008 crop is as yet unknown, but with December 2008 futures trading above $6 per bushel in April 2008, many producers are likely to receive substantially more than the $3.25 to $4.00 they received in 2007. The projected possible price is based on correlation with Chicago December futures in April from 1996-2007. It is not a prediction, but an assumption for purposes of the analysis that follows.

Producing high yields with high populations requires the right fertilizer decisions.

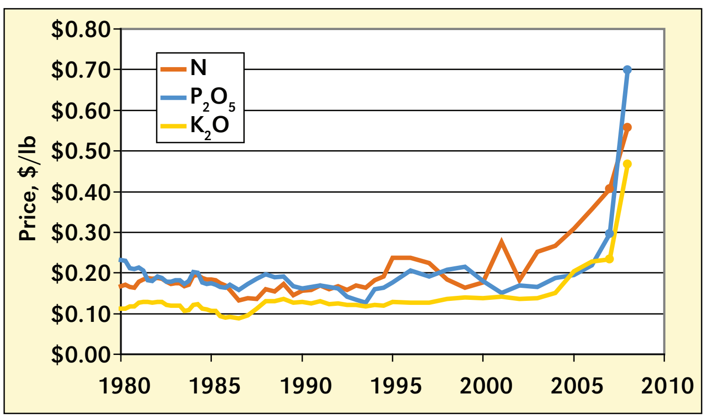

Figure 1. Average farm prices of fertilizer nutrients up to April 2008. Calculated from USDA-ERS data.

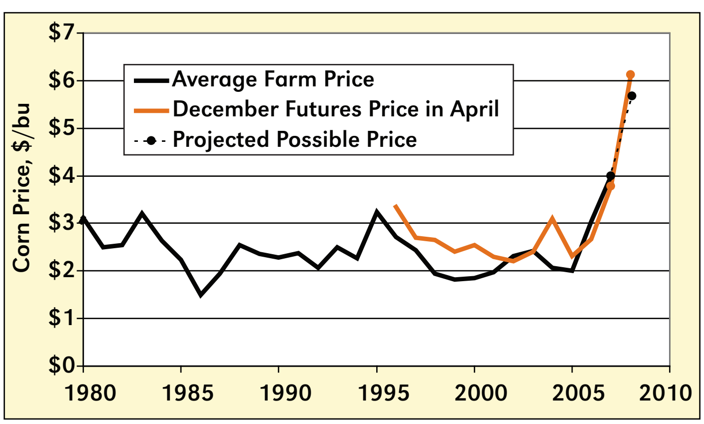

Figure 2. Average farm prices received for corn (USDA-NASS, 1980-2007) and April price for Chicago December futures from 1996-2008.

The price ratio between fertilizer and the crop determines the short-term profit resulting from fertilizer use. It influences optimum rates for N, P, and K, as discussed later in section 3. We express the ratios in pounds of corn grain required to purchase a pound of fertilizer nutrient. This is calculated as the fertilizer nutrient price ($/lb) divided by the corn price ($/lb, which is $/bu ÷ 56 lb/bu). Expressed this way, a higher ratio means relatively more expensive fertilizer. Note that others may express price ratios differently, resulting in a figure representing bushels of corn equal in value to a pound of fertilizer, or its reciprocal.

Table 1 shows the price ratios associated with various combinations of corn and fertilizer N prices. Historical variations shown in **Figure 3** cover a much narrower range than

Table 1. Price ratios associated with various prices of corn and fertilizer N (pounds of corn equal in value to one pound of N).

	Price of N fertilizer, $/lb		
Price of corn, $/bu	$0.20	$0.50	$0.80
$2.00	5.6	14.0	22.4
$5.00	2.2	5.6	9.0
$8.00	1.4	3.5	5.6

Abbreviations and notes for this article: N= nitrogen; P = phosphorus; K = potassium.

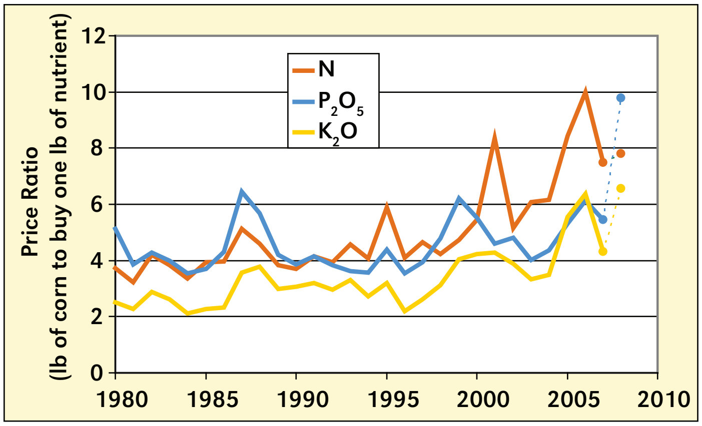

Figure 3. Ratio of fertilizer nutrient prices shown in Figure 1 to corn prices in Figure 2, expressed as pounds of corn required to purchase one pound of nutrient (1980-2008). Note that estimates shown for 2008 are hypothetical since they depend on the currently unknown 2008 average corn price.

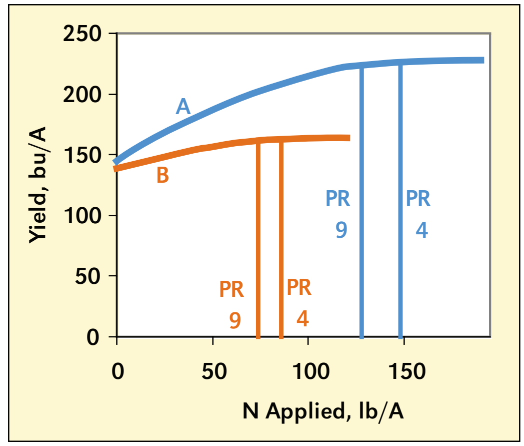

Figure 4. Increasing price ratio (PR) from 4 to 9 diminishes the optimum N rate. Site A (Below, 2007). Site B – 2005 data from Ontario Ministry of Agriculture, Food and Rural Affairs staff.

those in the table, because corn and fertilizer prices tend to go up and down together. If the average corn price for 2008 indeed turns out to be $5.67/bu, only the P price ratio would currently be at the high end of its historical range. Even so, its price ratio would not differ greatly from those endured in 1999 and 1986. The price ratios for N and K would be down substantially from the highs of 2005.

Overall, there is an increasing trend in these price ratios over the past 38 years. This might be expected in the context of a fertilizer industry reliant on fossil fuel resources, and a corn production industry in which yields are increasing faster than fertilizer application rates.

Managing by the Four Rights

1. Right Product

With higher prices for fertilizer nutrients, it becomes more important to use the product that provides the highest efficiency. Premiums previously considered unaffordable now become cost-effective. Controlled-release sources, or those with inhibitors slowing down the conversion to nitrate, can more efficiently deliver nutrients to the plant, provided they are applied in situations where their nutrient release matches the uptake needs of the crop.

Are these products always better than split application? Ongoing research is still needed to determine when they are or are not. A split application of soluble fertilizer entails different risks than those associated with a single application of a controlled-release product. The soil may be too wet at side-dress time to get on to the field. Or, in some years, soils may be so dry that side-dressed N—even in fluid form—does not get to the roots. Split applications also entail extra fuel costs. Controlled-release products can potentially be more reliable and more convenient. But weather and many other soil factors can influence the rate of release, so it's important to evaluate which product performs best in your own specific growing conditions. Limited research has been done on these products, so a combination of searching out relevant results and conducting on-farm trials is called for.

Price changes may affect some products more than others. Compare price per pound of N as anhydrous ammonia, urea, urea-ammonium nitrate, ammonium sulfate, ammonium nitrate, calcium nitrate, and potassium nitrate. But also make sure the product suits the application method. Avoid leaving urea or urea-ammonium nitrate on the soil surface.

2. Right Rate

Corn yield typically shows a diminishing response as the rate of N applied increases. The economically optimum rate occurs where the yield increase no longer pays for the last increment of fertilizer. As price ratio increases, the optimum rate decreases. **Figure 4** compares two examples: a site in Illinois with a high-yielding hybrid in 2006, and a site with lower yield potential in Ontario in 2005. In both these cases, increasing the price ratio from 4 to 9 decreases the optimum rate by about 14%. The Ontario N Calculator (Stewart, 2007) recommends a reduction of 30 lb/A for an increase in price ratio of this magnitude.

When prices for both corn and fertilizer increase proportionally, the optimum rate does not change, but the consequences of a non-optimal rate are more costly. It becomes more important to use every means at your disposal to get the best estimate possible of the optimum rate. For N, this can be difficult. A pre-sidedress soil nitrate test (PSNT), taken when the corn is 6 to 12 in. tall, can help guide decisions on sidedress N applications. For an in-season assessment, a SPAD meter (chlorophyll meter) has proven effective and many universities provide guidance on using it. For an end-of-season assessment, stalk nitrate tests are recommended by many institutions.

For nutrients less mobile than N—like P and K—increasing price ratios may lead to a change in approach to determining application rates. Soils built up in fertility to levels with response probabilities below 50% are often fertilized only for maintenance. A short-term strategy of reduced application rates is not likely to greatly reduce yield and profit. However, the consequent decline in soil fertility for future crops needs to be considered.

Price ratio does not alter the amount of P or K that corn removes from the soil. Higher price ratios increase the profitability of sound soil testing to identify fields and areas within fields where rates below removal may be justified for one or several years. But in the long term, nutrients removed will need to be replaced.

3. Right Timing

When fertilizer prices rise, and the extra cost associated with a better application system stays the same, the benefit:cost ratio may increase to make a different system cost-effective.

Generally, spring is a more effective time than fall to apply N for corn. Typically, a fall application carries a risk that it will be less effective. At its best, fall application can only equal the effectiveness associated with spring application. Fall applications are made to manage other risks – primarily logistical ones. Fall applications take advantage of typically drier soil conditions and more available field days compared to the spring. They also allow some of the tasks to be moved from a busy spring to a less busy fall, increasing the chances that the spring tasks will be timely.

In the western Corn Belt, high fertilizer prices may favor an investment in equipment to apply N in the spring rather than in the fall. Nitrogen should only be applied in the fall after the average daily soil temperatures at 4 to 6 in. deep (measured mid-morning) go below 50 ºF and are sustained at or below this for the winter.

In Iowa (Sawyer, 2006), preliminary fall application research with controlled-release urea products (PCU), has indicated an average 4 bu/A corn yield increase compared to fall-applied urea. However, the fall-applied PCU produced 4 bu/A less yield compared to spring-applied urea: an 8 bu/A yield advantage for spring- versus fall-applied urea.

In the eastern Corn Belt, fall-applied N is unreliable and inefficient. Even spring applications are often better applied split, with some at planting and the largest part in June when the corn is about 6 in. tall. There are two things you can estimate more accurately in June than at planting: one, the soil's ability to supply N, and two, the crop's potential need. While corn doesn't take up much for the first month after it emerges, it needs a good supply from the start. Applying the smaller part at planting and a larger dose in June maximizes yield and efficiency.

Starter fertilizer can efficiently prevent deficiencies in seedlings.

4. Right Placement

Corn has a special need for P early in the growing season. Phosphorus speeds maturity and can help lower grain drying expenses. Placement with the seed in small amounts, and near the seed in larger amounts, provides maximum availability to the young seedling. Applying it in bands below the soil surface reduces the risk of it moving to water by surface runoff.

Assess possibilities for with-seed and band placement. Corn responds most to P when its seedlings are young. Placement near the seed ensures access by the young seedlings, and placement in a band concentrates the nutrient to minimize fixation by the soil. Research suggests that combinations of N and P work most effectively, and that K is an important component of starter fertilizer for corn grown with reduced or no tillage (Vyn et al., 2002). Small amounts of a P-rich fertilizer placed with the seed of corn can provide an additional yield benefit (Lauzon and Miller, 1997). However, rates placed with the seed should be kept very low and will not be sufficient to replace crop removal.

Incorporate or inject volatile sources of N. When N sources containing urea or ammonium (urea, urea-ammonium nitrate, anhydrous ammonia, ammonium nitrate, and ammonium sulfate) are surface applied without incorporation, ammonia losses can be high. Loss can be minimized by incorporating the fertilizer into the soil as soon as possible.

Conclusion

Every farm and field is different. As a producer, you need to be able to select the best management practices suited to your conditions. Even in the context of high prices, managing corn nutrition right means more than applying the minimum to get an average crop. The manager needs to consider the best choices for product, rate, timing, and placement to keep the corn crop productive. BC

Dr. Bruulsema (e-mail: tom.bruulsema@ipni.net) is IPNI Northeast Region Director, located at Guelph, Ontario. Dr. Murrell is IPNI Northcentral Region Director, located at West Lafayette, Indiana.

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Optimizing Nutrient Use in Low Fertility Soils of the Tropics

By Luís I. Prochnow

This article presents some general principles for soil management in the tropics for efficient use of indigenous soil fertility or added nutrients, facilitating high and economical yields.

The tropical regions generally contain soils with low fertility, incapable of sustaining high and economical yields. These soils have to be carefully managed to guide production and achieve the goals of long-term sustainability. Especially in times of high input prices, it is important to employ all techniques that will lead to such sustainability. Some of the techniques are based on general concepts applied worldwide and others are specific for these agro-ecological areas. As a general worldwide concept, input application should aim to more adequately lead to optimum plant nutrition (lime, fertilizers, and gypsum), with the right product, at the right rate, right time, and right place.

With that in mind, let's consider some aspects with the goal of optimizing farmer activities and final results. The topics discussed are: (1) definition of area to crop, (2) soil evaluation and control, (3) nutrient rate strategy, (4) crop rotation, (5) liming, and (6) gypsum to ameliorate subsoil acidity. It should be emphasized that the techniques presented are not specific for times of high fertilizer prices, but are fundamental to seeking profit in this situation.

1. Definition of Area to Crop

Many times, farmers in the tropics try to crop areas too large for their technical and economical capabilities. This generally leads to inefficient soil and crop management and inadequate final yield and profit. Often, better results can be obtained by optimizing the management of smaller areas with higher nutrient application, as opposed to the extensive and inadequate cultivation of larger areas, with low input of nutrients. The optimum area to crop will depend on several factors, but especially on the type of response to the target nutrient. Consequently, access to previous yield data as related to the nutrient rate applied is important for a better definition. Farmers should carefully plan the areas to be cropped in terms of size and adequate management. There is no advantage in cropping larger areas, with more work and less profit at the end.

2. Soil Evaluation and Control

Soil chemical analysis (testing) should be the basis for all programs of plant nutrition. It can be complemented by other techniques, but it is the only one that efficiently, on a routine basis, makes it possible to anticipate the crop's nutrient needs. High soil acidity, low cation exchange capacity, and low amounts of available nutrients are common problems to be overcome in the tropics to enable the soil to sustain crops for high yields and profits. Soil chemical analysis will guide in many ways, possibly even cutting down on nutrient expenses. **Table 1** shows how this technique can help avoid mistakes. Note that the soil analysis would lead to different rates of P applied, as opposed to only one average common rate applied by the farmer when not using laboratory analysis. Compared to rates indicated by the soil chemical analysis, the general farmer practice at field area A would lead to less P than necessary with consequent lower yield potential. At the same time, field area C would receive more P than necessary and only field area B would be on target. By simply transferring the extra amount of P from field area C to A, the farmer would increase final yield with the same expense in fertilizer. This is a simple example of how by using soil testing, farmers would more efficiently monitor their fields with a much larger chance of success.


Photo by A. Pavinato.

Second crop (late planted) corn in a no-till crop rotation system at SLC farm, Brazil, leading to optimization of fertilizer inputs.

3. Nutrient Rate Strategy

The goal should always be to apply the most economical rate of fertilizer, which will depend in part on the price ratio of the crop produced and fertilizer and also on the type of response to the nutrient in that specific field. **Figure 1** conceptually shows the gross US$ return in yield (curve A) and the cost of

Table 1. Rate of P_2O_5 application comparing normal farmer practice versus when utilizing soil chemical analysis.

Area	Soil P[1]	Rate of P_2O_5 Applied by farmer	Rate of P_2O_5 Required[2]	P_2O_5 balance
	mg/dm³	kg/ha	kg/ha	kg/ha
A	3	60	90	- 30
B	12	60	60	0
C	44	60	30	+ 30

[1]Soil P (mg/dm³): 0 to 6 = very low, 7 to 15 = low, 16 to 40 = medium, 41 to 80 = high, > 80 = very high.
[2]According to maize calibration and response curve studies by the resin method to evaluate the bioavailable pool of P in the soil.

Abbreviations and notes for this article: P = phosphorus; K = potassium; Fe = iron; Mn = manganese; Cu = copper; Zn = zinc; Al^{3+} = aluminum; Mo = molybedenum; Cl^- = chloride; Ca^{2+} = calcium.

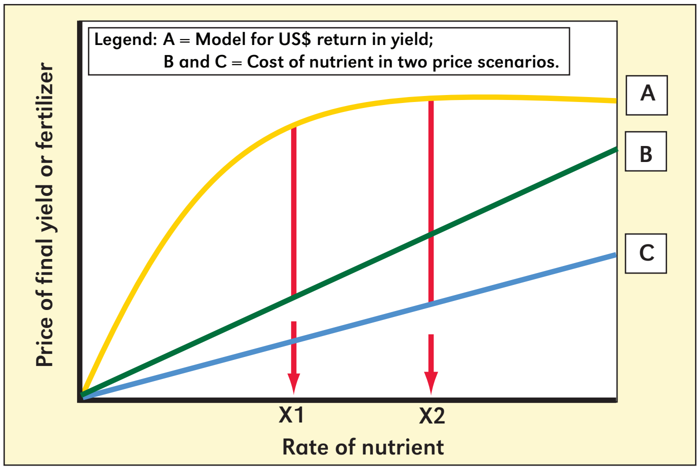

Figure 1. Concept for maximum economical rate of fertilizer.

a given nutrient in two scenarios of price (lines B and C). It is possible to visualize that a lower rate (X1) would be more economical when the nutrient cost is higher (B). This concept is valid only if the US$ return in yield is the same with variation only in the nutrient price. The decision regarding rates is site-specific and agronomists and farmers should monitor their fields and prices to define the best possible rate of fertilizer.

It is a good practice to study the responsiveness of the nutrients at the farm level. This consists of applying different rates of nutrients while keeping the other factors of production at optimum level. The final yields will help to make predictions for the future as related to fertilizer amounts to use. A more modest approach is to start by having at least a control plot or strip (no nutrient applied…for example K) in the field and compare the final yield with regular practices in the farm. This will lead to the calculation of a delta yield (yield with regular practices minus yield at control), which in turn will give guidance as to how much of the nutrient should be added in future crops in the same field or in similar conditions. While the delta yield may vary with yearly specific climatic conditions (especially for N), it will serve to guide the recommendations.

Soils testing medium to high for a specific nutrient can be an excellent indicator that rates can be decreased if capital is in short supply. Well-conducted programs for lime and fertilizer recommendation already take this into consideration by having different response curves for soils testing very low, low, medium, or high for a specific nutrient. As an example, when utilizing the anionic resin method to test for soil bioavailable P in Brazil, values varying from 16 to 40 mg/dm^3 would be considered medium (90% to 100% of maximum yield). Note that the recommendation would be the same, no matter the P content in this range (for example: 17 or 38 mg/dm^3 would both lead to a P_2O_5 recommendation of 60 kg/ha for maize with a yield target of 8 to 10 t/ha). When closer to the upper level limit, i.e., 40 mg/dm^3, the closer we are to the high level of P in the soil. Thus, adjusting to apply lower rates of nutrient would be a possibility. It is important that consultants have a clear idea that the levels of nutrients recommended in technical bulletins serve as a guide, but can be modified according to specific year and targets.

4. Crop Rotation

Nutrient management should target the cropping system. A well-conducted crop rotation program can help to achieve this goal, due to benefits related especially to root development, nutrient requirement, and capability in extracting nutrients from the soil. For example, farms of the SLC group in Brazil have been able to use balanced nutrition for second crop (late planted) corn leading to addition of nutrients (N-P_2O_5-K_2O) through soil fertilization similar to crop removal of these nutrients. (See photo on previous page.) Crops included in this rotation include soybean, cotton, millet, Brachiaria grass, and corn (A. Pavinato, personal communication).

The situation above is only possible due to planning and management of the system, which includes careful site-specific selection of the best corn cultivar, inter-row spacing of 45 cm, and plant population varying with time of seeding, in addition to crop rotation. Also very important to achieving effective results in the crop nutrition of second-crop corn are the practices utilized in the other crops in rotation, and especially for the soybean crop that precedes the corn. These practices include, but are not limited to: no-till practices with periodic subsoiling; application of herbicide at the correct time; and use of early maturity soybean cultivars.

Another good example of a successful cropping system is inclusion of pasture with the cultivation of cereal crops. This approach has been used with great success in parts of Brazil to produce plant residues of good quality for no-till cultivation, or even to be used as feed during winter. This combination generally consists of annual crops—corn, sorghum, millet, or upland rice—with pasture crops, usually Brachiaria. The best crop rotation system, and management that goes with the system, should be defined locally and only agronomic experimentation will lead to optimum results.

EMBRAPA rice and bean researcher Dr. Corival Silva, center, explains the advantages of growing corn and Brachiaria grass together.

5. Liming

Few agricultural practices in the tropics can add as many valuable advantages to crop development and final yield as liming of acidic soils. The advantages vary from improving soil physical and microbiological conditions to improving the use of nutrients by plants. Also very important is the neutralization of toxic Al^{3+}, which severely damages root and crop development. Some nutrients are more bioavailable at low soil pH (Fe, Mn, Cu, and Zn) and others that have an opposite behavior, with higher bioavailability at high soil pH (Mo, Cl) (**Figure 2**). The challenge is to modify the soil pH to have the best possible availability for all plant nutrients. The optimum pH is crop-specific and this should be taken into consideration in recommendations for lime, which is generally the most economical product to adjust soil pH. The concepts and practices of lime application are generally best defined by a local research group, so they are region-specific. Liming the soil should always be considered by farmers of the tropics to, among other advantages, lead to more efficient use of plant nutrients, native to the soil or added through fertilizers.

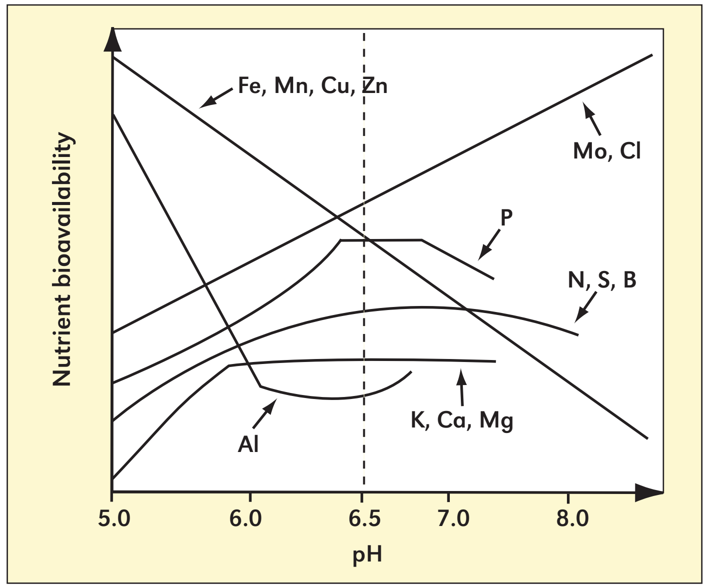

Figure 2. Nutrient bioavailability according to soil pH. Source: Malavolta (2006).

6. Gypsum to Ameliorate Subsoil Acidity

While liming has several advantages in ameliorating soil acidity and leading to better plant development, liming materials contain low solublility compounds ($CaCO_3$ and/or $MgCO_3$ for natural lime) that react and promote such advantages only close to the locality of application. Liming deep soil layers (below 30 cm) is generally not economical, so soil acidity may persist and influence root development at those deep layers, once the presence of Al^{3+} and/or absence of Ca^{2+} (very normal in acidic soil conditions) severely restricts root development.

Gypsum ($CaSO_4$)—natural or a byproduct of the production of phosphoric acid—is a more soluble compound than lime. Applied at correct rates, it was proven to ameliorate subsoil acidity (adding Ca^{2+} and/or decreasing Al^{3+} activity), allowing roots to grow more efficiently. **Table 2** shows agronomic trial results comparing the root development (root density, relative root distribution, or root length) when gypsum was applied or not applied in rates to ameliorate subsoil acidity. Note that in all cases, more root developed in deep soil layers with the application of gypsum. As a result of more root development, plants can absorb more nutrients and water, with higher yields.

Dr. Prochnow is IPNI Brazil Program Director, located in Piracicaba, São Paulo, Brazil; e-mail: lprochnow@ipni.net.

Table 2. Effect of gypsum ($CaSO_4 \cdot 2H_2O$) application in the root distribution for various crops and/or location in soils of the tropics.

Soil layer	Corn South Africa [1] Root density		Corn Brazil [2] Relative root distribution		Apple Brazil [3] Root density		Alfalfa Georgia, USA [4] Root length	
	Control	Gypsum	Control	Gypsum	Control	Gypsum	Control	Gypsum
cm	----- m/dm^3 -----		------- % -------		------ cm/g ------		------ m/m^3 ------	
0-15	3.10	2.95	53	34	50	119	115	439
15-30	2.85	1.60	27	25	60	104	30	94
30-45	1.80	2.00	10	12	18	89	19	96
45-60	0.45	3.95	8	19	18	89	10	112
60-75	0.08	2.05	2	10	18	89	6	28

Source: [1] Farina and Channon, 1988; [2] Sousa and Ritchey, 1986; [3] Pavan and Bingham, 1986; [4] Sumner and Carter, 1988.

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Optimizing Cotton Profitability with Efficient Nutrient Use

By Steve Phillips, Mike Stewart, and C.S. Snyder

High fuel prices, increased worldwide demand, and short supplies have driven fertilizer prices to record highs. Nonetheless, targeting high nutrient use efficiency by applying the right nutrient source in the right place at the right rate and right time allows growers to continue to strive for high cotton yields even in economically challenging times.

In 2007, much of the dryland cotton in the southern USA was affected by extreme drought. Growers throughout the region, particularly in several Southeast and Midsouth states, experienced the worst growing season in decades resulting in severely reduced yields and profitability. In 2008, inclement weather forced replanting in several areas, which has been costly to growers. In addition to increased establishment costs, fertilizer prices have increased approximately 50% since last year (**Figure 1**). Considering that many growers are still feeling the financial sting from last year and have concerns about the potential for this year's crop, it's no wonder that options for lowering costs are in the front of everyone's mind. One of the first places growers are looking to cut costs is fertilizer. The question is: Is it really economical to reduce fertilizer rates?

To answer this question, one must first consider the effect of reducing fertilizer rates on lint yield. Both dryland and irrigated cotton take up approximately 16 lb N/A to produce 100 lb lint/A (IPNI, 2008). Some of this N requirement will be provided through the soil; however, most of the N will need to be applied as fertilizer. **Tables 1 and 2** display the economic optimum N rates (EONR) for cotton production in Alabama and Arkansas across a range of N fertilizer and cotton prices. Obviously, EONR decreases as fertilizer price increases at a set cotton price. However, the decrease in EONR associated with a 50% increase in fertilizer price is only 5 to 10 lb N/A (**Tables 1 and 2**). Data from the southern high plains in Texas followed a similar pattern, demonstrating that EONR is sensitive to wide fluctuations in N fertilizer price, but net returns are affected more than the most profitable N fertilization rate (Bronson and Boman, 2008).

Other factors to take into account when considering reducing fertilizer applications below recommended rates are the long-term sustainability and balance of soil nutrients. Keeping essential plant nutrients in balanced supply results in more efficient utilization and prevents depletion of soil reserves. Research in Mississippi showed that optimum K fertility increased the efficiency of fertilizer N use by 19% and lint yield production per pound of N applied by 13% (Varco, 2000), which makes costly N applications more economical. It is true that when soil test levels are high for a particular nutrient, like P or K, a yield response to further additions is not expected even though a low application rate might be recommended as part of a maintenance program. However, a cotton crop will remove approximately 14 lb P_2O_5 and 20 lb K_2O/bale (IPNI, 2008); thus, maintenance applications can only be skipped so many times before yields begin to decline. So, allowing that reducing fertilizer inputs below recommended rates will immediately or eventually reduce yield, how can growers be

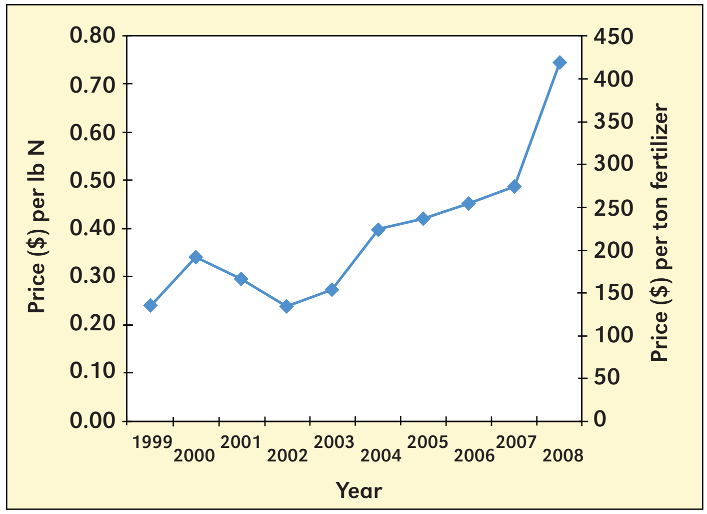

Figure 1. Urea ammonium nitrate fertilizer (28% N) price from 1999 through 2008 (Bronson and Boman, 2008).

Table 1. Economic optimum N rates for cotton on a Decatur silty clay loam in Alabama (adapted from Snyder and Stewart, 2005).

N price, $/lb	Cotton Price			
	$0.52/lb	$0.62/lb	$0.72/lb	$0.82/lb
	--------- Economic optimum N rate, lb/A --------			
0.50	81	84	86	88
0.55	79	82	85	87
0.60	78	81	83	86
0.65	76	79	82	85
0.70	74	77	81	84
0.75	72	76	80	83

Abbreviations and notes for this article: N= nitrogen; P = phosphorus; K = potassium.

Table 2. Economic optimum N rates for irrigated cotton on an alluvial Sharkey Silty Clay in Arkansas (adapted from Snyder and Stewart, 2005).

N price, $/lb	Cotton Price			
	$ 0.52/lb	$ 0.62/lb	$ 0.72/lb	$ 0.82/lb
	-------- Economic optimum N rate, lb/A -------			
0.50	151	154	157	158
0.55	150	153	155	156
0.60	148	151	154	155
0.65	146	150	153	154
0.70	144	149	152	153
0.75	143	147	150	151

Precision agriculture technologies such as variable-rate fertilizer applicators can increase cotton profitability by improving nutrient use efficiency.

more profitable while still targeting high yields? The answer is: By increasing nutrient use efficiency (NUE).

Nutrient use efficiency can be increased by improving the uptake and utilization of applied nutrients, which increases the percentage of applied fertilizer that results in increased crop yield. There are numerous ways to calculate NUE (Snyder and Bruulsema, 2007), but the basic premise to increasing NUE is by selecting the right nutrient source and applying it in the right place at the right rate and right time. All agroecosystems have inherent loss mechanisms that affect nutrient efficiency such as surface volatilization, denitrification, runoff, and leaching. By managing nutrients in a way that minimizes these loss mechanisms, NUE can be increased. Some key steps that can be taken to improve NUE and optimize cotton profitability include the following (Snyder, 2006):

- Use N forms appropriate for soil, crop, and environmental system.
- Place N beneath surface residues and place at least some of the less mobile nutrients like P and K in the root zone.
- Develop field-specific yield goals based on measured yield history
- Soil test annually for N where justified by university research (this is especially relevant in the drier, high plains region) and at least every three years for P and K.
- Consider plant nutrient uptake patterns when making decisions regarding time of application. Split applications of N according to crop development in high rainfall areas or areas prone to leaching.

Another consideration for increasing NUE is site-specific nutrient management using precision agriculture technologies. Precision agriculture technologies have not always been economical for small to medium-sized farming operations. However, with precision agriculture equipment becoming less expensive, tools such as guidance systems, yield monitors, and variable-rate fertilizer applicators may now contribute to savings for all growers. The rising costs of inputs considerably increase the risk of making the wrong management decision.

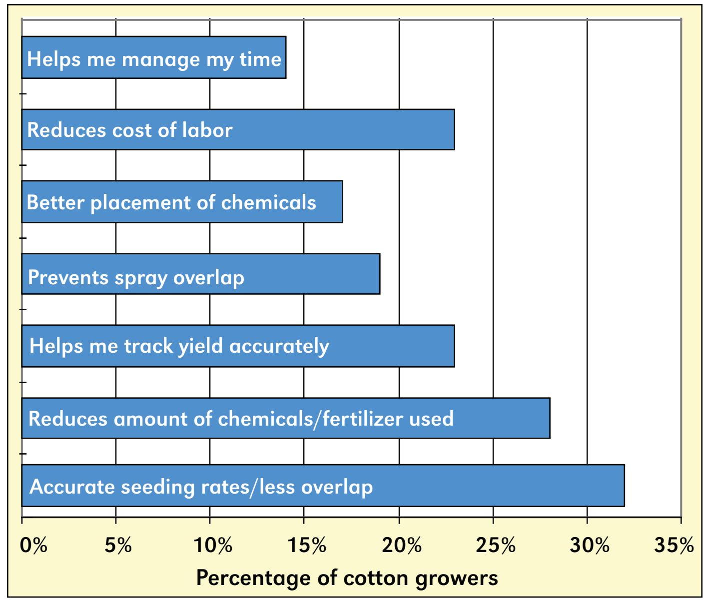

Figure 2. Primary cost reductions and production benefits to cotton growers adopting precision agriculture technologies (based on a survey of 65 cotton growers; Nowels, 2008).

Thus, even small farms can profit from using technologies that improve production efficiency. A recent survey of 271 growers across the USA found that 80% said they were more profitable since adopting a precision agriculture technology (Nowels, 2008). Reasons for the increased profitability included reduced fertilizer rates, reduced spray overlap, and several others (**Figure 2**). BC

Dr. Phillips (e-mail: sphillips@ipni.net) is IPNI Southeast USA Region Director, located at Owens Cross Roads, Alabama. Dr. Stewart is IPNI Southern and Central Great Plains Region Director, located at San Antonio, Texas. Dr. Snyder is IPNI Nitrogen Program Director, located at Conway, Arkansas.

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Soil Testing and Balanced Fertilization Perform Critical Roles in a High-Priced Market

By Fernando O. García

High fertilizer prices have raised many questions from farmers and agronomists regarding fertilizer management. Best management practices (BMPs) for fertilizer use provide adequate responses for these questions. This article discusses the situation for field crops in the Pampas region of Argentina.

The most commonly deficient nutrients for field crops of the Argentine Pampas are N, P, and S. Current FBMPs on applying the right rate indicate that N and P recommendations on wheat and maize, as well as P recommendations for soybeans, should be based on soil test levels of soil NO_3-N (0 to 60 cm) and soil Bray P-1 (0 to 20 cm) at planting.

Determining the Right Rate of N

For N in corn, if a field has soil NO_3-N availability (0 to 60 cm) of 70 kg/ha, and a potential corn grain yield of 10 to 11 Mg/ha, the N recommended rate would be 100 kg N/ha to increase yield by 2.7 t/ha (**Figure 1**).

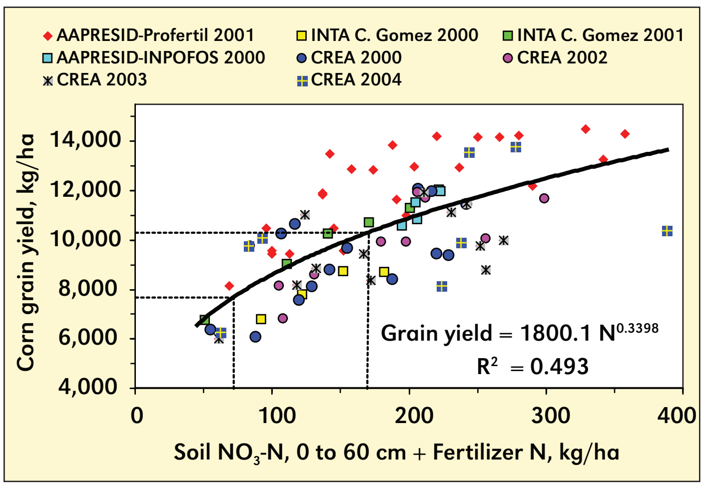


Figure 1. Corn grain yield as a function of soil N availability, soil NO_3-N (0 to 60 cm) + fertilizer N, at planting time in field experiments of the northern Pampas of Argentina carried out by several groups between 2000 and 2004.

Table 1 shows the economic results of N fertilization under this situation, with a net benefit of US$233/ ha, an increased return to the investment, and a decrease in cost of production of 6.9 US$/t of corn produced. Similarly, soil NO_3-N at planting (0 to 60 cm) can be used to guide N fertilizer rate decisions for wheat.

Table 1 Economic analysis of N fertilization in a corn field with a soil NO_3-N availability (0 to 60 cm) of 70 kg/ha at planting.

Treatment	Corn yield, t/ha	Total cost, US$/ha	Net income, US$/ha	Net margin, US$/ha	Return to investment, US$/US$	Cost per ton, US$/t
Check	7.8	647	1,115	468	1.7	82.9
N	10.5	799	1,500	701	1.9	76.0

Assumed prices: US$150/t corn; US$1.2 per kg N.

Determining the Right Rate of P

Higher fertilizer P/grain price ratios result in a need to reevaluate critical levels for P response and fertilizer P rates. Right rates of P fertilization would be determined through FBMPs such as soil testing. **Figure 2** indicates that, under current fertilizer P and wheat prices (US$180/t wheat; US$5.9/kg P) and ignoring any residual value of the P applied, responses to P application in wheat would be profitable in the short-term for soils with Bray P-1 levels of 13 mg/kg or lower.

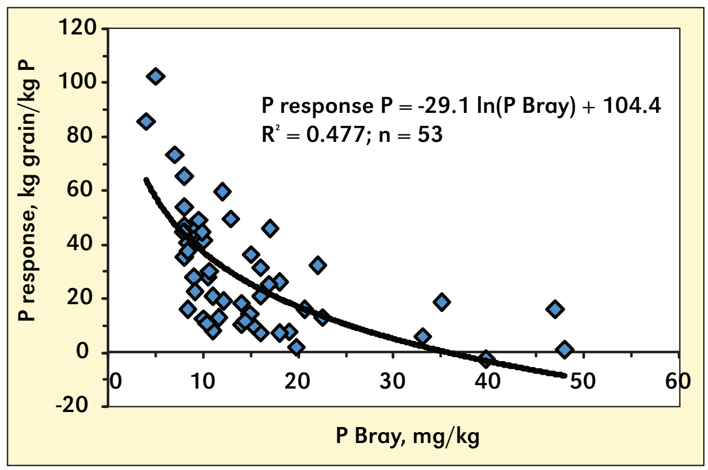


Figure 2. Wheat response to P, expressed as kg grain per kg applied P, as a function of soil Bray P-1 in 53 field experiments carried out by several authors from 1998 to 2007 in the Pampas region of Argentina.

Other points that should be considered before making any decision on P fertilization include: i) P balances and effects on soil test levels for the next years, ii) effects on the response to N or S applications and their use efficiency, and iii) the economic return on investments in land, seed, herbicides, and other inputs because of potentially lower yields.

Table 2 shows the impact of 6 years of continuous P fertilization at removal + 10% P rates in soils of low to medium soil Bray P-1 (average of 11 mg/kg Bray P-1) at the Nutrition Network of CREA Southern Santa Fe. The P fertilization resulted in gross

Abbreviations and notes for this article: N = nitrogen; NO_3^- = nitrate; P = phosphorus: S = sulfur.

Table 2. Gross margin and soil Bray P-1 changes from P application at removal + 10% P rates in 6 years of a wheat/soybean-corn rotation in the central Pampas of Argentina. Data from Nutrition Network CREA Southern Santa Fe (Garcia et al., 2006).

Total P applied[1]	Cost of applied P[2]	Gross income[3]	Gross margin	Soil Bray P-1 change[4]	Gross income from soil Bray P-1 change[5]	Total gross margin [6]
kg P/ha	US$/ha	US$/ha	US$/ha	ppm P	US$/ha	US$/ha
193	1,247	1,417	170	+13.4	394	564

[1]P applied along three rotations cycles in the NPS treatment. [2]Considering P cost of 5.9 US$/kg and application costs. [3]Gross income estimated from the differences in grain yields between NPS and NS treatments along the 6 years of experimentation; prices assumed were: US$150/t corn; US$180/t wheat; US$250/t soybean; US$1.2/kg N; US$5.9/kg P; and US$1.7/kg S. [4]Difference in soil Bray P-1 (0 to 20 cm) between NPS and NS treatments at the end of the 6 years. [5]Estimated value of the soil Bray P-1 change considering a requirement of 6 kg P to increase 1 mg/kg soil Bray P-1. [6]Sum of gross margin because of grain yield increase and gross margin because of soil Bray P-1 change.

Table 3. Wheat grain yields, net margin, return to investment, and cost per Mg of wheat produced at different soil Bray P-1 levels with and without P application for the southeastern area of the Pampas. Elaborated from data of Berardo et al. (1999).

Bray P-1, mg/kg	Treatment	Wheat grain yield, kg/ha	Net margin, US$/ha	Return to investment, US$/US1$	Cost per Mg, US$/t
	Check	3,291	260	0.93	169
<5	+P1	5,173	422	1.18	133
	Check	3,648	315	1.03	152
5-10	+P	5,259	435	1.2	131
	Check	4,044	377	1.14	137
10-15	+P	5,354	450	1.22	128
	Check	4,440	439	1.25	125
15-20	+P	5,449	465	1.24	126
	Check	4,836	501	1.36	115
20-25	+P	5,544	480	1.26	124
	Check	5,232	563	1.47	106
>25	+P	5,639	495	1.28	122

[1]Rate of 22 kg P/ha. Assumed prices: US$180/t wheat;US$5.9/kg P.

margins of 170 US$/ha in 6 years, and an average increase in soil Bray P-1 of 13.4 mg/kg. Considering that 6 kg/ha of P would be required to increase Bray P-1 by 1 mg/kg, the change in soil Bray P-1 represents a gross income of 394 US$/ha, increasing the total gross margin (grain yield + soil Bray P-1) to 564 US$/ha. These results emphasize the importance of considering not only the short-term profits, but also the long-term effects of P fertilization on soil P balances and cropping system sustainability.

Response to balanced fertilization in maize at the Nutrition Network CREA Southern Santa Fe: NPS treatment to the left and check at right.

Adequate P fertilization improves use efficiency of other nutrients such as N and S in corn and wheat, and S in soybean. **Figure 3** shows the improvement in N use efficiency (NUE) in wheat with adequate P application. NUE increased by 27% and 36% in field trials carried out at the beginning of the 1980s and in the last 10 years, respectively. Seven soybean field trials in the northern Pampas have shown average S use efficiencies of 22 and 27 kg soybean per kg applied S, without and with P application, respectively.

Economic analysis of grain production and response to fertilization should include not only the net profit, but also other economic indicators such as return per investment and cost per Mg of grain produced. Return to investment would be defined as the relationship of the gross income respect to the gross costs, including land, capital, and labor, this is the return to the whole investment not just the fertilizer cost. Research carried out at the southern Pampas on wheat (Berardo et al., 1999), indicates that the greatest wheat grain yield, net margin, and return to investment and the lowest cost per Mg were obtained at soil Bray P-1 levels above 25 mg/kg, emphasizing the importance of high Bray P levels for getting high yields and profits (**Table 3**). Thus, getting high soil P levels would be a goal for the

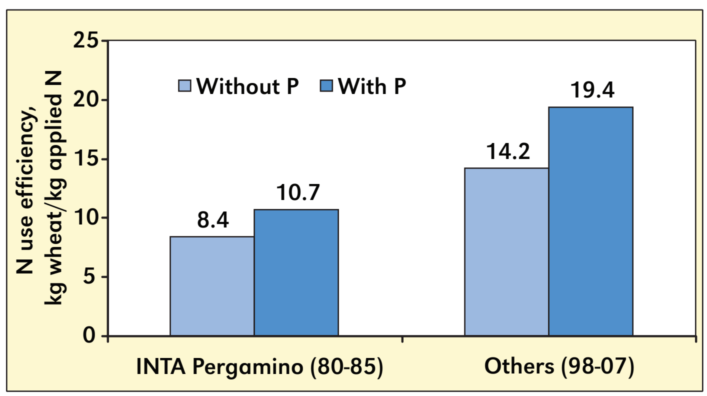


Figure 3. Nitrogen use efficiency in wheat with or without P application for trials carried out by EEA INTA Pergamino (Buenos Aires, Argentina) between 1980 and 1985, and by several other groups in the Pampas region of Argentina between 1998 and 2007.

(continued on page 27)

Food Production and Economics of Fertilizer Use — Tracking the Returns in a Grain Crop

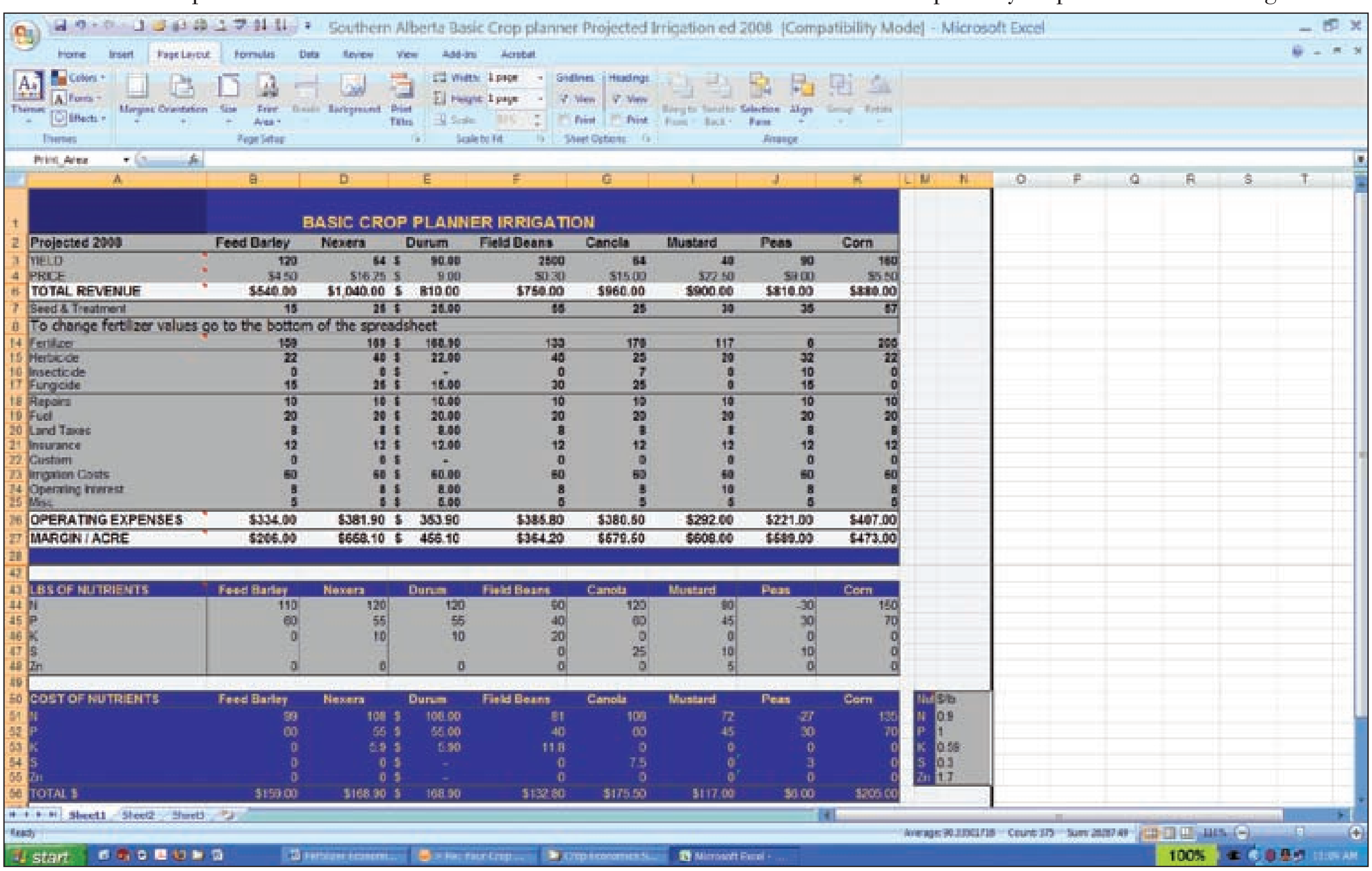
By Tom Jensen

Most grain and oilseed producers are pleased to realize the recent increase in crop prices after many years of relatively low and at times depressed grain and oilseed prices. There is an overall feeling of optimism in crop production. However, the accompanying increases in fertilizer prices have growers questioning whether or not the changes in crop and fertilizer prices relative to one another justify changes in fertilizer application rates.

A few calculations show that optimum rates of fertilizer have changed very little if at all, while the size of fertilizer expenditure has increased. Associated with the larger fertilizer expenditure is more up-front financing and much more valuable potential crop growing in the field. This combines to create an increased need for careful decision making. Growers can manage this increased need by doing the following.

- Have **soil samples taken and analyzed for nutrient availability** and adjust fertilizer rates on each individual field. Soil test laboratories are seeing an increase in fields being soil sampled.
- **Time fertilizer applications to maximize crop utilization** and minimize unwanted losses. Generally this may mean application near the time of planting or in split applications during the growing season for some crops.
- **Place N fertilizers in the soil in bands** to reduce losses compared to broadcast applications.
- Use appropriate **starter fertilizer blends** precision placed near or for some crops in the seed-row when planting.
- Consider using **fertilizer forms or additives** that can result in enhanced efficiency and /or reduced losses of applied nutrients. This may include use of controlled release fertilizers or addition of inhibitors that keep fertilizers in forms less susceptible to losses.
- Seek the advice of **Certified Crop Advisers (CCAs) and crop consultants** in making fertilizer decisions.

Sound advice from an experienced CCA can help a grower determine whether or not there should be changes in fertilizer rates. This is especially important when both grain and



Projected 2008	Feed Barley	Nexera	Durum	Field Beans	Canola	Mustard	Peas	Corn
YIELD	120	64	$ 90.00	2500	64	40	90	160
PRICE	$4.50	$16.25	$ 9.00	$0.30	$15.00	$22.50	$9.00	$5.50
TOTAL REVENUE	$540.00	$1,040.00	$ 810.00	$750.00	$960.00	$900.00	$810.00	$880.00
Seed & Treatment	15	25	$ 25.00	55	25	30	35	57
To change fertilizer values go to the bottom of the spreadsheet								
Fertilizer	159	169	$ 168.90	133	176	117	6	205
Herbicide	22	40	$ 22.00	40	25	20	32	22
Insecticide	0	0	$ -	0	7	0	10	0
Fungicide	15	25	$ 15.00	30	25	0	15	0
Repairs	10	10	$ 10.00	10	10	10	10	10
Fuel	20	20	$ 20.00	20	20	20	20	20
Land Taxes	8	8	$ 8.00	8	8	8	8	8
Insurance	12	12	$ 12.00	12	12	12	12	12
Custom	0	0	$ -	0	0	0	0	0
Irrigation Costs	60	60	$ 60.00	60	60	60	60	60
Operating Interest	8	8	$ 8.00	8	8	10	8	8
Misc.	5	5	$ 5.00	5	5	5	5	5
OPERATING EXPENSES	$334.00	$381.90	$ 353.90	$385.80	$380.50	$292.00	$221.00	$407.00
MARGIN / ACRE	$206.00	$658.10	$ 456.10	$364.20	$579.50	$608.00	$589.00	$473.00

LBS OF NUTRIENTS	Feed Barley	Nexera	Durum	Field Beans	Canola	Mustard	Peas	Corn
N	110	120	120	90	120	80	-30	150
P	60	55	55	40	60	45	30	70
K	0	10	10	20	0	0	0	0
S				0	25	10	10	0
Zn	0	0	0	0	0	5	0	0

COST OF NUTRIENTS	Feed Barley	Nexera	Durum	Field Beans	Canola	Mustard	Peas	Corn
N	99	108	$ 108.00	81	108	72	-27	135
P	60	55	$ 55.00	40	60	45	30	70
K	0	5.9	$ 5.90	11.8	0	0	0	0
S	0	0	$ -	0	7.5	0	3	0
Zn	0	0	$ -	0	0	0	0	0
TOTAL $	$159.00	$168.90	$ 168.90	$132.80	$175.50	$117.00	$6.00	$205.00

Nut	$/lb
N	0.9
P	1
K	0.59
S	0.3
Zn	1.7

Figure 1. Screen shot of the Crop Planner.

Abbreviations and notes for this article: N = nitrogen.

Table 1. Estimated margins (total revenue minus operating expenses) for years 2005 through 2008 for irrigated durum wheat, southern Alberta.

	Nutrients								
	N 120 lb/A	P_2O_5 55 lb/A	K_2O 10 lb/A	Expected	Market	Gross	Fertilizer	Operating	
Crop year	--------- Price, $/lb ---------			yield, bu/A	price, $/bu	revenue, $/A	cost, $/A	cost, $/A	Margin, $/A
2005	0.40	0.30	0.15	90	$4.27	$384.30	$66.00	$229.00	$155.30
2006	0.45	0.38	0.15	90	$4.27	$384.30	$76.40	$233.40	$150.90
2007	0.60	0.70	0.15	90	$6.40	$576.00	$112.00	$300.00	$276.00
2008	0.90	1.00	0.59	90	$9.00	$810.00	$168.90	$353.90	$456.10

fertilizer prices change.

An excellent example of a crop planning tool used with farm customers was developed by Keith Mills, a CCA working for a retail grain and crop input company in Western Canada. He works with farm customers growing crops under both irrigated and rain-fed conditions in southern Alberta. His easy-to-use Basic Crop Planner is a spreadsheet program he uses with customers to estimate potential returns per acre for a number of different crops. His customers often use this tool to help them decide which crops to grow if they are considering changes in their crop rotations. The grower can quickly calculate margins per acre by entering realistic crop yields for their farm along with current area prices for crop inputs, including fertilizers, and prices expected for harvested crops.

Keith Mills emphasizes that the yield and input price estimates entered need to be realistic for the area. The Basic Crop Planner is based on variable crop inputs and expected crop yields and current market prices, and doesn't include fixed costs as this can vary greatly from farm to farm depending on specific land ownership and rental conditions. Mills updates his crop planner each year with average crop prices and input costs for the area where he works. It can be modified by an individual customer especially for expected crop yields depending on specific field conditions, and if an alternate source for crop inputs at different prices is found.

It is interesting to compare information from a number of years for a specific crop and see how changes in crop input prices or operating costs and grain prices affect margin returns per acre. This growing season (2008) some farm customers were considering reducing their rates of fertilizer solely because of increases in fertilizer prices. However, when they saw what the margins were using current fertilizer and crop prices, fertilizer rates have in most cases remained similar to recent years and margins have increased. An example in **Table 1** shows estimated returns over the years 2005, 2006, 2007, and 2008 for irrigated durum wheat.

Operating costs have increased and fertilizer inputs have increased more compared to most other crop inputs, such as herbicides and fuel. The fertilizer costs as a percentage of operating costs are 29%, 33%, 37%, and 48%, respectively for the years 2005, 2006, 2007, and 2008. For example, if the years 2006 and 2008 are compared, fertilizer costs increased 121%, but margins increased 202%. Between the 2 years, every extra $1.00 of investment in fertilizer has been offset by $2.49 in increased margin per acre.

Fertilizer rates have remained similar over the past 4 years even though the portion of the operating costs from fertilizers has increased. Fortunately for growers, the return on fertilizer expenditures remains very positive and optimum economic fertilizer rates have remained similar to rates before the increases in both grain and fertilizer prices. BC

Dr. Jensen is IPNI Northern Great Plains Region Director, located in Saskatoon, Saskatchewan, Canada; e-mail: tjensen@ipni.net.

Soil Testing and Balanced Fertilization…from page 25.

long-term P management.

In a short-term analysis of P fertilization, it improved net margin at soil Bray P-1 levels below 15 to 20 mg/kg, and return to investment and cost per Mg grain at soil Bray P-1 levels lower or equal to 10 to 15 mg/kg (**Table 3**). The highest grain yields obtained at these experiments were 5.7 Mg/ha, and the rate used provides enough P to replenish the P extracted in wheat crops of up to 6 Mg/ha. Thus, soil testing and adequate P rates provided for high yields, economic profit, and neutral to positive soil P balances. Fertilizer P rates would be increased at lower soil Bray P-1 levels (i.e. less than 10 mg/kg) to improve Bray P-1 status of these soils.

Conclusions

- Balanced fertilization…NPS for this region…results in higher use efficiency of all the resources and inputs implied in grain production.
- Soil testing is a key BMP in defining the right rate of N and P for field crops of the Pampas of Argentina.
- Applying BMPs for fertilizer allows the objectives of productivity, profitability, sustainability, and a healthy environment to be achieved. BC

Dr. Garcia is IPNI Regional Director, Latin America-Southern Cone Program; e-mail: fgarcia@ipni.net.

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Economic Viability of Site-Specific Nutrient Management in Rice-Wheat Cropping System

By V.K. Singh, K.N. Tiwari, M.S. Gill, S.K. Sharma, B.S. Dwivedi, A.K. Shukla, and P.P. Mishra

The most dominant rice-wheat system of India is showing signs of fatigue, mainly due to inadequate and unbalanced fertilization. The current productivity of 2,130 kg/ha of rice and 2,670 kg/ha of wheat can be doubled by growing hybrid rice and locally recommended high-yielding varieties of wheat and by increasing and balancing fertilizer application rates to correct multiple nutrient deficiencies which are being widely observed. The net return to the extra fertilizer used in SSNM of the rice-wheat system averaged US$732/ha across all nine locations, a return of US$6.1 per US$1 invested.

The rice-wheat cropping system (RWCS) is India's most widely adopted system, covering over 10.5 million (M) ha – mostly in the country's north-west zone (Paroda et al., 1994). The productivity of both rice and wheat is low...2,130 and 2,670 kg/ha, respectively. The combination of poor soil fertility and inadequate, unbalanced, and inefficient use of fertilizers contributes much to this problem (Yadav et al., 2000; Dwivedi et al., 2001). Continuous rice-wheat cropping without adequate and balanced nutrition has resulted in a widespread problem of multiple nutrient deficiencies (Timsina and Connor, 2001). A multi-location, on-station research program was initiated to evaluate the significance of SSNM towards breaking yield stagnation. The research considers the correction of all existing nutrient deficiencies and the nutrient requirements of regionally attainable yield goals.

Field experiments were conducted for 3 years during 2003-04 to 2005-06 to evaluate the effect of SSNM in rice-wheat cropping system at 9 locations representing intensive agriculture system of north-west India. The deep alluvial soils of the experimental sites were generally sandy loam to loamy sand, but were clayey at Faizabad and Varanasi. Soils were generally neutral to slightly alkaline (pH 6.0 to 8.2) with the exception of Palampur which has acidic soil (pH 5.2). Soils were low to medium in available N, K, S, B, and Mn, and had medium to high levels of available P and Zn. The initial soil analysis was done by Agro-International, USA as per methods described by Portch and Hunter (2002). These soil analyses were the basis for developing the SSNM recommendations for attainable yield targets of 10 t/ha of hybrid rice and 6 t/ha of wheat.

Selected treatments allowed the assessment of responses to all the deficient nutrients so as to develop viable FBMPs for high yield sustainable agriculture. The SSNM nutrient packages for each site included all major, secondary and micronutrients considered deficient (**Table 1**). Both rice and wheat received N, P, and K while S and micronutrients were only applied to rice. At each location, the efficacy of the SSNM treatment was compared against SR and FP. Omission plots for different treatments were maintained to determine the individual responses to specific nutrients.

The fertilizer sources included urea (46% N), diammonium phosphate (18% N and 46% P_2O_5), potassium chloride (60% K_2O), elemental S, zinc sulfate (21% Zn and 10% S), Borax (10.5 % B), manganese sulfate (30.5% Mn, 17.5% S), and copper sulfate (24% Cu, 12% S). Entire quantities of P, K, S, micronutrients, and one-third of total N recommendation were applied at planting and the remaining N was top-dressed in two equal splits. Hybrid rice cv. PHB 71 and the locally recommended HYV of wheat were grown under optimum management conditions at all locations. Apart from differences in nutrient application rates, all other management practices were

Table 1. Experimental location and the nutrient applied in the rice-wheat cropping system.

		Nutrient applied, kg/ha					
		Rice			Wheat		
Location	State	SSNM	SR	FP	SSNM	SR	FP
Sabour	Bihar	$N_{150}P_{30}K_{100}S_{40}$	$N_{100}P_{40}K_{40}$	$N_{60}P_{30}$	$N_{150}P_{30}K_{100}$	$N_{120}P_{60}K_{40}$	$N_{60}P_{30}$
Palampur	Himachal Pradesh	$N_{100}P_{25}K_{80}S_{40}Zn_{20}B_5$	$N_{100}P_{30}K_{30}$	$N_{80}P_{20}$	$N_{100}P_{25}K_{80}$	$N_{100}P_{30}K_{30}$	$N_{80}P_{20}$
Ranchi	Jharkhand	$N_{150}P_{60}K_{100}S_{25}Zn_{30}B_5$	$N_{150}P_{75}K_{60}$	$N_{80}P_{40}K_{20}$	$N_{150}P_{60}K_{100}$	$N_{150}P_{75}K_{60}$	$N_{80}P_{40}K_{20}$
R.S. Pura	Jammu & Kashmir	$N_{150}P_{100}K_{120}S_{50}Zn_{40}Mn_{20}$	$N_{120}P_{60}K_{30}$	$N_{50}P_{30}K_{20}$	$N_{150}P_{100}K_{120}$	$N_{120}P_{60}K_{30}$	$N_{50}P_{30}K_{20}$
Ludhiana	Punjab	$N_{150}P_{60}K_{150}S_{40}Zn_{25}B_5Mn_{20}$	$N_{120}P_{30}K_{30}Zn_{25}$	$N_{180}P_{60}Zn_{10}$	$N_{150}P_{60}K_{150}$	$N_{120}P_{30}K_{30}$	$N_{180}P_{30}$
Faizabad	Uttar Pradesh	$N_{150}P_{60}K_{120}S_{40}Zn_{25}B_5Mn_{20}$	$N_{120}P_{60}K_{60}$	$N_{90}P_{40}$	$N_{150}P_{60}K_{120}$	$N_{120}P_{60}K_{60}$	$N_{90}P_{40}$
Kanpur	Uttar Pradesh	$N_{150}P_{30}K_{120}S_{50}Zn_{40}$	$N_{150}P_{75}K_{60}S_{25}$	$N_{80}P_{30}$	$N_{150}P_{30}K_{120}$	$N_{150}P_{75}K_{60}$	$N_{80}P_{30}$
Modipuram	Uttar Pradesh	$N_{150}P_{30}K_{80}S_{20}Zn_{25}B_5Mn_{20}$	$N_{150}P_{75}K_{75}Zn_{25}$	$N_{180}P_{60}Zn_{25}$	$N_{150}P_{30}K_{80}$	$N_{120}P_{60}K_{40}$	$N_{180}P_{60}$
Varanasi	Uttar Pradesh	$N_{150}P_{30}K_{80}S_{40}Zn_{40}B_5Mn_{20}Cu_{20}$	$N_{150}P_{75}K_{75}Zn_{25}$	$N_{180}P_{60}Zn_{25}$	$N_{150}P_{30}K_{80}$	$N_{120}P_{60}K_{40}$	$N_{180}P_{60}$

The equal levels of P and K are in the form of P_2O_5 and K_2O, Zn, Mn, and Cu are in the form of sulfate and B as borax.

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; B = boron; Mn = manganese; Zn = zinc; Cu = copper; RWCS = rice-wheat cropping system; HYV = high yielding variety; SSNM = site-specific nutrient management; FBMP = fertilizer best management practices; SR = state fertilizer recommendation; FP = farmer fertilizer practice; BCR = benefit-to-cost ratio.

While SSNM treatments required more investment in fertilizer nutrients, net returns were very favorable.

the same for the SSNM, SR, and FP plots. Economic comparisons for each of the nutrient management options included analysis of gross and net returns, as well as the additional return per unit investment in each individual crop and the entire RWCS. Results reported here are averages of 3 years of study.

The mean grain yield of rice (unhusked) obtained with SSNM was 8.20 t/ha compared to 6.95 t/ha with the SR and 6.03 t/ha with the FP (**Table 2**). SSNM out-yielded FP by an average of 2.17 t/ha or 36%. The extra yield obtained with rice through SSNM (over FP) ranged from 1 t/ha at Varanasi to 3.27 t/ha at Sabour, indicating an almost three-fold difference amongst locations. This yield advantage with rice was on the order of 25% or more at 7 out of 9 sites. The SSNM treatment out-yielded FP by more than 2 t/ha at 5 out of 9 locations. Similarly, the rice yield advantages were 3 t/ha or more at Sabour, Faizabad, and Modipuram. Although the SR had a significant edge over FP, the overall response was restricted to only 0.92 t/ha, or 15%.

Averaged over the locations, the grain yield of the succeeding wheat crop was 4.86 t/ha with SSNM against 3.56 t/ha under FP (**Table 2**). Averaged across the locations, the SSNM plot out-yielded the FP by 1.30 t/ha, or 41%. The additional yield obtained with SSNM over FP ranged from 0.39 t/ha at Ludhiana to 1.92 t/ha at Sabour indicating an almost 5-fold difference amongst locations. This yield advantage was 30% or more at 6 out of 9 locations. Similarly, the productivity gain over FP by 1.0 t/ha or more was at 7 out of 9 locations. As with rice, significant yield response for SR was also obtained in wheat and the magnitude of yield increase over FP was 0.74 t/ha, or 21%.

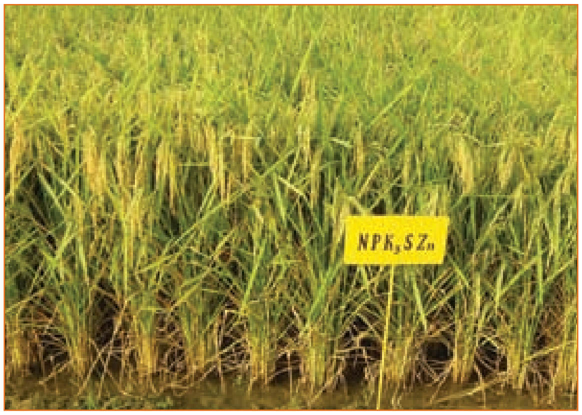
Table 2. Grain yield response to SSNM and state recommended fertilizer doses over farmer nutrient management practice.

	Rice			Wheat			Rice-wheat system		
	Yield,	Response		Yield,	Response		Yield,	Response	
Treatment	t/ha	t/ha	%	t/ha	t/ha	%	t/ha	t/ha	%
Sabour									
SSNM	8.23	3.27	66	5.18	1.92	59	13.40	5.19	63
SR	6.03	1.07	22	4.55	1.30	40	10.58	2.37	29
FP	4.96	–	–	3.25	–	–	8.21	–	–
Palampur									
SSNM	5.28	1.14	28	3.41	1.26	59	8.70	2.41	38
SR	4.70	5.58	14	2.99	0.84	39	7.68	1.39	22
FP	4.14	–	–	2.15	–	–	6.29	–	–
Ranchi									
SSNM	6.76	2.56	61	4.05	1.47	57	10.80	4.03	60
SR	5.96	1.76	42	3.40	0.82	32	9.36	2.58	38
FP	4.20	–	–	2.58	–	–	6.77	–	–
R.S. Pura									
SSNM	8.40	1.71	26	4.64	1.35	41	13.04	3.06	31
SR	7.38	0.69	10	4.07	0.78	24	11.46	1.47	15
FP	6.69	–	–	3.29	–	–	9.99	–	–
Ludhiana									
SSNM	10.43	1.30	14	6.02	0.39	7	16.45	1.69	11
SR	9.81	0.67	7	5.79	0.16	3	15.60	0.83	6
FP	9.13	–	–	5.63	–	–	14.77	–	–
Faizabad									
SSNM	8.28	3.08	59	4.43	1.75	65	12.71	4.83	61
SR	6.13	0.93	18	3.42	0.74	28	9.55	1.67	21
FP	5.20	–	–	2.68	–	–	7.88	–	–
Kanpur									
SSNM	9.23	2.34	34	5.69	1.15	25	14.91	3.48	30
SR	8.28	1.39	20	5.26	0.73	16	13.55	2.12	19
FP	6.89	–	–	4.54	–	–	11.43	–	–
Modipuram									
SSNM	10.18	3.16	45	6.10	1.55	34	16.28	4.71	41
SR	7.73	0.70	10	5.41	0.86	19	13.14	1.56	14
FP	7.03	–	–	4.55	–	–	11.58	–	–
Varanasi									
SSNM	7.03	1.00	17	4.19	0.81	24	12.46	1.93	18
SR	6.53	0.50	8	3.85	0.47	14	11.61	1.08	10
FP	6.02	–	–	3.39	–	–	10.53	–	–
Mean over location									
SSNM	8.20	2.17	36	4.86	1.30	41	12.79	3.30	35
SR	6.95	0.92	15	4.31	0.74	21	11.04	1.55	16
FP	6.03	–	–	3.56	–	–	9.49	–	–
CD at 5%	0.59	–	–	0.25	–	–	0.71	–	–

CD = critical difference

The productivity of the entire rice-wheat system was highest under SSNM (12.79 t/ha), which was 35% more than FP (9.49 t/ha). The productivity gain due to SSNM in rice plus wheat through SSNM over FP ranged from 1.69 t/ha at Ludhiana to 5.19 t/ha at Sabour, indicating an almost 3-fold difference among locations. The productivity gain under SSNM had a yield improvement of 3 t/ha or more at 6 out of 9 locations. The extent of yield increase was more than 4 t/ha at 4 sites including Sabour, Ranchi, Faizabad, and Modipuram.

SSNM in rice cultivation involved an additional expenditure ranging from US$27 to US$147/ha (average US$84/ha) over the FP (**Table 3**). This additional expenditure generated an average extra produce value (rice grain plus straw) worth US$467/ha within a range of US$216 at Varansi to US$702/ha



Fertilizer treatments in rice plot.

at Sabour. After deducting the additional costs, the resulting average net return was US$383/ha with a BCR (US$ per US$ investment) of 4.6.

In wheat, moving from FP to SSNM involved an additional fertilizer expenditure of US$8 to US$74/ha with an average of US$36/ha (**Table 3**). Generally, the lower additional investment needed for wheat as compared to rice was due to the cost incurred for S and micronutrients application in rice only. Since wheat has also benefited from the residual effect of these nutrients, the net returns have been affected proportionately. The additional net return under SSNM over FP ranged from US$96 at Ludhiana to US$530 at Sabour. As expected, the improvements in wheat were associated with higher BCRs compared to rice because of the high additional input cost debited to rice for S and micronutrients.

The cumulative effect of SSNM under the entire RWCS involved an additional average expenditure of US$120/ha and resulted in an additional produce value worth US$852/ha (gross) and US$732/ha (net) after deducting the extra input costs. This was achieved at an average BCR of 6.1, which means that every extra US$1 invested in nutrients for SSNM over FP produced an extra crop value of US$6.1. Any technological improvements with a BCR of 5 would be highly remunerative and suitable for large-scale adoption. Considering 50% of the increase in productivity on farmer fields as compared to the increases observed in these on-station experiments, and only a 25% area coverage with SSNM, the total annual increase in RWCS production could be 11 M t for rice and 4.75 M t for wheat. Site- and crop-specific balanced fertilization in addition to maintaining food security will help sustain soil and environment health due to improved nutrient use efficiency. BC

Table 3. Changes in economic returns while shifting from farmer nutrient management practice to SSNM in the rice-wheat cropping system[1].

Location	Crop	SSNM versus Farmer practice: Extra cost of fertilizer, US$/ha	Value of extra produce, US$/ha	Net return, US$/ha	Benefit-to-cost, US$ per US$ extra invested in nutrients
Sabour	Rice	69	702	633	9.2
	Wheat	42	572	530	12.6
	System	111	1,274	1,163	10.5
Palampur	Rice	76	246	170	2.2
	Wheat	36	376	340	9.4
	System	112	622	510	4.6
Ranchi	Rice	78	551	474	6.1
	Wheat	42	437	395	9.4
	System	120	988	869	7.2
R.S. Pura	Rice	147	367	220	1.5
	Wheat	74	401	327	4.4
	System	221	768	547	2.5
Ludhiana	Rice	74	279	205	2.8
	Wheat	20	116	96	4.8
	System	94	395	301	3.2
Faizabad	Rice	105	662	557	5.3
	Wheat	46	521	475	10.3
	System	151	1,182	1,032	6.8
Kanpur	Rice	94	503	409	4.4
	Wheat	41	343	302	7.4
	System	135	846	711	5.3
Modipuram	Rice	27	678	651	24.1
	Wheat	8	462	454	56.8
	System	35	1,140	1,105	31.6
Varanasi	Rice	87	216	129	1.5
	Wheat	15	240	225	15.0
	System	102	456	354	3.5
Mean over location					
	Rice	84	467	383	4.6
	Wheat	36	385	349	9.7
	System	120	852	732	6.1

[1]Economic analysis based on 2007/08 costs of nutrients and grain/straw values. Fertilizer (US$/kg): N, 0.26; P_2O_5, 0.41; K_2O, 0.19; S, 0.66; zinc sulfate, 0.50; borax, 0.85; manganese sulfate, 0.75; copper sulfate, 0.33. Grain (US$kg): rice, 0.17; wheat, 0.23. Straw (US$/kg): rice, 0.025; wheat, 0.038.
Note: The government of India subsidizes the cost of fertilizer for farmers and controls the prices for crops.

Dr. Singh is Senior Scientist at Project Directorate for Cropping Systems Research, (PDCSR) Modipuram Meerut, India, e-mail: vkumarsingh_01@yahoomail.com. Dr. Tiwari is Director, IPNI India Program, Gurgaon, Haryana, e-mail kntiwari@ipni.net. Dr. Gill is Project Director and Dr. Sharma is PDCSR, Modipuram Meerut. Dr. Dwivedi is Principal Scientist at Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute New Delhi. Dr. Shukla is Senior Scientist and Mr. Mishra is Technical Officer, both with PDCSR, Modipuram Meerut.

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IPNI Supports New Professorship to Explore Link between Fertilizer and Food Nutrition

IPNI has committed funding in support of the new "Nutrients for Life Foundation Professor of Soil and Food Crop Nutrition" position at Oklahoma State University (OSU). The professorship endowment is being supported in cooperation with the Nutrients for Life Foundation (NLF) and The Fertilizer Institute (TFI). "It is our hope that this professorship will encourage the expansion of an untapped and important area in academic research," said NLF Executive Director Harriet Wegmeyer. "If, as predicted, a correlation between fertilizer and healthier foods is established, imagine the impact. An increasingly health-conscious public will finally regard fertilizers for what they truly are…nutritious for both plants and, in turn, people." A gift totaling $250,000 from the three organizations to the university was announced in July 2008.

Through a rare matching program made available from oil and gas executive and OSU alumnus T. Boone Pickens and the state of Oklahoma, the fertilizer industry's $250,000 will translate to $1 million to fund a professorship in perpetuity. This position brings the strengths of three organizations together to address fertilizer's affect on food nutritional quality.

"The quality of the food we eat is directly related to the fertility of the soil where the crop was grown. The nutrients in food crops originate from the soil, but soils do not have an unlimited supply of nutrients and may not supply plant nutrients in proper balance … hence the need for fertilizer nutrients," said IPNI President Dr. Terry L. Roberts. "It would be difficult, if not impossible, to manage food crop nutrition without understanding how to manage the fertility of agricultural soils."

The gift will create the "Nutrients for Life Foundation Professor of Soil and Food Crop Nutrition", within the College of Agricultural Sciences and Natural Resources. The cross-disciplinary position will work closely with the college's plant and soil sciences department and the Robert M. Kerr Food and Agricultural Products Center. The university expects to fill the position in 2009. OSU President Burns Hargis expressed appreciation to the fertilizer industry for this support of academics and research.

"Presently, the global food crisis is top of people's minds and appropriate application of fertilizer is key to the solution. Not only is fertilizer responsible for 40 to 60% of food production, but we hope to show through research at OSU its importance on food nutrition as well," said TFI President Ford B. West.

Endowed professorships and chairs are academic designations which provide support for faculty salary, graduate assistantships, equipment, and research needs, as well as other support. BC

Conversion Factors for U.S. System and Metric Units

Because of the diverse readership of *Better Crops with Plant Food*, units of measure are given in U.S. system standards in some articles and in metric units in others…depending on the method commonly used in the region where the information originates. For example, an article reporting on corn yields in Illinois would use units of pounds per acre (lb/A) for fertilizer rates and bushels (bu) for yields; an article on rice production in Southeast Asia would use kilograms (kg), hectares (ha), and other metric units.

Several factors are available to quickly convert units from either system to units more familiar to individual readers. Following are some examples which will be useful in relation to various articles in this issue of *Better Crops with Plant Food*.

To convert Col. 1 into Col. 2, multiply by:	Column 1	Column 2	To convert Col. 2 into Col. 1, multiply by:
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in.	2.54
	Area		
2.471	hectare, ha	acre, A	0.405
	Volume		
1.057	liter, L	quart (liquid), qt	0.946
	Mass		
1.102	tonne[1] (metric, 1,000 kg)	short ton (U.S. 2,000 lb)	0.9072
0.035	gram, g	ounce	28.35
	Yield or Rate		
0.446	tonne/ha	ton/A	2.242
0.891	kg/ha	lb/A	1.12
0.159	kg/ha	bu/A, corn (grain)	62.7
0.149	kg/ha	bu/A, wheat or soybeans	67.2

[1]The spelling as "tonne" indicates metric ton (1,000 kg). Spelling as "ton" indicates the U.S. short ton (2,000 lb). When used as a unit of measure, tonne or ton may be abbreviated, as in 9 t/ha. A metric expression assumes t=tonne; a U.S. expression assumes t=ton.

Fertilizer Still Pays

About 7 years ago I wrote an article titled "Fertilizer Still Pays…Even in Today's Economy." At that time crop prices were low, with soybeans at $4/bu and corn at $2/bu. Urea was $0.30/lb nitrogen, phosphorus was $0.25/lb P_2O_5, and potash was $0.14/lb K_2O. The gist of the article — fertilizer was a good investment, even with the low crop prices. Today, urea-nitrogen is about $0.75/lb, phosphorus is $0.70/lb P_2O_5, and potash is $0.64/lb K_2O. And today, more than ever, farmers are wondering if "Fertilizer Still Pays?"

Fertilizer prices are at historic highs, having increased 250 to 450% in the last 7 years. But corn and soybean prices are also higher; they have quadrupled. With $8/bu corn and $16/bu soybeans, the fertilizer-to-crop price ratio today is not that different from back then. Fertilizer is still a good investment. Applied at the proper rate, and used efficiently, returns of $3 or more are still possible for each dollar invested in fertilizer.

The principles of fertilizer economics are just as applicable today as they were 50 years ago. Gordon Nance and John Falloon of the University Missouri, from an article they wrote on fertilizer economics in *Better Crops* in 1958, summarized it this way: "*The most promising way to increase volume of business, net profit per unit of production, and net income on most farms is to increase production per acre — and increased use of fertilizer is the most important factor in accomplishing this.*"

Now is not the time to cut back on fertilizer … few farm investments pay greater dividends. My back-of-the-envelope calculations show that at recent prices, it would take 6 to 7 bu of soybeans and 24 bu of irrigated corn to pay for the fertilizer needed to grow the crop. As you make your fertilizer decisions this fall — sharpen your pencil and pay close attention to soil testing, fertilizer rate and placement, and other best management practices that will ensure fertilizers are used most efficiently — and I am confident your fertilizer will continue to be a good investment.

Terry L. Roberts
President, IPNI

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