BETTER CROPS
WITH PLANT FOOD

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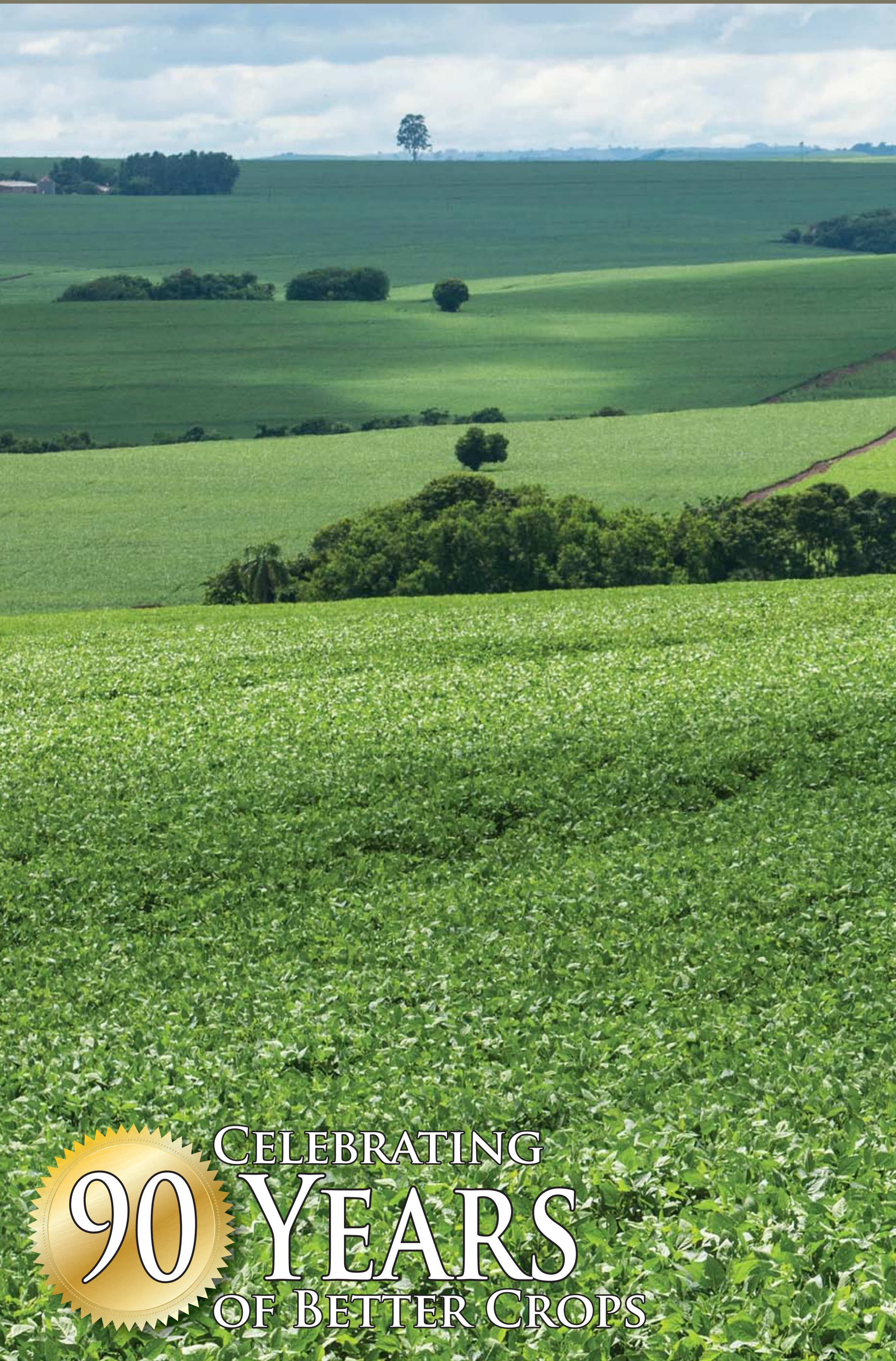

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BETTER CROPS
WITH PLANT FOOD

Vol. XCVII (97) 2013, No. 1

Our cover: Soybean fields near Maringa, Parana, Brazil.
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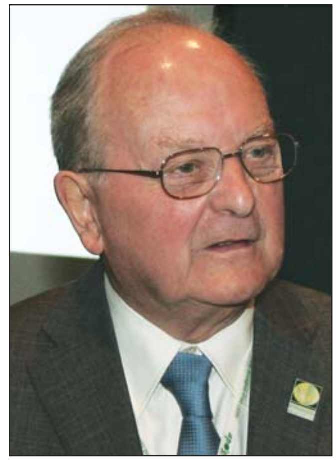
Note to Readers: Articles which appear in this issue of *Better Crops with Plant Food* can be found at: >**www.ipni.net/bettercrops**<

2012 IPNI Science Award Goes to A.E. Johnston of Rothamsted Research



Mr. A.E. Johnston

The International Plant Nutrition Institute (IPNI) has named Mr. Arthur Edward (Johnny) Johnston as the winner of the 2012 IPNI Science Award. Mr. Johnston receives a special plaque along with a monetary award of USD 5,000.

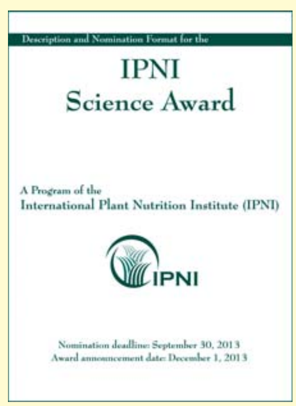
"We are honored to be able to announce Johnny as the recipient of the IPNI Science Award," said Dr. Terry Roberts, President of IPNI. "As an internationally-acclaimed expert on soil organic matter improvement and the efficient use of N, P and K fertilizers, Johnny's contributions have been critical to our understanding of basic processes in soil fertility and crop nutrition. His work provides much of the base from which soil quality and sustainable agriculture research finds its center. We applaud Johnny's dedication to long-term research and his many contributions in written, oral and leadership form."

Dr. Roberts also acknowledged the other outstanding nominees for the award, and encouraged future nominations of qualified scientists. Private or public sector agronomists, soil scientists and crop scientists from all countries are eligible for nomination. This is the sixth year the IPNI Science Award has been presented. The previous recipient in 2011 was Dr. Michael McLaughlin of the University of Adelaide and the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

Johnny Johnston received his B.Sc. degree in Chemistry and Agricultural Chemistry from the University College of North Wales, Bangor in 1950. From 1953 to present day, Johnny has been associated with Rothamsted Research, Harpenden, UK. From 1983 to 1986, he was Head, Soils Division; 1987 to 1989, Head, Soils and Crops Production Division; 1989 to current date, Lawes Trust Senior Fellow.

Mr. Johnston is a Past President and an Honorary Member of the International Fertiliser Society, Honorary Member of the Fertiliser Manufacturers Association (UK), and Honorable Member of the Royal Swedish Academy of Agriculture and Forestry. Johnny is or has been a member of the Scientific Advisory Committee of the International Potash Institute, the World Phosphate Institute, the British Beet Research Organisation and the Technical Advisory Committee of the Potash Development Association (UK). He has undertaken commissions for scientific societies, institutes and agricultural industry associations. His awards and honors include the Annual Crop Nutrition Award presented by the International Fertilizer Industry Association (1994), the Francis New Memorial Medal presented by the International Fertiliser Society (1997); and the Leo M. Walsh Memorial Lecture invited by the Soil Science Society of America (2010). BC

Annual Awards Offered by IPNI


Description and Nomination Format for the

IPNI Science Award

A Program of the International Plant Nutrition Institute (IPNI)

IPNI

Nomination deadline: September 30, 2013
Award announcement date: December 1, 2013


International Plant Nutrition Institute IPNI

ANNOUNCEMENT of the International Plant Nutrition Institute (IPNI) Scholar Awards — 2013

IPNI Science Award - Each year, IPNI offers the IPNI Science Award to recognize and promote distinguished contributions by scientists. The Award is intended to recognize outstanding achievements in research, extension or education; with focus on efficient management of plant nutrients and their positive interaction in fully integrated crop production that enhances yield potential. Such systems improve net returns, lower unit costs of production, and maintain or improve environmental quality.

The Award requires that a nomination form (no self-nomination) and supporting letters be received at IPNI Headquarters by September 30, 2013. A committee of noted international authorities selects the recipient. Nomination forms for the 2013 IPNI Science Award are available from the IPNI Award website >www.ipni.net/awards<.

IPNI Scholar Award - IPNI is proud to continue its support of the IPNI Scholar Award program in 2013. This Award of USD 2,000 is an annual competition amongst students enrolled in graduate degree programs supporting the science of plant nutrition and crop nutrient management including: agronomy, horticulture, ecology, soil fertility, soil chemistry, and crop physiology. Graduate students must also attend a degree-granting institution located in any country with an IPNI Program.

The deadline for applications for the 2013 IPNI Scholar Award is June 30. Regional committees of IPNI scientific staff select the recipients. The selection committee adheres to rigorous guidelines while considering each applicant's achievements. The awards can be presented directly to the students at their universities and no specific duties are required of them.

More information on the IPNI Scholar Award is available from IPNI Staff, the IPNI Award website listed above, or from participating universities. BC

4R Management: Differentiating Nitrogen Management Categories on Corn in Iowa

By Peter M. Kyveryga and Tracy M. Blackmer

Results of two large-scale on-farm evaluation studies are summarized where farmers used later-season digital aerial imagery, corn stalk nitrate tests (CSNT) and yield monitoring technology to quantify differences between five major N management categories—formed by combining different application timings and N fertilizer sources.

The role of N fertilizer source and its timing of application in corn production is often emphasized in many soil fertility textbooks as major factors determining the economic efficiency of N fertilization as well as the risk of N loss from excessive soil moisture. In practice, however, the effects of common timings and sources on economic optimum N rates are difficult to quantify, complicating development of fertilizer N recommendations (Sawyer et al., 2006).

Historically in Iowa, farmers could apply N in fall, spring, as a sidedress and could use at least four N sources, including manure. To study the effects of these timing and source options, traditional yield response studies were required to include several (e.g. 3 by 4) treatment combinations at a single location. Moreover, studying the common interaction between rainfall, timing and N source required a relatively large number of trial locations. Even with this large number of environmental replications, studying these effects was often both impractical and cost prohibitive.

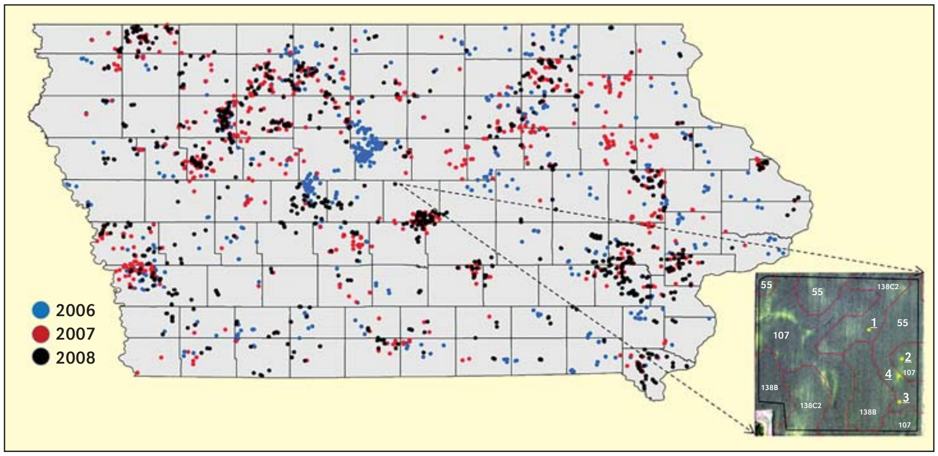


Figure 1. Locations of on-farm evaluations of late-season corn N status using digital aerial imagery of the corn canopy and CSNT across Iowa. Corn stalk samples were collected within the three predominant soil types and within a targeted deficient "Area 4" in each of > 2,300 corn fields during 3 years.

A renewed focus on using the best timing and sources of N application has been recently discussed in the 4R (Right source, Right rate, Right time and Right place) Nutrient Stewardship framework (IPNI, 2012). Using a variety of precision agriculture tools (i.e. yield monitoring, remote sensing and GPS) farmers can conduct studies on their own farms to collect data to quantify the effects of N timing and source on corn N status and corn yields across relatively large areas.

We summarize two types of on-farm studies conducted by farmers in Iowa to identify differences among five major N management categories—Fall AA, Fall Manure, Spring AA, Spring UAN (broadcast and incorporated in the majority of trials), and SD UAN or AA (referred to hereafter as just SD UAN)—created by combining common N timing and source applications in corn.

Interactive Effects of Rainfall and N Management Categories on the Size of N Deficient Areas within Fields

A 3-year survey was conducted within 683 farm fields in 2006, 824 fields in 2007, and within 828 fields in 2008 across Iowa (**Figure 1**). Using late-season digital aerial imagery of the corn canopy, four sampling areas were selected within each corn field to conduct a CSNT. Three stalk samples (10 individual stalks in each) were collected within the three predominant soil types to characterize the field-average corn N status. A fourth targeted sample was collected in an area that exhibited a lighter colored corn canopy in the aerial imagery, which we interpreted as a N deficient area of the field. The stalk sample collection and test interpretations were done according to the previous CSNT test interpretations in Iowa (Blackmer and Mallarino, 1996).

Digital aerial imagery (comprised of blue, green, red, and near-infrared bands) of the corn canopy was acquired in late August or early September. Green band reflectance values of the imagery and stalk nitrate values were used to estimate the size (%) of N deficient and sufficient areas within each field. The estimated N deficient areas corresponded to the deficient category (< 250 ppm) and the N sufficient areas (> 250 ppm) corresponded to the marginal, optimal, and excessive categories of the CSNT results. Kyveryga et al. (2011; 2012) describes more information about the properties of digital aerial imagery and the methods of normalization of the imagery, and estimation of the areas (%) within fields with different N status. The size of the N deficient area and summary statistics of N rates that corresponded to the optimal corn N status were compared among the five N management categories (Fall AA, Fall Manure, Spring AA, Spring UAN, and SD UAN).

The average estimated N deficient area for corn after soybean in 2007 (relatively wet) and 2008 (extremely wet), was from 45 to 300% higher than that in 2006, a relatively dry

Common abbreviations and notes: N = nitrogen; Fall AA = fall-applied anhydrous ammonia; Fall Manure = fall-injected liquid swine manure; Spring AA = spring-applied anhydrous ammonia; Spring UAN = spring-applied urea-ammonium nitrate solution; SD UAN = sidedress UAN; GPS = global positioning system; ppm = parts per million.

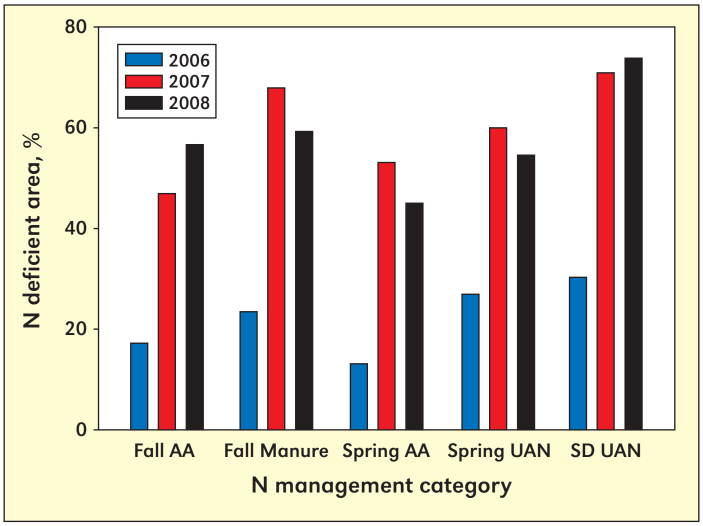


Figure 2. Estimated average N deficient areas within cornfields for five N management categories for corn after soybean in relatively dry 2006, wet 2007, and extremely wet 2008 growing seasons. Only fields (565 in 2006, 240 in 2007, and 311 in 2008) that did not have extensive flooded areas, terraces, waterways and more than one corn hybrid were used in the analysis.

year (**Figure 2**). More than 50% of the field area in some N management categories was estimated as N deficient in 2007 and 2008, with about 75% of the SD UAN areas being deficient in 2008. In 2006, Spring UAN and SD UAN management had larger N deficient areas than where other fall or spring N management categories were used, mostly due to limited soil moisture and lower N availability. In 2007 and 2008, average N deficient areas for Fall AA, Fall Manure and Spring UAN were significantly larger than those for Spring AA. Assessments of spatial variability in the corn canopy reflectance for Spring AA also indicated that N losses were lower under this management category. In fact, Spring AA had the smallest percentage N deficient areas of all the timing and source combinations tested in relatively dry 2006.

Observed N Rates Corresponding to the Optimal Corn N Status

In each year, more N from Fall Manure was required to reach the optimal CSNT status than from any other N source or application timing (**Figure 3**). This could be explained by relatively larger N losses, the larger uncertainty in estimated N rates applied by farmers, and/or by smaller than expected N availability from liquid swine manure. Fall AA required the second highest amount of N for optimal stalk nitrate status while spring and sidedress N applications consistently required the lowest amount of N. Most of the CSNT samples from the SD UAN management category were N deficient in extremely wet 2008 (**Figure 2** and **3**).

Differences in Critical CSNT Values between N Management Categories

In 125 on-farm trials conducted from 2007 to 2010 across Iowa, farmers compared their normal N rates to those that were one-third or 50 lb N/A higher or lower (**Figure 4**). Each corn after corn or corn after soybean trial consisted of two non-randomized alternating N treatments (normal and normal plus

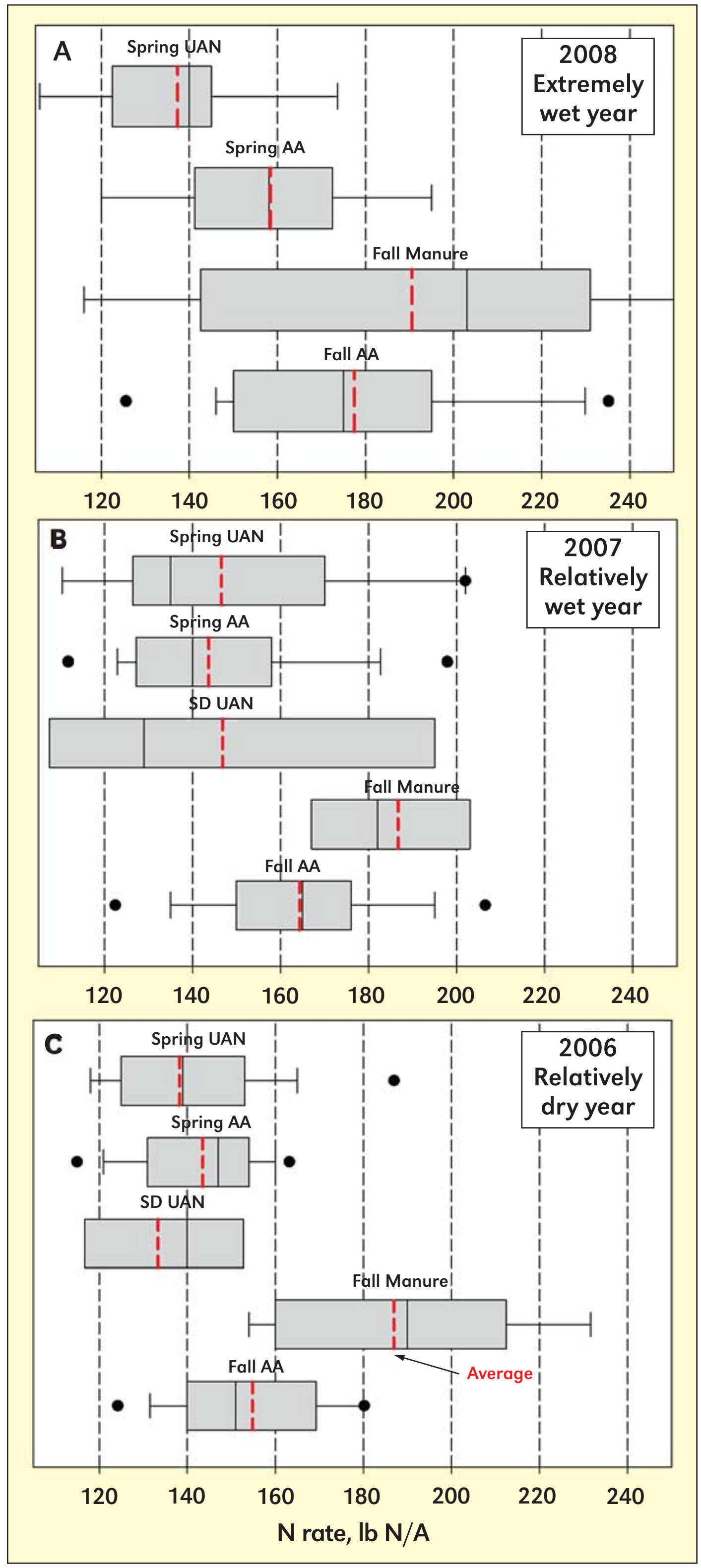


Figure 3. Box plots showing summary statistics for observed N rates corresponding to the optimal category of CSNT for five N management categories for > 1,400 corn-after-soybean fields evaluated during the 3 years. The boxes indicate 25th and 75th percentiles, the black vertical line represents the median, the red vertical line is the average, and whisker bars indicate 5th and 95th percentiles. The summary for applied N rates for SD UAN in 2008 is not shown because most of the fields with SD applications tested below the optimal.

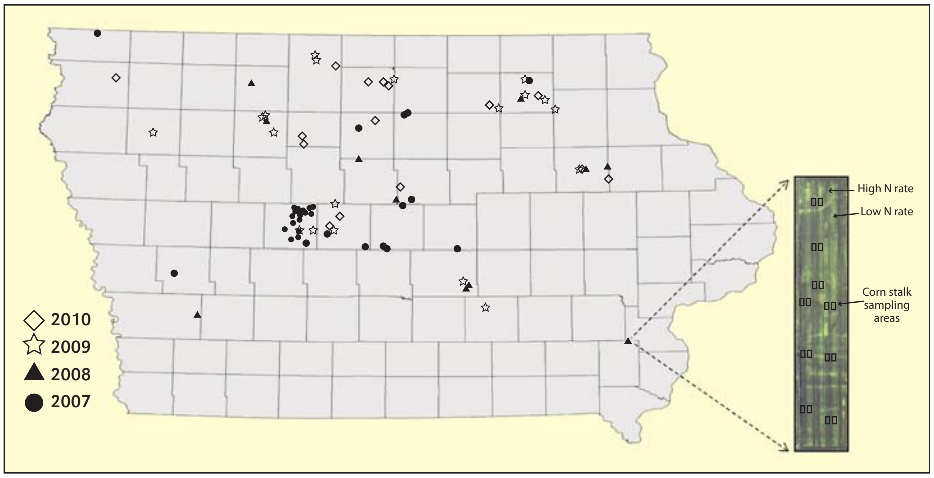


Figure 4. Locations of 125 on-farm two-treatment N evaluation trials conducted during 4 years. Each trial had the farmer's normal N fertilizer rate compared to a rate that was one-third or 50 lb N/A higher or lower. Nine sampling areas were used to collect CSNT samples within fertilizer strips which received the lower N rates.

or minus 50 lb N/A) replicated at least three times within an area > 20 acres. The risk of potential bias from not randomizing N fertilizer treatments in these multi-location trials is relatively small compared with small-plot trials, which are often conducted at one or at very few locations (Kyveryga et al., 2013). The treatments were harvested with combines equipped with yield monitors and GPS. Categorical economic (profitable and non-profitable) yield response was related to CSNT values collected within nine sampling areas from the lower N rate in each trial. A yield response of > 5 bu/A was considered profitable from application of an additional 50 lb N/A. Using estimated probabilities of a profitable yield response to the additional N, critical CSNT values were estimated for each N management category using multilevel binary (profitable and non profitable) categorical analysis from the data across 4 years.

The probability of receiving a profitable yield response (> 5 bu/A) to an additional 50 lb N/A applied in the near-optimal range of fertilization and the critical CSNT values for the five N management categories for corn after corn and corn after soybean are shown in **Figure 5**. The critical values separated deficient samples (those with probabilities > 0.51) from N sufficient samples (those with probabilities < 0.49). The critical CSNT value for Fall Manure was about 3,500 ppm, which was about 1,500 ppm higher than is currently recommended for the upper end of the optimal CSNT category in Iowa (Blackmer and Mallarino, 1996). Also, the critical CSNT value for Fall Manure was about 3,000 ppm higher than CSNT values for Fall AA, Spring UAN and SD UAN or AA. The estimated probability values for Fall Manure were also consistently higher across all N sufficiency ranges. These observations confirmed the results of the 3-year survey shown in **Figure 3**. Despite the higher amount of N applied, a category of Fall Manure is characterized by larger uncertainty and variability in corn N status than N management categories with commercial N sources used in Iowa.

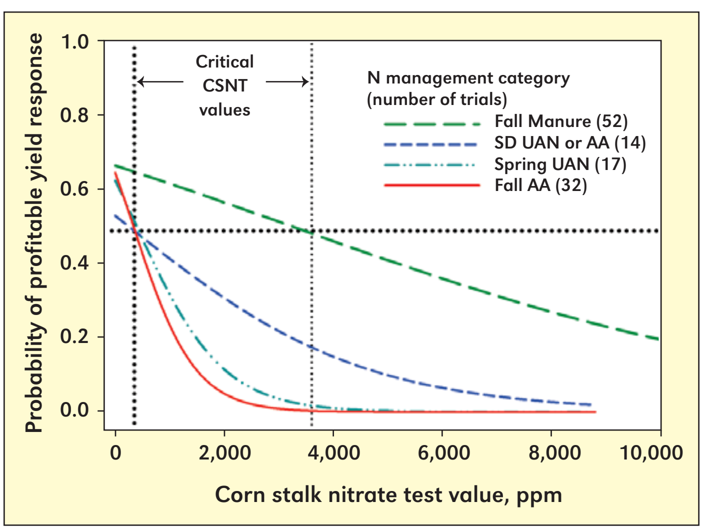


Figure 5. Critical CSNT values separating N deficient and sufficient categories for the five N management categories for corn after corn and corn after soybean, based on 125 two-treatment on-farm N evaluation trials.

Summary

Two large-scale on-farm evaluation studies confirmed the importance of considering interactions between rainfall, N timing and N sources in Iowa cornfields. Commonly used N management categories showed differences in the size of N deficient areas within fields, average N rates corresponding to the optimal corn N status, and the probability of receiving a profitable yield response to additional N applied in the near-optimal range. The described field methodology and data analysis can be used to focus more on collecting local data to study the complex interactive effects of rainfall, application timing and N fertilizer sources on corn N status and yields. These on-farm research approaches can be used to support guidance on fertilizer best management practices to increase the economic efficiency of applied N while reducing its potential negative impacts on the environment. Assessment of the risk associated with reducing normal N rates applied by farmers can also be estimated using similar on-farm evaluations conducted at different spatial and temporal scales (Kyveryga et al., 2013). BC

Dr. Kyveryga (e-mail: pkyveryga@iasoybeans.com) is a Senior Research Associate, and Dr. Blackmer is Director of Research for the On-Farm Network, Iowa Soybean Association.

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Modern Corn Hybrids' Nutrient Uptake Patterns

By Ross R. Bender, Jason W. Haegele, Matias L. Ruffo, and Fred E. Below

Biotechnology, breeding, and agronomic advancements have propelled corn yields to new highs with little guidance as to how to fertilize these modern corn hybrids to achieve their maximum yield potential. Current fertilization practices, developed decades ago, may not match uptake capabilities of modern hybrids that contain transgenic insect protection now grown at population densities higher than ever before. A re-evaluation of nutrient uptake and partitioning can provide the foundation for fine-tuning our practices as we strive to achieve corn's maximum yield potential.

As summarized by Bruulsema et al. (2012), optimizing nutrient management includes using the right source at the right rate, right time, and right place—the 4R approach. Research pertaining to primary macronutrient uptake, partitioning, and timing (Sayre, 1948; Hanway, 1962; Karlen et al., 1988), though fundamentally accurate for previous hybrids and management practices, may be unrepresentative of modern hybrids in higher yielding environments. The objective of this study was to determine how modern, transgenic insect-protected corn hybrids in high-yielding systems take up and utilize nutrients.

Nutrient contents of N, P, K, S, Zn, and B were determined at six incrementally spaced growth stages: V6 (vegetative leaf stage 6), V10, V14, R2 (blister), R4 (dough), and R6 (physiological maturity) (Hanway, 1963). Field experiments were conducted at the Northern Illinois Agronomy Research Center in DeKalb, Illinois and the Department of Crop Sciences Research and Education Center in Urbana, Illinois. A total of six hybrids ranging in relative maturity from 111 to 114 days were used with genetic resistance to feeding from Western Corn Rootworm (*Diabrotica virgifera virgifera*), European Corn Borer (*Ostrinia nubilalis*), and other species in the Lepidoptera order. In all cases, hybrids were seeded to obtain a final stand of 34,000 plants/A. Representative plants were separated, analyzed, and evaluated in four tissue fractions: 1) stalk and leaf sheaths; 2) leaf blades; 3) tassel, cob, and husk leaves; and 4) corn grain, respectively referred to as stalk, leaf, reproductive, and grain tissues. Agronomic management at planting included a soil insecticide and a broadcast application of 150 lb P_2O_5/A as MicroEssentials® SZ™ along with 180 lb N/A as urea. This was followed by 60 lb N/A as Super-U (with urease and nitrification inhibitors) side-dressed at V6 and a fungicide at VT/R1 (tasseling/silking).

Nutrient Uptake and Removal

Across the two sites in 2010, these transgenic corn rootworm resistant hybrids yielded an average of 230 bu/A (range of 190 to 255 bu/A) and we will base our discussion of nutrient needs assuming this yield level.

When developing fertilizer recommendations, two major aspects of plant nutrition are important to understand and manage in high yield corn production including: 1) the amount of a given mineral nutrient that needs to be acquired during the growing season, referred to as "total nutrient uptake," or nutrients required for production, and 2) the amount of that nutrient contained in the grain, referred to as "removed with grain" (**Table 1**). Our grain nutrient concentration values, in units of lb/bu (**Table 1**) are in agreement with those recently used by the fertilizer industry to determine replacement fertilizer rates (Bruulsema et al., 2012). In the past 50 years, however, the quantity of N, P, and K required for production and the amount of nutrients removed with the grain have nearly doubled across a variety of management systems used in the 1960s (Hanway, 1962).

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Zn = zinc; and B = boron; HI = harvest index; R1 = silking (silks visible outside the husks); R2 = blister (kernels are white and resemble a blister in shape); R4 = dough (milky inner fluid thickens to a pasty consistency); R5 = dent (nearly all kernels are denting); R6 = physiological maturity (the black abscission layer has formed); V6 = six leaves with collars visible; V10 = 10 leaves with collars visible; V14 = 14 leaves with collars visible; VT = last branch of tassel is completely visible.

Fully-filled ears of corn—an indicator of successfully matching soil nutrient supply with crop demand.

Individual nutrient HI values were calculated, which quantify the percentage of total plant uptake that is removed with the grain. Nutrients with high requirements for production (N, P, K) or that have a high HI (P, Zn, S, N) allude to key nutrients for high yield (**Table 1**). In relation to total uptake for example, nearly 80% of P is removed in corn grain compared to K and B, which are retained to a greater percentage in stover. For each nutrient, the fraction that is not removed with the grain remains in leaf, stalk, and reproductive tissues and constitutes the stover contribution that is returned to the field. Production practices that utilize all or portions of aboveground stover (i.e. cellulosic ethanol, corn grown for silage) may remove an additional 20.8 lb N, 4.0 lb P_2O_5, 23.3 lb K_2O, 1.9 lb S, 0.5 oz Zn, and 0.2 oz B per ton of dry matter.

Maximum Uptake Rates

Further improving fertility practices require matching in-season nutrient uptake with availability, a component of the right source applied at the right rate and right time. The maximum rate of nutrient uptake coincided with the greatest

Table 1. Total macronutrient and micronutrient uptake and removal in Urbana, IL and DeKalb, IL (2010).

Nutrient	Total nutrient uptake	Removed with grain	Harvest index, %	Nutrient removal coefficient, lb/bu
	- - - - - - lb/A	- - - - - -		
N	256	148	58	0.64
P_2O_5	101	80	79	0.35
K_2O	180	59	33	0.26
S	23	13	57	0.06
Zn (oz)†	7.1	4.4	62	0.019
B (oz)	1.2	0.3	23	0.001

† Zn and B are expressed in oz (i.e. oz/A and oz/bu).
Each value is a mean of six hybrids at both locations (mean = 230 bu/A). Harvest index was calculated as the ratio between nutrient removed with grain and total nutrient uptake and is reported as a percent. Multiply grain yield by Nutrient Removal Coefficient to obtain the quantity of nutrient removal.

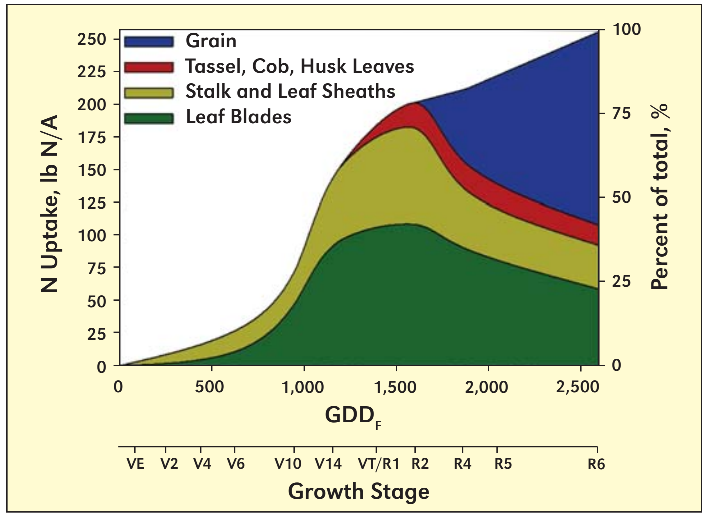

Figure 2. Total maize N uptake and partitioning across four plant stover fractions: leaf, stalk, reproductive, and grain tissues. Each value is a mean of six hybrids across two site-years at Urbana, IL (2010) and DeKalb, IL (2010). GGD_F = growing degree days (Fahrenheit)

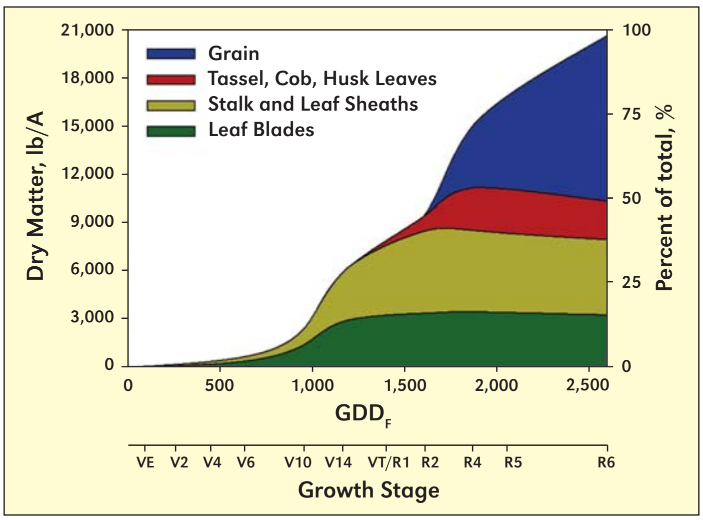

Figure 1. Total maize dry matter production and partitioning across four plant stover fractions: leaf, stalk, reproductive, and grain tissues. Each value is a mean of six hybrids across two site-years at Urbana, IL (2010) and DeKalb, IL (2010). GGD_F = growing degree days (Fahrenheit)

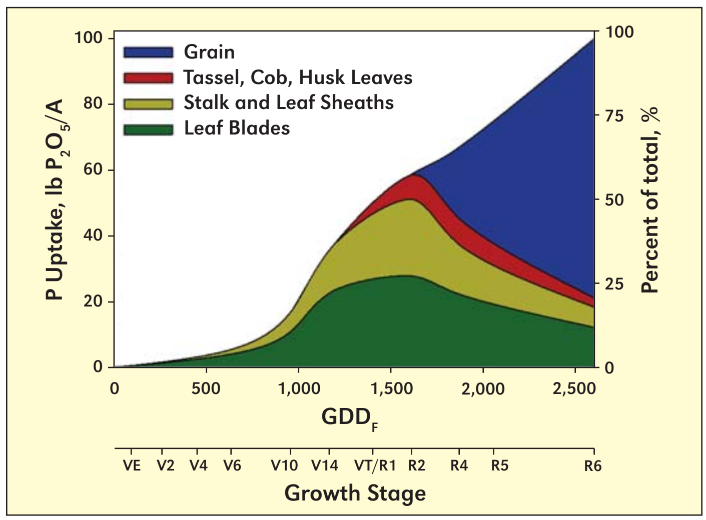

Figure 3. Total maize P uptake and partitioning across four plant stover fractions: leaf, stalk, reproductive, and grain tissues. Each value is a mean of six hybrids across two site-years at Urbana, IL (2010) and DeKalb, IL (2010). GGD_F = growing degree days (Fahrenheit)

period of dry matter accumulation during vegetative growth (**Figure 1**) for all observed nutrients (**Figures 2** to **7**). Between V10 and V14, greater than one-third of total B uptake occurred, compared to the other nutrients which ranged from 20 to 30%. During the V10 to V14 growth stages, corn required the availability of 7.8 lb N/day, 2.1 lb P_2O_5/day, 5.4 lb K_2O/day, 0.56 lb S/day, 0.21 oz Zn/day, and 0.05 oz B/day. Fertilizer sources that supply nutrients at the rate and time that match corn nutritional needs are critical for optimizing nutrient use and yield.

Timing of Nutrient Uptake

Effectively minimizing nutrient stress requires matching nutrient supply with plant needs, especially in high-yielding conditions. Sulfur and N, for example, are susceptible to similar environmental challenges in the overall goal of improving nutrient availability and uptake. However, the timing of N uptake (**Figure 2**) in comparison to S (**Figure 5**) is surprisingly different, suggesting practices that are effective for one may not improve uptake of the other. Nitrogen uptake, unlike S, followed a more traditional sigmoidal (S-shaped) uptake pattern with two-thirds of the total plant uptake acquired by VT/R1. In contrast, S accumulation was greater during grain-filling stages with more than one-half of S uptake occurring after VT/R1 (**Figure 5**). Potassium, like N, accumulated two-thirds of total uptake by VT/R1 (**Figure 4**). Interestingly, greater than one-half of total P uptake occurred after VT/R1 as well (**Figure 3**). These figures suggest that season-long supply of P and S is critical for corn nutrition while the majority of K and N uptake occurs during vegetative growth.

Unlike N, P, K, and S, which have a sigmoidal or relatively constant rate of uptake, micronutrients exhibited more

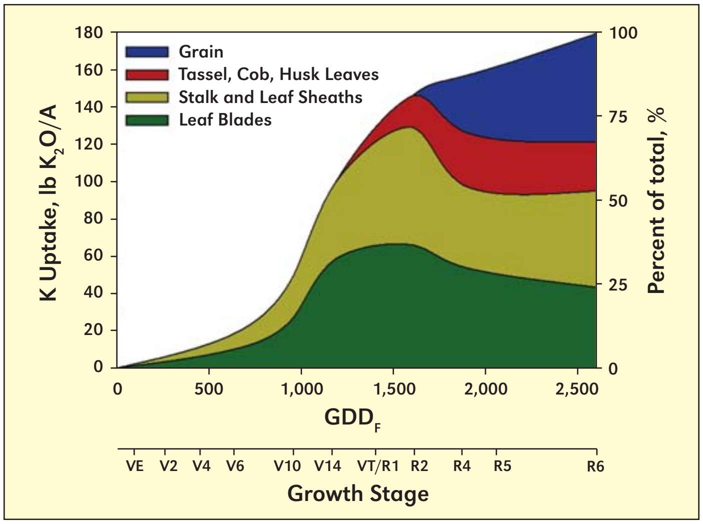

Figure 4. Total maize K uptake and partitioning across four plant stover fractions: leaf, stalk, reproductive, and grain tissues. Each value is a mean of six hybrids across two site-years at Urbana, IL (2010) and DeKalb, IL (2010). GGD_F = growing degree days (Fahrenheit)

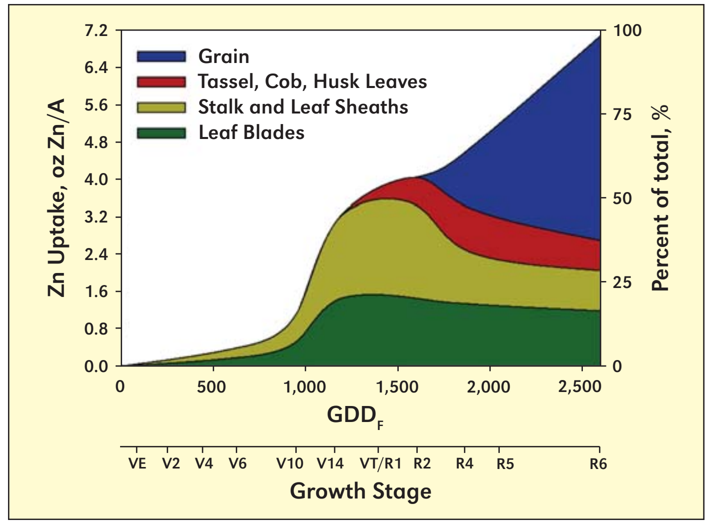

Figure 6. Total maize Zn uptake and partitioning across four plant stover fractions: leaf, stalk, reproductive, and grain tissues. Each value is a mean of six hybrids across two site-years at Urbana, IL (2010) and DeKalb, IL (2010). GGD_F = growing degree days (Fahrenheit)

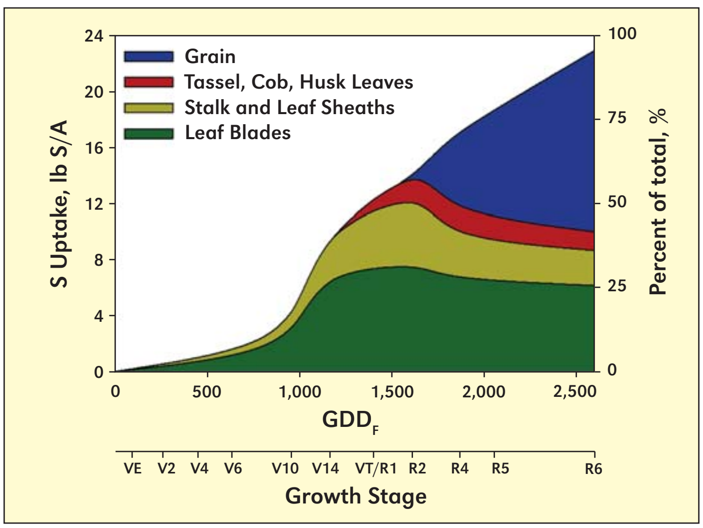

Figure 5. Total maize S uptake and partitioning across four plant stover fractions: leaf, stalk, reproductive, and grain tissues. Each value is a mean of six hybrids across two site-years at Urbana, IL (2010) and DeKalb, IL (2010). GGD_F = growing degree days (Fahrenheit)

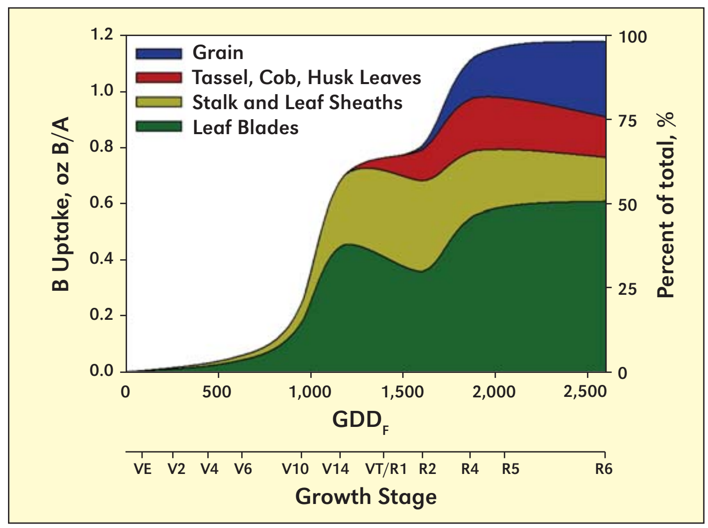

Figure 7. Total maize B uptake and partitioning across four plant stover fractions: leaf, stalk, reproductive, and grain tissues. Each value is a mean of six hybrids across two site-years at Urbana, IL (2010) and DeKalb, IL (2010). GGD_F = growing degree days (Fahrenheit)

intricate uptake patterns. Uptake of Zn and B, for example, began with a sigmoidal (S-shaped) uptake pattern in the early vegetative stages and plateaued at VT/R1 (**Figures 6** and **7**). Thereafter, Zn exhibited a constant uptake rate similar to that of P and S, while B uptake included a second major sigmoidal uptake phase concluding around R5 (dent). Zinc and B favored shorter periods of more intense uptake in comparison to macronutrients. During only one-third of the growing season, late vegetative and reproductive growth accounted for as much as 71% of Zn uptake (**Figure 6**). A similar trend was noted for B; as much as 65% of B uptake occurred over only one-fifth of the growing season (**Figure 7**). Matching corn micronutrient needs in high-yielding conditions clearly requires supplying nutrient sources and rates that can meet crop needs during key growth stages.

Plant Nutrient Mobility

Unlike plant dry matter, specific nutrients possess mobility characteristics allowing them to be utilized in one tissue, then later transported (remobilized) and used in another (Sayre, 1948; Hanway, 1962; Karlen et al., 1988). For many nutrients, including N, P, S, and Zn, a large percentage of total uptake is stored in corn grain at maturity (**Table 1**). Nutrients with high HI values accumulated them from a combination of assimilation during grain fill (after VT/R1) and remobilization from other plant parts. Phosphorus, for example, accumulated more than one-half of total uptake after VT/R1 and remobilized a significant portion that was originally stored in leaf and stalk tissues (**Figure 3**). Nitrogen and S achieved similar HI values although through two different mechanisms. Post-flowering S uptake was the major source of grain S (**Figure 5**) compared to N, which was largely obtained from remobilization (**Figure 2**). Plant Zn exhibited a unique mobility characteristic in which stalk tissue served as a major, but temporal Zn source. By R6, nearly 60% of stalk Zn was remobilized, presumably to corn grain. Similar to that of Karlen et al. (1988), leaf B content appeared to drop around VT/R1, indicative of its role in reproductive growth (**Figure 7**).

Optimization of Nutrient Management

Although nutrient management is a complex process, improving our understanding of uptake timing and rates, partitioning, and remobilization of nutrients by corn plants provides opportunities to optimize fertilizer rates, sources, and application timings. Unlike the other nutrients, P, S, and Zn accumulation were greater during grain-fill than vegetative growth; therefore, season-long supply is critical for balanced crop nutrition. Micronutrients demonstrated more narrow periods of nutrient uptake than macronutrients, especially Zn and B. As a percentage of total uptake, P was removed more than any other nutrient. In a corn-soybean rotation, it is commonplace in Illinois to fertilize for both crops in the corn production year. While farmers fertilize, on average, 93 lbs P_2O_5 for corn production (Fertilizer and Chemical Usage, 2011), the 80% of soybean fields receiving no applied P would have only 13 lbs P_2O_5 remaining (Fertilizer, Chemical Usage, and Biotechnology Varieties, 2010). These data suggest a looming soil fertility crisis if adequate adjustments are not made in usage rates as productivity increases. This plant nutrition knowledge is critical in understanding our current nutrient management challenges.

Summary

As a result of improved agronomic, breeding, and biotechnological advancements during the last 50 years, yields have reached levels never before achieved. However, greater yields have been accompanied by a significant drop in soil macronutrient and micronutrient levels. The latest summary on soil test levels in North America by IPNI reported that an increasing percentage of U.S. and Canadian soils have dropped to levels near or below critical P, K, S, and Zn thresholds during the last 5 years (Fixen et al., 2010). Soils with decreasing fertility levels coupled with higher yielding hybrids suggest that producers have not sufficiently matched nutrient uptake and removal with accurate maintenance fertilizer applications. Integration of new and updated findings in key crops, including corn, will better allow us to achieve the fundamental goal of nutrient management: match plant nutritional needs with the right source and right rate at the right time and right place. BC

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InfoAg 2013 Conference Set for July 16 to 18, Springfield Illinois

IPNI invites you to consider attending InfoAg if you have an interest in learning about the very latest agricultural technologies and how these tools are being put to use in production agriculture today. InfoAg is the premier conference on precision ag technology and its practical applications. Last InfoAg attendance topped 730 crop advisers, farmers, ag retailers, ag services, state and federal agents, researchers, extension, and other agribusiness professionals.

The conference format features multiple concurrent speaker sessions providing a wide range of topics from high-level discussions among key executives to boots on the ground decisions in producing a crop. "We offer a blended program hitting on key aspects of precision ag," said Dr. Steve Phillips, IPNI Regional Director, Southeast U.S. "Our program attracts participants from all aspects of the industry, which builds on InfoAg's strength as a networking tool for participants, speakers, exhibitors and sponsors."

The InfoAg Conference

InfoAg 2013 will be held at the Crowne Plaza in Springfield, Illinois. All details, including on-line registration for the conference, are now available at www.infoag.org BC

Ratios and Concentrations of Nitrogen, Phosphorus, and Potassium Affect Production of Herbaceous Perennials

By Helen T. Kraus and Stuart L. Warren

Both the concentration and ratio of N, P, and K affect flowering and growth of herbaceous perennials. Based on experiments to determine the effects of N, P, and K and their ratio, it appears that herbaceous perennials N requirements are similar to herbaceous annual plants, but require lower P and K concentrations, more similar to woody perennial plants.

Successful container-grown plant production requires management of many variables. Nutrient management includes appropriate selection of both the fertilizer rate and ratio to optimize plant growth. However the nutrient needs of many ornamental plants are not well defined. Additionally, producers who grow many varieties of ornamental plants cannot afford the time or fertilizer products to selectively meet the nutrient needs of each species. If the nutritional needs of certain groups of plants were known, a plant producer could choose from a selection of fertilizers that would meet the objectives of plant production, economics, and environmental stewardship.

Many herbaceous perennials have the same rapid growth rate as herbaceous annual plants, but they also store nutrients in roots for re-growth following a dormant season like a perennial woody plant. Research to date has provided few recommendations for appropriate nutrient concentrations and ratios for container production of herbaceous perennials. Complicating nutrient recommendations for herbaceous perennials is their tendency for luxury consumption.

Four experiments were conducted to determine the effects of N, P, and K concentrations and their ratio on flowering and vegetative growth of *Hibiscus moscheutos* L. (hibiscus) and *Rudbeckia fulgida* var. *sullivantii* Ait. 'Goldsturm' (rudbeckia). These plants were selected as models of herbaceous perennials, which flower profusely and have rapid growth rates.

Beginning in the summer of 2005, a series of experiments were conducted. Initially two concurrent but separate experiments evaluated treatments consisting of either six N:P or six N:K ratios in the fertilizer solution. The six N:P ratios (1:1, 2:1, 4:1, 8:1, 16:1 or 32:1) were evaluated with the N and K concentrations held constant at 100 and 50 mg/L, respectively. The six N:K ratios (1:2, 1:1, 2:1, 4:1, 8:1, or 16:1) had N and P concentrations held constant at 100 and 25 mg/L, respectively. Based on results from these experiments, further research was conducted evaluating six concentrations of P (50, 33, 25, 12.5, 8, or 4 mg/L) and six concentrations of K (100, 66, 50, 25, 16, or 8 mg/L) producing six N:P:K ratios (2:1:2, 3:1:2, 4:1:2, 8:1:2, 12:1:2 and 24:1:2) with the concentration of N held constant at 100 mg/L. A final experiment was conducted that considered three N concentrations (200, 100, or 50 mg/L) and three N:P:K ratios (4:1:2, 8:1:2 and 12:1:2). All plants were grown in 1-gallon pots with a pine bark/sand substrate. The nutrient solutions were added during each irrigation event.

Plant growth and flowering of both hibiscus and rudbeckia were influenced by concentration and ratio of N, P, and K (**Figure 1**). When N was held constant at 100 mg/L, 4:1 N:K and 16:1 N:P were optimal for growing hibiscus. However, a higher K concentration (200 mg/L K) and lower P concentration were required for optimal growth of rudbeckia. When holding N constant at 100 mg/L and varying both P and K in the fertilizer solutions, higher P and K concentrations and a 2:1:2 ratio best supported hibiscus growth, while a 3:1:2 ratio optimized growth of rudbeckia. Finally, when both N concentration and N:P:K ratio were altered, optimum growth of both hibiscus and rudbeckia was achieved at similar and lower P and K concentrations (200 mg N/L, 25 mg/L P, and 50 mg/L K). An 8:1:2 ratio was optimum for production of both hibiscus and rudbeckia (although a 12:1:2 ratio produced similar growth of rudbeckia).

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium.

Growers of ornamental plants like Rudbeckia (commonly called coneflowers or black-eyed-susans; top) and Hibiscus (bottom) would benefit from more plant-specific fertilizer recommendation systems.

Both species required surprisingly high levels of P (25 mg/L P) and K (50 mg/L K) in fertilizer solutions when the N concentration was also high. Plants grown with the highest concentrations of N (200 mg/L) were larger than when supplied with less N, but the lower N treatment still had excellent visual quality (see photo). Additionally, hibiscus and rudbeckia grown with 100 mg/L N and an 8:1:2 ratio had leaf N, P, and K concentrations similar to those deemed optimal in our initial experiments (**Figure 2**).

We found that foliar N concentration increased by 26% as N concentration in the fertilizer solution increased from 100 to 200 mg/L. Foliar P concentrations increased slightly as the

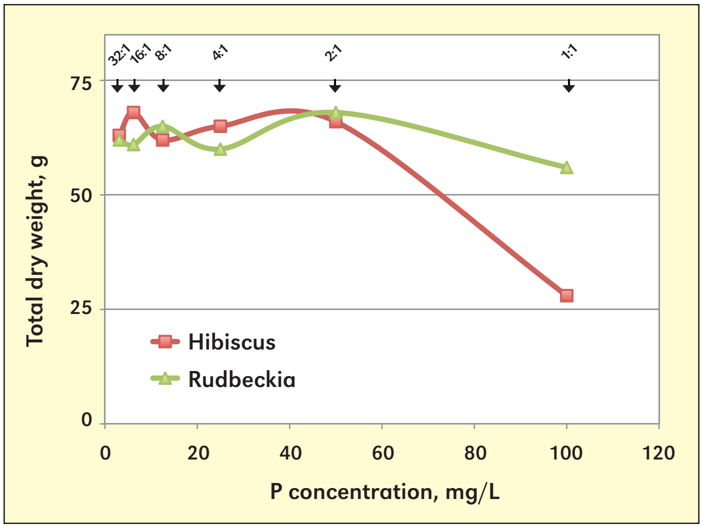


Figure 1. The effect of P concentration and the N:P ratio (denoted by arrows) on the total plant dry weight (roots and shoots) of rudbeckia and hibiscus. The N concentration was maintained at 100 mg/L and the K concentration was 50 mg/L. Each data point is the mean of six plants.

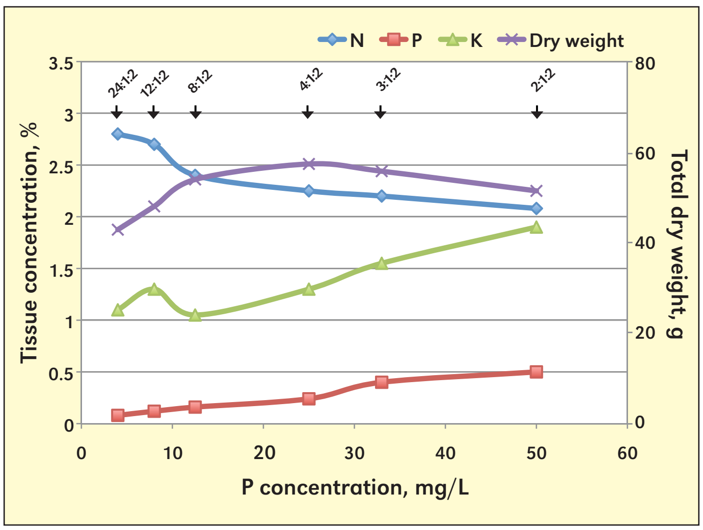
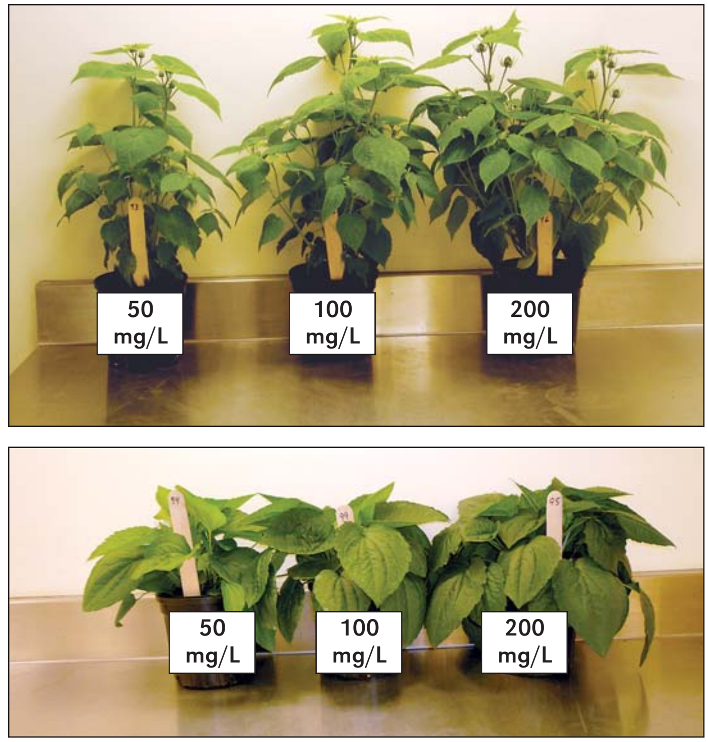


Figure 2. The effect of P and K concentrations and the N:P:K ratio (denoted by arrows) on leaf tissue concentrations and the total plant dry weight (roots and shoots) of hibiscus. The N concentration was maintained at 100 mg/L. Each data point is the mean of six plants.

N concentration was increased, while foliar K concentrations decreased by over 20%.

Average plant biomass was reduced 24% when fertilized with 100 mg/L N and an 8:1:2 compared to 200 mg/L N and the same 8:1:2 ratio. Maximum plant size is not always the goal with landscape plants when shipping, environmental impacts, and fertilizer costs are considered. Although, plants grown with 200 mg/L N were larger and had more flower buds (hibiscus), they would have been more prone to breakage during shipping. Fertilizing with the lower N concentration (100 mg N/L) and a 8:1:2 ratio will also lessen the potential for nutrient loss with inadvertent leakage from the production area.



Hibiscus (top) and rudbeckia (bottom) growth with 50, 100, or 200 mg N/L (left to right) and an 8:1:2 N:P:K ratio.

Similar results were reported by Adam and Sluzis (2005) where growth of a variety of species of herbaceous perennials was enhanced with increasing N rate. They also reported acceptable growth was often achieved at a lower N rate (136 mg/L N) and that luxury consumption was prevalent with many species. Adam and Sluzis (2005) suggest fertilizer application rates be used to achieve 85% to 95% of maximum growth. Using their guideline of 85 to 95% application rates, this would result in a N recommendation of 175 to 190 mg N/L in our study. The growth stimulation observed with higher N concentrations may not be desirable for producing marketable plants.

Based on our growth and foliar nutrient measurements, we recommend that 100 mg/L N, a 50% reduction in N concentration from what would produce maximum growth, in an 8:1:2 ratio is the most appropriate fertilizer regime for the production of most herbaceous perennials.

Additional details of these results are available in Kraus et al. 2011. BC

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Networking Soil Fertility Studies at the Agro-ecosystem Level using Meta-analysis

By Leon E. Parent and Tom Bruulsema

Research supporting 4R plant nutrition must address the complexity of its four factors interacting with many more soil and climatic factors varying among agro-ecosystems. Increasing emphasis must be placed on analysis of networked datasets. Meta-analysis provides statistical rigor for such analysis.

The objective of soil fertility studies is to provide a scientific basis for making fertilizer recommendations. Research considers the environmental context, the goal and the methodology. In classical soil fertility trials, researchers are concerned with Type I error, i.e. rejecting the hypothesis of "no effect" (H_0) when it is true, and Type II error, i.e. accepting H_0 when it is false. Soil fertility research strives to define a set of conditions in which a response is expected, and to distinguish them from conditions in which no response is expected. The conditions may include, but need not be limited to, a soil test value for the nutrient in question. Two errors are common in the interpretation of fertilizer response trials: first, mistaking random variation for a true response (Type I error), and second, failing to detect true responses because of background variability (Type II error).

When conducting fertilizer experiments, one assumes that either (1) all other factors are equal or (2) all factors except the ones being varied are at a sufficient but not excessive level. Methods designed to address a narrow set of questions at any one experimental site may restrict the number of answers specifically related to any underlying assumptions. Averaging site-specific optimum rates across experiments within an assumed group of trials disregards the fact that several factors may vary widely among sites. In most fertilizer experiments, one factor is varied at a time, assuming no significant interaction with factors other than the soil test.

Within most jurisdictions, crop fertilization guidelines are based on grouping procedures defined only by soil test levels, rather than agro-ecosystems. The crop, however, grows in the context of higher-order interactions including the climatic zone, soil classification (soil series and texture), soil degradation state (compaction, aggregation, erosion), and crop and soil management (e.g. crop sequence, conservation practice, etc.). The problem of assumed invariant factors in making fertilizer recommendations may lead to wrong decisions.

Type III Error

Type III error occurs when the null hypothesis (H_0) is rejected for a wrong reason (as related to definitions and methodologies). In other words, any relationship between a risk factor and an output may also depend on the prevalence and patterning of other risk factors in the population (Schwartz and Carpenter, 1999). For example, a crop grown in a high-nutrient soil may respond significantly to added nutrients due to soil degradation problems such as compaction or genetic horizons that restrain rooting. Arguing that crops are responsive to added nutrient in all high-nutrient soils would clearly be wrong, and even for the subset of high-nutrient soils with the specific degradation, the application of nutrients should not be concluded to be the only means of obtaining the yield response; repairing the degradation by relieving compaction should be evaluated as an alternative. Degraded soils may be prevalent in this case although the answer was "right" as controlled by Type I error (α). The question must be reformulated considering crop response to added nutrients on soils of hampered quality. The solution may thus be to improve soil quality rather than applying fertilizers. Relying on fertilization alone may lead to even more soil and water degradation and deny principles of sustainable agriculture. Research supporting practical management should be more concerned about interpreting results for the best possible system performance, rather than relying on a single mathematical model based on a single factor.

Common abbreviations and notes: N = nitrogen.

Soil and climate effects on corn N response can be revealed by meta-analysis.

The 4R concept (the right source, applied at the right rate, time and place) may help to avoid Type III errors. Its 4-factor interaction introduces a problem for the science of soil fertility: high-order interactions are difficult to interpret from limited volumes of observed field data. Single-factor research has the greatest power to precisely measure responses, but multi-factor research has more power to identify interactions and can suggest more management alternatives to attain the same result.

Models recognizing factor variation and high-order interactions while minimizing the size of datasets are needed to solve this concept in practice. The parsimony principle to simplify complex problems to manageable solutions, or Occam's Razor, states "Of two equivalent theories or explanations, all other things being equal, the simpler one is to be preferred." Meta-analysis is a procedure to analyze and synthesize datasets from separate studies pursuing similar objectives (Borenstein et al.,

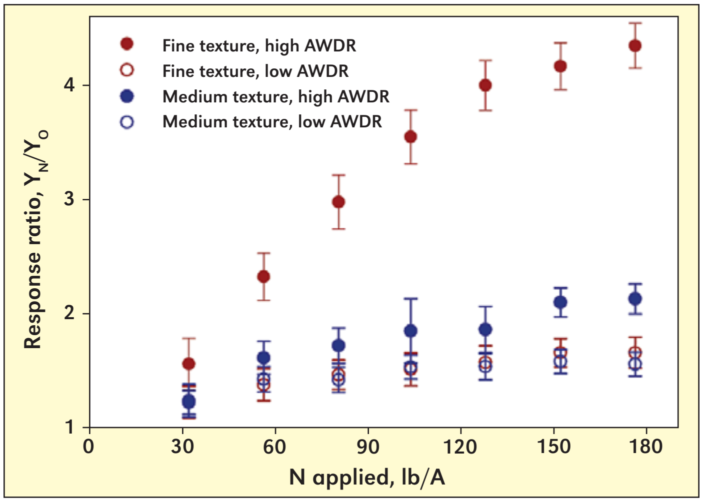

Figure 1. Ratio of corn yield with N versus without N, as a weighted mean across sites in four categories of soil texture and AWDR. AWDR refers to a measure of abundant and well-distributed rainfall during the period from 15 days before to 30 days after side-dress application of N. Error bars represent standard errors derived from meta-analysis. Adapted from Tremblay et al., 2012.

2009). It provides a quantitative synthesis of results that is objective and statistically defensible, compared to the traditional narrative review (Ainsworth et al., 2007). Meta-analysis has been introduced recently in soil fertility studies (Tonitto et al., 2006; Valkama et al., 2009). By combining studies, meta-analysis tests whether an effect is robust over a wider range of conditions, and estimates the magnitude of the effect more precisely, as compared to a single study.

Grouping is a means to reduce the heterogeneity commonly observed in crop response data. Subsets of studies may be selected based on agro-ecosystem hierarchy: climate, soil classification and quality, conservation practice, crop sequence. The significance of within-subset crop response is measured by the Q statistic that is distributed like a χ^2 variable. The heterogeneity of within-subset means is measured by the I^2 statistic. Heterogeneity is minimized by assigning studies to other subsets or by forming new ones. Meta-analysis is conducted using metafiles that contain metadata and experimental results.

Metafiles

Metafiles provide the necessary data for conducting meta-analyses. Factors and variables influencing crop yield and quality are assembled into metafiles. Metafiles comprise metadata on climate, soils (series, texture, chemical analyses, physical properties, etc.), fertilization treatments and plant response (leaf chemical analysis, crop yield and quality, crop chemical analyses). The more subsets formed, the more fertilizer trials are needed to reduce the heterogeneity of the controlling factors in the agro-ecosystem.

Meta-analysis

Meta-analysis requires reliable classification criteria that are accurate and relevant in order to avoid ideological biases and personal preferences (Littell et al., 2008). Sites must be classified by institution and year, as annual or long-term, and by size (small vs. large plots). The control treatment must be identified univocally; for a fertilizer experiment it should be zero nutrient addition whenever possible. This is different than the traditional relative yield response model, where the control is yield with the nutrient in question at non-limiting levels (Nelson and Anderson, 1984). The response ratio used in meta-analysis is the log ratio between treatment and control (Borenstein et al., 2009). The related variance term weighs the effect size that is statistically evaluated using Q and I^2. Where crop response patterning is too heterogeneous within the subset, sites may be re-allocated to other subsets, or to another grouping of subsets. As the number of subsets increases, the need for more data increases dramatically. This is why research networking is essential to support meta-analysis of fertilizer experiments accounting for heterogeneous agro-ecosystems.

In meta-analysis, the inverse of each site's variance (determined by ANOVA) is used to assign weights in the global analysis of a subset. The within-subset analysis across several sites provides more statistical power for the computation of the optimum economic rate compared to examining individual sites one at a time (Kyveryga et al., 2007). The combination of soil and climatic conditions acting on crop response to added nutrients should provide fine-tuned information in decision-support systems for precision agriculture and the 4R concept applied at the farm level. In Quebec, metafiles are being updated to facilitate knowledge transfer to farmers. We are in the process of acquiring the climatic and soil datasets to improve the interpretation of crop response by agro-climatic region, and other derived or observed properties such as soil textural class, susceptibility to erosion and compaction, etc.

As agro-ecosystem studies face problems of complexity, agricultural scientists must analyze their data in a more organized way to avoid Type III errors, rather than limiting themselves to primary statistical analyses. In Quebec, networking among agricultural scientists led to several metafiles that formed the basis for new fertilizer guidelines (Parent and Gagné, 2010). Soil grouping was conducted using soil testing since the climatic and soil datasets were not available for site grouping at that time. However, data on year and exact location of the sites were collected, allowing data importation from climatic and soil datasets. Groups with insufficient information were identified to update the metafile with new research. Much larger datasets than before will be required to understand the complex patterning of crop response to added nutrients.

An example of the application of meta-analysis to find common factors controlling the response of corn to N is shown in **Figure 1**. In this study, conducted over 51 sites across North America, the response ratio was shown to relate to groupings based on soil texture and rainfall. Sites with fine texture and abundant and well-distributed rainfall showed much greater response to N than those in the other three categories. The results demonstrate the need for adaptation of N recommendations to variations in both soil and weather, simultaneously.

Future Prospects

Although widely accepted in other disciplines like medical, physical and behavioural sciences, meta-analysis of agronomic data is in its infancy. As was the case in ecology, it must be used correctly and at full potential and be open to the large arsenal of other statistical tools (Ainsworth et al., 2007). Agricultural scientists will also face new challenges on data classification, such as grouping sites where different fertilizer rates were applied, how to define a subset, how to improve current models, and how to apply other methods of linear statistics to meta-analysis. Last but not least, in order to achieve the agro-ecosystem level of data synthesis and bring the 4R concept into practice, the networking of research efforts across political jurisdictions is urgently needed. BC

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Potassium Fellowship Program Request for Proposals

Over 50% of the world's food supply exists today because of the use of commercial fertilizers. By 2050, global demand for food is expected to increase by 70 to 100% and it is highly likely that its production will be even more dependent on fertilizers than it is today. The three nutrients most frequently limiting to crop production globally are N, P and K. It is critical that the science of how these nutrients can efficiently and effectively contribute to productivity in rapidly evolving cropping systems be advanced to meet the increased demand for agricultural products. Due to environmental aspects, significant research funding is often available on N; however, funding for production-oriented P and K research is more difficult to acquire. Nutrient stewardship based on the 4Rs—application of the right nutrient source at the right rate, time and place—requires a balanced approach addressing the full complement of needed nutrients in systems focused on meeting economic, environmental and social goals. Therefore, P and K must be efficiently and effectively managed if N performance is to be optimized. Leading fertilizer manufactures have established the *Phosphorus and Potassium Graduate Fellowship* programs to help fill the need for additional P and K research. This request for proposals is part of the *Potassium Fellowship* program.

Goals of the Potassium Fellowship Program

The program is a long-term commitment by the fertilizer industry to:

1. Establish research programs that will attract top students and additional funding for production-oriented aspects of K research.
2. Build human resources needed by the industry that are strong scientifically, knowledgeable about K as a plant nutrient, and understand how farms and the fertilizer industry function.
3. Advance the science of K use in agriculture.

Funding and Donors

Individual fellowships are for a maximum of $70,000 per year for a maximum of four years. Fellowships cover the tuition, fees and stipend for the institution plus expenses associated with the research project proposed in response to the Fellowship Program RFP. The fellowship program is supported by voluntary contributions from K fertilizer manufacturers servicing the needs of the North American Corn Belt and Great Plains. Program donors are: **Agrium Inc., Intrepid Potash Inc., Mosaic Company, PotashCorp, and Simplot.**

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium.

Eligibility

Fellowships are awarded to individuals in the early stages of their graduate study or about to enter a graduate program in sciences relevant to plant nutrition and management of crop nutrients. Typical applicants would be seniors in a B.Sc. program who want to start a Ph.D. program, M.Sc. candidates in their final year who want to pursue a Ph.D., or First year Ph.D. students. Eligible institutions must be degree granting and generally located within the Corn Belt or Great Plains of the U.S. or Canada. Exceptional applications from outside these regions will be considered.

Submissions

Research proposals in response to this request should be received by IPNI (e-mail: ppates@ipni.net; phone: 605-692-6280) by April 1, 2013. Awards will be announced by June 1, 2013.

These and more details on this opportunity are available at http://info.ipni.net/KFellow BC

2012 Crop Nutrient Deficiency Photo Contest Winners

IPNI has announced the winners of the 2012 Crop Nutrient Deficiency Photo Contest. We are pleased to note that photo submissions were once again strong across all categories and many excellent photos were received from around the globe. Our judges were faced with many tough choices on deciding which entries would gain top honors. In the majority of cases, preference was given to those well-photographed entries that provided a good representation of the impact of the deficiency to the plant, adequate soil and/or plant tissue nutrient analyses information, and some details concerning current or historical fertilization at the site.

IPNI extends our congratulations to all winners and we thank all entrants for submitting images to our annual contest. We encourage all to please check back with the contest website maintained at www.ipni.net/photocontest for details on submitting your fresh entries for 2013!

Best Overall Image

Grand Prize (USD 200): Iron (Fe) Deficiency in Plum. Sala Florin, Banat's University of Agricultural Sciences and Veterinary Medicine, Timisoara, Romania, captured this image of iron deficiency in plum grown on a pre-luvisol soil type. The deficiency occurred due to the temporary storage of limestone near plum trees for application on nearby farmland. Water from rainfall washed enough limestone into the soil to cause iron deficiency as indicated by elevated Ca levels in the affected soil compared to the unaffected soil. The leaf iron content of affected trees was 11.4 ppm compared with 23.6 ppm in unaffected tree leaves.

Nitrogen (N) Category

1st Prize (USD 150): N-Deficient Corn. Guillermo Roberto Pugliese, Bunge Argentina S.A., Tres Arroyos, Buenos Aires, Argentina, provided a close up shot of N deficiency in corn (var. Dekalb 670). The soil at the site tested low in N content at 60 kg N/ha.

Runner-up (USD 75): M.R. Umesh, University of Agricultural Sciences, Raichur, Karnataka, India, captured a field image of corn plants taken at the end of silking stage. There was slight drying of stigmata (silk) 64 days after planting. Plants had stunted and a lesser number of leaves, delayed tasseling, and either immature or no setting of cobs compared with non-N deficient leaves. Lower leaves were dried up and younger leaves remained light green. Veins had dried up and the V-shaped yellowing of leaves was also prominent.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; B = boron; Fe = iron; me = milliequivalents; ppm = parts per million.

Phosphorus (P) Category

1st Prize (USD 150): P-Deficient Corn. S. Srinivasan, Assistant Professor of Crop Physiology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Killikulam, Vallanadu, Tamil Nadu, India, submitted this noticeable example of P deficiency in 20-day old corn plants grown in a P omission plot. The purpling of corn tissues is due to the accumulation of reddish-purple anthocyanin pigments. Root growth was also greatly reduced. Available (Olsen-P) content in the soil was quite low (less than 1.9 mg P/kg). Leaf tissue analysis also registered a low value of 0.10%.

Runner-Up (USD 75): Nathan D. Mueller, South Dakota State University, Brookings, SD, USA, shot this close-up showing P deficiency in hybrid corn at V4 growth stage. Soil test P (Mehlich-3) was low (<20 ppm) for this Eudora silt loam. Application of P fertilizer did decrease or eliminate P deficiency symptoms.

Potassium (K) Category

1st Prize (USD 150): K-Deficient Apple. Bruce Scott, E.E. Muir & Sons, Laverton North, Victoria, Australia, submitted this classic example of K deficiency in apple leaves (var. Pink Lady) 2 weeks prior to harvest. Deficiency symptoms showed marginal leaf scorch and small and poorly-colored fruit. Dry matter leaf analysis showed a K content of 0.7%, whereas the desirable range is 1.2 to 1.8% K.

Runner-up (USD 75): K-Deficient Bitter Gourd. Manoj Kumar Sharma, Irrigation Management and Training Institute, Kota, Rajasthan, India, shot this characteristic example of K deficiency in a bitter gourd hybrid, wherein K-deficient plants exhibited marginal yellowing and scorching of older leaves. Plant analysis of this K-deficient crop found 2.0% K, while soil available K (ammonium acetate extractable K) was 60 kg/ha.

Other Category (Secondary and Micronutrients)

1st Prize (USD 150): Calcium (Ca) Deficiency in Tomato. Manoj Kumar Sharma, Irrigation Management and Training Institute, Kota, Rajasthan, India, provided this example of Ca deficiency in an 85-day-old tomato crop. Tomato fruits exhibited this blossom end rot, which is associated with Ca deficiency. Soil status (ammonium acetate extractable Ca) was 0.7 me/100 g. Plant analysis found 0.2% Ca.

Runner-up (USD 75): Boron (B) Deficiency in Cauliflower. Kaushik Batabyal, Dept. of Soil Science and Agricultural Chemistry, College of Agriculture, Agartala, Tripura, India, submitted this interesting case of B deficiency in cauliflower at early curd maturity stage. The soils of experimental area tested low in available B (0.38 mg/kg). Even the rhizospheric soil had low available B content (0.30 mg/kg). Besides, the deep tube well water used for irrigation contained negligible amounts of B. Boron concentration in the curd was only 12.9 mg/kg dry weight, which was much below the critical plant tissue B concentration of 17.8 mg/kg.

Fertilizer Plays an Important Role in Current Crop Production: A Case Study from Hubei

By Weini Wang, Jianwei Lu, Yinshui Li, Juan Zou and Wei Su

Results from large-scale multipoint field experiments with rice, winter wheat, rapeseed, and cotton showed that site-specific combinations of N, P and K fertilizers significantly increased crop yields, and that fertilizers play a much more important role in crop production today than in the past.

Worldwide experience in agricultural development has provided much evidence that fertilizer application is the most efficient measure for sustainably increasing crop production and ensuring food security (Bockman et al., 1990) and that sustained yield growth is almost impossible without fertilizer supply (Larson and Frisvold, 1996). At the global scale, crop yields have increased by at least 30 to 50% as a result of fertilization (Stewart et al., 2005). In China, the fertilizer contribution rate (FCR) to cereal crop yield, from the national network on chemical fertilizer experiments, was 40.8% (Shi et al., 2008).

During the past 20 years the consumption of inorganic fertilizers in China has increased every year, leading to a decline in fertilizer use efficiency and therefore a slow-down in the rate of crop productivity improvement (Zhang et al., 2008). This has led many to doubt, or minimize, the importance of the role of fertilizers in crop production. In reality though, increasing consumption of fertilizers can be attributed to the numerous factors in China like its large population and limited farmland (Chen et al., 2011) where fertilizer has contributed greatly to increasing crop yields over the past few decades. However, lack of knowledge on scientific fertilization techniques has resulted in low fertilizer use efficiency. Therefore, developing scientific fertilization methods through research, and then helping farmers adopt balanced nutrient management practices through extension, is of primary concern to agricultural scientists today. We conducted large-scale multipoint field experiments with rice, wheat, rapeseed, and cotton crops in 21 counties of Hubei province in Central China from 2006 to 2009 to investigate the combined effect of N, P and K on crop yields as well as on FCR and agronomic efficiency (AE) under present production conditions.

Hubei province is situated in the subtropical region with an average annual temperature of 15 to 17°C, precipitation of 750 to 1600 mm, and a mean frost-free period of 230 to 300 days (Shen and Zhang, 2006). Field experiments on rice, winter wheat, winter rapeseed, and cotton were conducted at 251, 47, 62, and 26 sites, respectively, in 21 counties from 2006 to 2009. The soils where rice and rapeseed were grown had higher organic matter, available N and available P contents than the soils at sites where wheat and cotton were grown (**Table 1**).

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium.

All trials had two fertilization treatments including a check (no fertilization) and NPK (full fertilization) and three replications. The application rates of fertilizer N, P and K were different for each crop-type and site (**Table 2**). Fertilizers used in the study were urea (46% N), calcium superphosphate (12% P_2O_5) and potassium chloride (60% K_2O). Seed cotton yield was taken as the cotton yield in the study. FCR (Yu et al., 2007) and AE (Yadav, 2003) were calculated as follows:

$$FCR = (Y_{NPK} - Y_{CK}) / Y_{NPK} \times 100\%$$
$$AE = (Y_{NPK} - Y_{CK}) / (Nr + Pr + Kr)$$

where Nr, Pr and Kr are the amounts of fertilizer N, P_2O_5 and K_2O applied, Y_{NPK} is the crop yield with applied fertilizer, and Y_{CK} is the crop yield without fertilizer applied.

Effect of NPK Fertilization on Crop Yields

At all locations, the yields of rice, winter wheat, rapeseed, and cotton in plots receiving NPK fertilization were significantly greater than those in check plots (**Table 3**). These differences, however, varied widely due to differences in crop cultivars, soil fertility, climatic conditions, and cultivation practices at different sites. Also, the effect of fertilization on yields among crops varied in the following order rapeseed (174%), winter wheat (110%), cotton (69%), and rice (47%). In other words, rapeseed showed the strongest response to fertilizer N, P and K application, while rice had the smallest response.

The variations and distributions in the fertilization effect encountered during these trials are shown in **Figure 1**. Among the 251 rice experimental sites, 69% of the sites showed yield increases between 1 and 3 t/ha, and 6.4% of the sites showed increases in yield by over 4 t/ha. In addition, 28% of rice sites had yield increases above 60%. Among the 47 winter wheat experimental sites, 34% of the sites had yield increases between 2 and 2.5 t/ha and 13% had yield increases of more than 3 t/ha. About 40% of the winter wheat sites had yield

Table 1. Organic matter and available N, P and K status of experimental soils (0 to 20 cm depth) in Hubei province, 2006 to 2009.

Crop	Organic matter, g/kg Range	Organic matter, g/kg Average	Available N, mg/kg Range	Available N, mg/kg Average	Available P, mg/kg Range	Available P, mg/kg Average	Available K, mg/kg Range	Available K, mg/kg Average
Rice (n=251)	4.8-56.4	28.8±10.4*	13.5-233	124±35.5	1.1-60.2	12.8±8.6	6.2-276	87.1±44.0
Wheat (n=47)	5.0-29.3	17.6±5.7	14.0-206	92.9±45.5	2.7-37.2	11.8±7.5	39.8-205	98.0±38.7
Rapeseed (n=62)	8.6-57.4	25.2±9.1	38.5-199	114±41.9	3.4-32.6	12.5±6.9	29.7-246	96.0±44.8
Cotton (n=26)	6.0-25.3	16.3±4.4	42.0-160	89.2±32.4	4.5-18.0	9.9±3.9	23.9-165	83.8±34.3

* ± denotes the standard deviation.

increases over 120%. The distributions for rapeseed and cotton were similar, with 39% of rapeseed sites and 35% of cotton sites showing yield increases between 1 and 1.5 t/ha; and 16% of rapeseed sites and 27% of cotton sites showing yield increases over 2 t/ha. Rapeseed yields in 32% of sites increased by over 200% due to fertilization and 50% of cotton sites had yield increases that exceeded 60%.

Table 2. Fertilizers application rates for rice, winter wheat, rapeseed, and cotton in Hubei province, 2006 to 2009.

	N, kg/ha		P_2O_5, kg/ha		K_2O, kg/ha	
Crop	Range	Average	Range	Average	Range	Average
Rice	83-248	172±29*	30-90	62±16	45-150	95±25
Wheat	120-180	153±16	45-75	58±7	45-90	75±14
Rapeseed	150-270	190±35	45-113	76±19	60-180	100±28
Cotton	225-330	291±39	72-225	97±40	120-300	195±50

* ± denotes the standard deviation.

Fertilizer Contribution Rate and Agronomic Efficiency

Fertilizer contribution rate reflects the contribution of fertilizer to crop yield. The mean values of FCR were obviously different in the four different crops and amounted to 30% for rice, 49% for winter wheat, 56% for rapeseed, and 38% for cotton (**Table 4**). The FCR distribution frequency placed 31% of rice sites in the 20 to 30% range, 28% of winter wheat sites in the 50 to 60% range, 24% of rapeseed sites in the 40 to 50% range, and 42% of cotton sites in the 30 to 40% range. In addition, the FCRs were over 50% in 4.8% of rice sites, 53% of winter wheat sites, 61% of rapeseed sites, and 12% of cotton sites.

Table 3. Effect of fertilizer application on rice, winter wheat, rapeseed, and cotton yields in Hubei province, 2006 to 2009.

		Yield, t/ha		Yield Increase, t/ha		Yield increase rate, %	
Crop	Treatment	Range	Average	Range	Average	Range	Average
Rice	CK	1.30-9.27	5.43±1.43b[+]*				
	NPK	3.05-13.06	7.70±1.55a	0.21-6.65	2.27±1.04	3.1-166	46.7±28.7
Wheat	CK	1.24-4.42	2.32±0.80b				
	NPK	2.33-6.15	4.52±0.82a	0.08-3.52	2.20±0.74	3.4-269	110±56.6
Rapeseed	CK	0.28-2.61	1.16±0.54b				
	NPK	1.08-4.04	2.60±0.63a	0.49-2.80	1.44±0.53	23.3-576	174±136
Cotton	CK	1.36-4.13	2.60±0.60b				
	NPK	2.96-5.89	4.22±0.64a	0.40-2.88	1.62±0.62	9.7-213	68.6±40.4

[+]Values followed by different letters (a, b) among treatments for each crop indicate significance at 5% level.
* ± denotes the standard deviation.

Agronomic efficiency, an incremental efficiency from applied fertilizer N, P and K over a control, is proportional to the benefit-to-cost ratio from purchased N, P and K inputs (Yadav, 2003). The mean values of AE of cereal crops (7.2 kg/kg for rice and 7.7 kg/kg for winter wheat) were obviously higher than those of cash crops (4.0 kg/kg for rapeseed and 3.0 kg/kg for cotton) (**Table 4**). However, compared with results from India (i.e., 12.3 kg/kg for rice and 10.4 kg/kg for wheat), the AE of both rice and wheat in this study were lower because of higher fertilizer inputs (Yadav, 2003). The AE distribution frequency for rice had 34% of sites between 3 to 6 kg/kg, 36% of winter wheat sites between 7 to 9 kg/kg, 27% of rapeseed sites between 4 to 5 kg/kg, and 50% of cotton between 2 to 3 kg/kg (data not shown). In addition, the AE in 28% of rice sites and 30% winter wheat sites exceeded 9 kg/kg; and 21% of rapeseed sites and 8% of cotton sites exceeded 5 kg/kg.

Table 4. Fertilizer contribution rate (FCR) and agronomic efficiency (AE) of rice, winter wheat, rapeseed, and cotton in Hubei province, 2006 to 2009.

	FCR, %		AE, kg/kg	
Crop	Range	Average	Range	Average
Rice	3.0-62.4	29.6±12.1*	0.8-21.2	7.2±3.8
Wheat	3.3-72.9	48.6±15.0	0.3-12.7	7.7±2.7
Rapeseed	18.9-85.2	56.2±16.7	1.2-7.8	4.0±1.5
Cotton	8.9-68.0	38.0±12.2	0.8-7.8	3.0±1.5

* ± denotes the standard deviation.

Table 5. Fertilizer application rates, nutrient ratios, yield increase, fertilizer contribution rate to yields (FCR), and agronomic efficiencies (AE) of rice, winter wheat, rapeseed, and cotton in the 1980s.

	Fertilizer application rate, kg/ha							
Crop	N	P_2O_5	K_2O	$N:P_2O_5:K_2O$	Yield increase, t/ha	Yield increase, %	FCR, %	AE, kg/kg
Rice	108	37	38	1:0.34:0.35	1.70	40.8	29.0	9.3
Wheat	105	66	0	1:0.63:0	1.65	56.6	36.1	9.6
Rapeseed	87	58	19	1:0.67:0.22	0.82	64.4	39.2	5.0
Cotton	137	74	49	1:0.54:0.36	0.82	48.6	32.7	3.2

Data derived from China national network on chemical fertilizer experiments (Lin and Li, 1989).

Comparison of Fertilization Effect on Crop Yields between the 1980s and 2006-2009

When compared with the results from the China national network on chemical fertilizer experiments during the 1980s (**Table 5**), the yield increases with NPK fertilization in rice, winter wheat, rapeseed, and cotton under more current conditions were higher by 568, 550, 622, and 798 kg/ha, respectively. The corresponding rates of yield increase were also higher by 6%, 53%, 109%, and 20%. The FCRs in rice, winter wheat, rapeseed, and cotton from 2006 to 2009 were higher by 0.6%, 12%, 17%, and 5.3%, respectively, than the corresponding values extracted from the 1980s. These data suggest that fertilizer plays a much more important role in

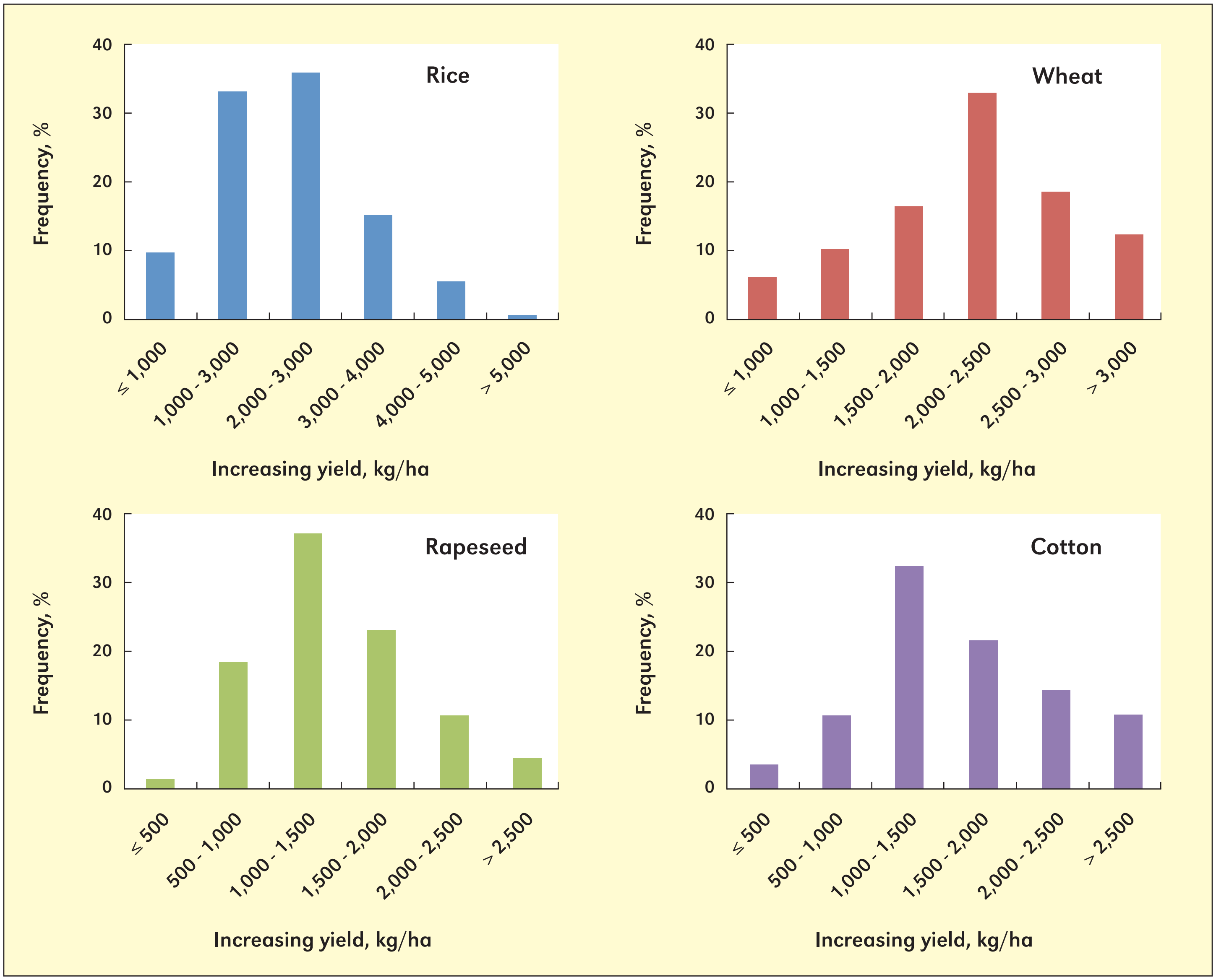

Figure 1. Frequency distributions of yield increase with fertilizer in rice, winter wheat, rapeseed and cotton, Hubei province, 2006 to 2009.

agricultural production today than it did in the past. This is likely due to the use of higher yielding varieties today.

The AEs of fertilizers ($N+P_2O_5+K_2O$) in rice (9.3 kg/kg), winter wheat (9.6 kg/kg), rapeseed (5.0 kg/kg), and cotton (3.2 kg/kg) in 1980s were all higher than those from 2006 to 2009 (**Table 4**). The results clearly indicated that the AE has dropped with the increase in fertilizer application rates, and this challenge needs to be addressed. However, the ratios of applied NPK ($N:P_2O_5:K_2O$) were 1:0.36:0.55 for rice, 1:0.38:0.49 for winter wheat, 1:0.40:0.53 for rapeseed, and 1:0.33:0.67 for cotton from 2006 to 2009 (**Table 2**) with higher application rates of fertilizer K and higher K/N ratios than the corresponding rates in 1980s (**Table 5**). This indicated that farmers are paying more attention to the application of K, and thus to balanced nutrition, today than in the past.

Summary

The results from 386 field experiments in Central China indicated that NPK fertilization increased all crop yields significantly. Similarly, both the rate of yield increase with fertilizer and the FCR for the four experimental crops were higher today than in the 1980s. However, the AE values today are lower than in the 1980s, and this needs to be addressed urgently through more scientific research and extension. BC

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Nutrient Expert™: A Tool to Optimize Nutrient Use and Improve Productivity of Maize

By T. Satyanarayana, K. Majumdar, M. Pampolino, A.M. Johnston, M.L. Jat, P. Kuchanur, D. Sreelatha, J.C. Sekhar, Y. Kumar, R. Maheswaran, R. Karthikeyan, A. Velayutahm, Ga. Dheebakaran, N. Sakthivel, S. Vallalkannan, C. Bharathi, T. Sherene, S. Suganya, P. Janaki, R. Baskar, T.H. Ranjith, D. Shivamurthy, Y.R. Aladakatti, D. Chiplonkar, R. Gupta, D.P. Biradar, S. Jeyaraman, and S.G. Patil

Nutrient Expert (NE)-based field-specific fertilizer recommendations offered solutions to the farmers of southern India for better nutrient use in maize under the current scenario of escalating fertilizer prices. Results from validation trials, comparing NE-based recommendations with farmer practice and the state recommendation in 82 farmer fields of southern India, demonstrated the utility of the decision support system tool in improving the yield and profitability of maize farmers in the region.

Maize, a crop of worldwide economic importance, together with rice and wheat, provides approximately 30% of the food calories to more than 4.5 billion people in 94 developing countries, and the demand for maize in these countries is expected to double by 2050. In India, maize is considered as the third most important food crop among the cereals and contributes to nearly 9% of the national food basket (Dass et al., 2012). The annual maize production of the country is about 21.7 million t with an annual growth rate of 3 to 4 % (ASG, 2011). Maize yields in India need to be increased significantly to sustain this growth rate and there is a need to further increase the productivity of maize to efficiently meet India's growing food, feed and industrial needs.

In Southern India, farmers are substituting maize for traditional crops such as rice wherever there is a drop in the water table due to over use of water by the rice crop. Maize is considered as a viable option for diversifying agricultural production, owing to its adaptability in multiple seasons under different ecologies. Recently, maize is gaining popularity as a rice-maize cropping system in the state of Andhra Pradesh, replacing the second rice crop in the existing rice-rice or rice-rice-pulse cropping systems due to water scarcity in rice and incidence of diseases in pulses. Similarly, maize is also becoming an important crop in Tamil Nadu and Karnataka due to its higher productivity and profitability, and is grown either as a sole crop in *Kharif* or in sequence after rice during the *Rabi* season. In the emerging rice-maize system in the region, the maize crop following rice is mostly grown under no-till conditions due to lack of time between crops for preparatory cultivation. Farmers in the region lack knowledge about managing nutrients within this highly demanding cereal system and are often applying inadequate and imbalanced rates. This has resulted in uncertain system yields and raised doubts on long-term sustainability. Further, conservation tillage systems pose greater challenges for farmers due to lack of information on efficient nutrient management strategies under these systems.

The average maize yields in southern India are much lower than reported attainable yields and one of the key factors responsible for low yields is inadequate and improper fertilization. Considering the optimum nutrient requirement by maize hybrids, the current fertilizer use by farmers is quiet imbalanced to achieve maximum economic yields. Moreover, nutrient requirement varies from field-to-field due to high

IPNI, CIMMYT, and UAS Raichur staff visiting the Nutrient Expert validation trials at CSISA hub site in Bheemarayanagudi, Karnataka.

variability in soil fertility across farmer fields, and single homogenous and sub-optimal official state recommendations may not be very useful in improving maize yields. Also, the current scenario of escalating prices of fertilizers demands solutions for optimized use of nutrients. Thus, there is ample opportunity to improve maize yields through the right use of nutrients. Nutrient Expert™, a new, nutrient decision support system (DSS) based on the principles of site-specific nutrient management (SSNM), offers solutions for providing field-specific fertilizer recommendations to improve the yield and economics of maize growing famers in the region.

While generating recommendations, NE considers yield response and targeted agronomic efficiency in addition to quantifying the contribution of nutrients from indigenous sources. It also considers other important factors affecting nutrient management recommendations in a particular location and enables crop advisers to provide farmers with fertilizer guidelines that are suited to their farming conditions. The tool uses a systematic approach of capturing site information that is important for developing a location-specific recommendation (Pampolino et al. 2012a). Currently, the International Plant Nutrition Institute (IPNI) has developed NE for different geographies of Asia and Africa. The objective of this article is to evaluate and compare the performance of NE-based fertilizer recommendation with FP and SR, and demonstrate the merits of using NE in maize by presenting results from on-farm evaluation trials conducted in southern India.

Field evaluation of NE was conducted in varying maize growing environments, under rainfed and assured irrigated conditions, at 82 major maize growing sites in southern India. The study area covered Karimnagar, Ranga Reddy, Guntur, and West Godavari districts of Andhra Pradesh; Dharwad, Gulbarga, Yadgir and Bangalore districts of Karnataka; and Perambalur, Dindigul, Thanjavur, and Coimbatore districts of

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Zn = zinc; Mn = manganese; Fe = iron; B = boron; CO_2 = carbon dioxide; FP = farmer practice; SR = state recommendation; INR = Indian rupee, 1 USD = 54.8 INR.

Table 1. Comparison of nutrient use across three nutrient management options, Southern India.

Parameter	Unit	Kharif 2011 (Monsoon season): FP[1]	SR	NE	NE-FP		Rabi 2011-12 (Winter season): FP	SR	NE	NE-FP	
		Andhra Pradesh (n = 8)					**Andhra Pradesh (n = 27)**				
Fertilizer N	kg/ha	121-550 (229)	180	110-210 (148)	-82	ns	140-855 (288)	200	150-230 (203)	-85	**
Fertilizer P_2O_5	kg/ha	38-230 (87)	60	17-64 (37)	-51	ns	25-753 (153)	60	27-71 (54)	-99	***
Fertilizer K_2O	kg/ha	42-150 (74)	50	18-55 (38)	-35	ns	0-168 (68)	50	51-104 (74)	6	ns
		Karnataka (n = 12)					**Karnataka (n = 11)**				
Fertilizer N	kg/ha	80-174 (125)	150	110-230 (152)	27	*	80-218 (130)	150	110-190 (154)	24	ns
Fertilizer P_2O_5	kg/ha	58-148 (113)	75	20-81 (38)	-75	***	58-115 (77)	75	17-64 (42)	-35	***
Fertilizer K_2O	kg/ha	23-110 (67)	75	22-104 (62)	-5	ns	0-75 (29)	75	29-81 (57)	28	*
		Tamil Nadu (n = 12)					**Tamil Nadu (n = 12)**				
Fertilizer N	kg/ha	147-332 (225)	135	130-210 (182)	-43	*	95-360 (210)	210	130-150 (148)	-62	*
Fertilizer P_2O_5	kg/ha	48-79 (67)	63	27-47 (42)	-25	***	25-258 (111)	70	28-47 (39)	-72	*
Fertilizer K_2O	kg/ha	48-352 (201)	50	29-55 (43)	-158	***	50-270 (128)	65	22-59 (31)	-97	**
		Southern India (n = 32)					**Southern India (n = 50)**				
Fertilizer N	kg/ha	80-550 (193)	-	110-230 (161)	-32	ns	80-855 (209)	210	110-230 (168)	-41	**
Fertilizer P_2O_5	kg/ha	38-230 (89)	-	17-81 (39)	-50	***	25-753 (114)	70	17-71 (45)	-69	***
Fertilizer K_2O	kg/ha	23-352 (114)	-	18-104 (48)	-66	***	0-270 (75)	65	22-104 (54)	-21	ns

***, **, *Significant at $p < 0.001$, 0.01 and 0.05 level; ns = non-significant.
[1]FP, SR and NE = Farmer Practice, State Recommendation and Nutrient Expert.
Values in parenthesis represent mean values

Tamil Nadu during the *Kharif* and *Rabi* seasons of 2011-12. The experiments were carried out by IPNI in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT), the Directorate of Maize Research (DMR), state agricultural universities (UAS Dharwad, UAS Raichur and TNAU Coimbatore), Industry (Canpotex, Coromandel International Ltd. and Bayer BioScience Ltd.) and farmers. A survey was carried out in all locations prior to initiation of experiments and the current maize yields along with the nutrient application rates were recorded to understand the actual yields realized by the farmers. Nutrient Expert was used to provide field-specific fertilizer recommendations for an attainable yield target at each site, which was tested against fertilizer recommendations followed in SR and FP. Conventional (CT) and conservation tillage (CA) were considered as the options of crop establishment. There were 26 sites under CT and 6 sites under CA during the *Kharif* season, whereas, 31 sites had no-till (CA) and the remaining 29 sites were grown under CT during the *Rabi* season. Performance of NE was evaluated in terms of fertilizer use, maize grain yield, fertilizer cost, and gross returns above fertilizer cost (GRF).

Comparison of Fertilizer Use (FP vs. SR vs. NE)

A survey conducted on fertilizer use revealed that the nutrient use by maize growing farmers is highly skewed in southern India (**Table 1**). In *Kharif*, nutrient use data in three southern states indicated that N, P_2O_5 and K_2O fertilizer use in FP varied from 80 to 550, 38 to 230 and 23 to 352 kg/ha, with an average of 193, 89 and 114 kg/ha, respectively. The corresponding NPK use based on NE recommendations varied from 110 to 230, 17 to 81 and 18 to 104 kg/ha, with an average of 161, 39 and 48 kg/ha, respectively. The NE-based fertilizer recommendations reduced N, P_2O_5 and K_2O use by 32, 50 and 66 kg/ha indicating 17, 56 and 58% reductions in fertilizer use over FP. Close observation of data in **Table 1** for nutrient use in *Kharif* further revealed that the lowest N use in FP has increased from 80 to 110 kg/ha in NE, whereas, the maximum N use in FP has decreased from 550 to 230 kg/ha in the NE-based recommendations. This indicates that NE, in addition to suggesting a right rate of nutrients sufficient to meet the attainable yield targets, also helps in optimizing nutrient use through appropriate reductions in fertilizer application. Similar observations were also noted for optimizing P_2O_5 and K_2O use with NE-based fertilizer recommendations (**Table 1**). The difference between NE and FP for N and P_2O_5 use in Karnataka and NPK use in Tamil Nadu were statistically significant.

Table 2. Performance of NE-based recommendations for yield and economics of maize in southern India.

Parameter	Unit	Kharif 2011 (Monsoon season) FP[2]	SR	NE	NE-FP		Rabi 2011-12 (Winter season) FP	SR	NE	NE-FP	
		Andhra Pradesh (n = 8)					Andhra Pradesh (n = 27)				
Grain Yield	kg/ha	7,254	7,569	8,007	753	*	8,568	8,635	9,699	1,131	***
Fertilizer Cost	Rs/ha	6,820	4,991	3,580	-3,240	ns	9,509	5,220	5,459	-4,050	**
GRF[1]	Rs/ha	65,586	72,114	75,211	9,625	*	76,167	80,894	91,770	15,603	***
		Karnataka (n = 12)					Karnataka (n = 11)				
Grain Yield	kg/ha	5,214	5,907	7,026	1,812	***	8,831	9,385	10,215	1,384	**
Fertilizer Cost	Rs/ha	6,335	5,543	4,112	-2,223	**	4,522	5,543	4,183	-339	ns
GRF	Rs/ha	45,809	54,958	64,716	18,907	***	83,784	89,671	96,602	12,818	***
		Tamil Nadu (n = 12)					Tamil Nadu (n = 12)				
Grain Yield	kg/ha	8,154	7,622	8,774	620	**	6,550	7,114	7,405	855	***
Fertilizer Cost	Rs/ha	8,488	4,514	4,232	-4,256	***	8,395	5,960	3,546	-4,849	**
GRF	Rs/ha	73,058	71,988	83,230	10,172	***	57,106	67,595	68,099	10,993	***
		Southern India (n = 32)					Southern India (n = 50)				
Grain Yield	kg/ha	6,874	7,033	7,936	1,062	***	7,983	8,378	9,106	1,123	***
Fertilizer Cost	Rs/ha	7,214	5,016	3,975	-3,239	***	7,475	5,574	4,396	-3,079	***
GRF	Rs/ha	61,484	66,353	74,386	12,902	***	72,352	79,387	85,490	13,138	***

***, **, *Significant at $p < 0.001$, 0.01 and 0.05 level; ns = non-significant.
[1]GRF = gross return above fertilizer cost.
[2]FP, SR and NE = Farmer Practice, State Recommendation and Nutrient Expert.
Prices (in INR/kg): Maize = 10.00; N = 11.40; P_2O_5 = 32.2; K_2O = 18.8

NE-based fertilizer application during *Rabi* season revealed that application of N, P_2O_5 and K_2O across the states of southern India varied from 110 to 230, 17 to 71 and 22 to 104 kg/ha with an average of 168, 45 and 54 kg/ha, respectively (**Table 1**). Across all sites, NE reduced N, P_2O_5 and K_2O rates by 41, 69 and 21 kg/ha over FP, resulting in a rate reduction of 20, 61 and 28% of N, P and K fertilizers, respectively. NE recommended slightly higher N, P_2O_5 and K_2O rates during *Rabi* in comparison to the *Kharif* season. This is due to the fact that nutrient rates generated through NE are based on the estimated yield response to NPK application and NE estimated relatively high yield responses in *Rabi* season over the *Kharif* season (**Figure 1**). The mean yield response to application of N, P_2O_5 and K_2O during *Kharif* were 4.56, 0.48 and 0.58 t/ha; whereas, the estimated responses during *Rabi* were 5.47, 0.9 and 0.95 t/ha, respectively.

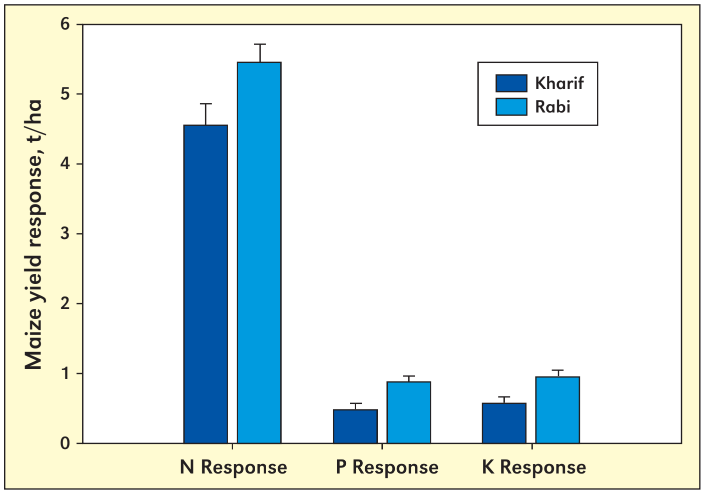

Figure 1. Average maize yield response to NPK application across growing seasons in Southern India (all 82 sites).

Performance of NE in Conventional vs. Conservation Tillage Areas

Conservation tillage practices are gaining importance in southern India. The study area had 6 out of 32 locations in *Kharif* and 31 out of 52 locations in *Rabi* season with CA where maize did not receive preparatory cultivation and was grown under no-till conditions. Nutrient recommendations from NE were tested against FP and SR under CT and CA during both the growing seasons. Across seasons, NE recorded higher grain yield in CA (9.3 t/ha) in comparison to CT (8.4 t/ha) and the magnitude of yield increase over CT (**Figure 2**) was higher in *Kharif* (20%) than in the *Rabi* (3%) season, respectively. Several researchers (Moschler and Martens, 1975; Wells, 1984) comparing CT and no-till production systems suggested that more efficient utilization of fertilizer with no-till production gave higher yields in CA. Pampolino et al. (2012b) also reported similar observations while evaluating NE for wheat in different tillage options under varied growing environments.

NE-based Fertilizer Recommendations Improving Yield and Economics of Maize

Data pertaining to relative performance of NE over SR and FP for grain yield of maize, fertilizer cost and GRF are given in **Table 2**. Across all sites (n=32) during the *Kharif* season, NE increased yield and economic benefit (i.e. gross return above fertilizer costs or GRF) over FP and SR (**Table 2**). Compared to FP, on average it increased yield by 1.06 t/ha and GRF by 12,902 INR/ha with a significant reduction in fertilizer cost of 3,239 INR/ha. Recommendations from NE also increased yield (by 0.9 t/ha) and GRF (by 8,033 INR/ha) over SR with a moderate reduction in fertilizer cost (-1,041

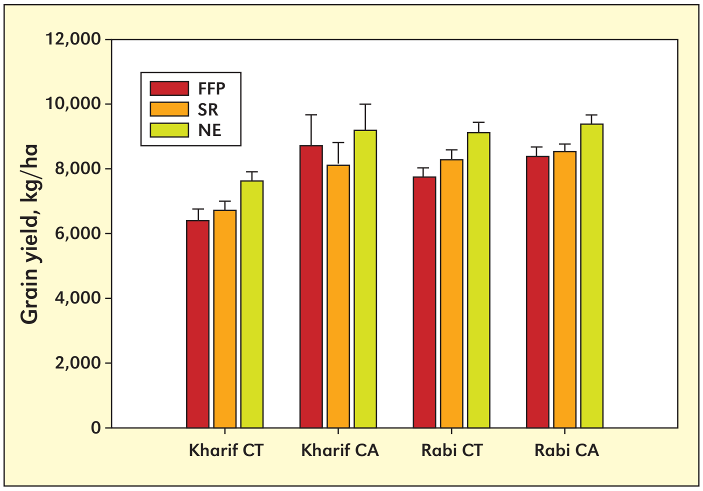

Figure 2. Effect of nutrient management options under varied seasons and crop establishments on grain yield of maize, Southern India.

INR/ha). NE-based fertilizer recommendations were also tested against FP and SR during *Rabi* season of 2011-12. Across the three southern states during *Rabi* season (n=50), grain yield with NE was significantly increased by 14 and 9% over FP and SR, respectively (**Table 2**). NE also increased GRF by 13,138 and 6,103 INR/ha over FP and SR and it reduced the fertilizer cost by 3,079 and 1,178 INR/ha over FP and SR, respectively.

Yield improvement with NE-based fertilizer recommendation could primarily be attributed to a balanced application of nutrients rather than to increasing the nutrient rates. The NE program recommended application of secondary and micronutrients especially S, Zn, Mn, Fe, and B at 48 out of 82 locations in the study area (data not shown). Also, farmers in 11 out of 82 locations did not apply K fertilizers under FP, whereas, NE-based recommendations bridged such gaps and provided optimum rates of K recommendations in the respective fertilizer schedules. This clearly explains how NE helped in promoting balanced use of all the essential nutrients thereby improving yields and optimizing nutrient use in the maize growing areas of Southern India.

The higher GRF when using NE than in FP and SR justifies the substantial reduction in fertilizer cost with NE-based recommendations. NE provides nutrient recommendations that are tailored to location-specific conditions. In contrast to SR, which gives one recommendation per state (e.g. 150 kg N, 75 kg P_2O_5 and 75 kg K_2O per ha in Andhra Pradesh), NE recommends a range of N, P_2O_5 and K_2O application rates within a site depending on attainable yield and expected responses to fertilizer at individual farmer's fields. Further, the estimated maize yield response by NE to application of N, P_2O_5 and K_2O fertilizers across the growing seasons varied from 2 to 8, 0 to 1.8 and 0 to 2 t/ha with a mean response of 5.02, 0.69 and 0.77 t/ha (data not shown) and captured the temporal variability of nutrient requirement between seasons along with the spatial variability between fields. The varied yield response to N, P and K application suggests that single homogenous state recommendations (**Table 1**) may become inadequate for improving maize yields in the region. Thus, fertilizer N, P_2O_5 and K_2O requirements determined by NE, varied among fields or locations, proved to be critical in improving the yield and economics of maize farmers in the region. In effect, use of the NE actually increased yields and profit, while reducing economic risk to the farmer, simply by providing some direction in the most appropriate fertilizer rate.

Summary

Maize, owing to its efficient utilization of radiant energy and fixation of CO_2 from the atmosphere, is considered as one of the major high yielding crops of the world. This versatile crop has wider adaptability to varied growing seasons and diverse ecologies and can address some of the food security issues of the nation. Despite maize being grown predominantly as a rainfed crop, its productivity is more than other cereals like rice and wheat, which are grown under assured irrigated/favorable rainfed conditions in south India. However, maize is an exhaustive feeder of nutrients and balanced and adequate application of fertilizer nutrients is the key not only for improving the current yield levels, but also for sustaining the profitability of maize growing farmers in the country. Nutrient Expert-based field specific fertilizer recommendations, demonstrated in southern India, increased yield and economic benefits through balanced application of nutrients. This DSS was able to capture the inherent differences between conventional and conservation practices of crop management, and NE-based fertilizer recommendations generated on the principles of SSNM performed better than FP and SR for maize. Besides providing location-specific nutrient recommendations rapidly, the tool has options to tailor recommendations based on resource availability to the farmers. There is a need to rapidly disseminate NE-based fertilizer recommendations for maize through extension agents and we anticipate that a user-friendly tool like NE, with it's robust estimation of site-specific nutrient recommendations, will be attractive to extension specialists working with millions of small holder farmers in the intensively cultivated maize areas in southern India.

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How Important are Phosphorus and Potassium for Soybean Production in the Cerrado of Brazil?

By Eros A.B. Francisco

Brazil appears poised to overtake the U.S. at the world's largest soybean producer. The successful establishment of a sustained, high-yielding environment within Brazil's highly productive, but nutrient poor, cerrado soils is at the heart of this new claim to fame.

Visual symptoms of K deficiency in soybean. Plants have green stems with yellow/brown discoloration and scorching along outer margins of older leaves.

The Cerrado is a vast tropical savanna eco-region of Brazil, covering 200 M ha in seven states, with a typical climate of two seasons per year, wet and dry, and a variety of weathered soils. Besides its relevance for biodiversity with hundreds of different species of fauna and flora, the Cerrado is also known for its vigorous agriculture development causing praiseful comments that refer to the area as the "world's barn". But, in order to build such agriculture in this region, extensive field research was conducted to identify the soil limitations and P and K were found to be the most limiting nutrients for profitable crop production, especially soybeans.

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium.

The poor fertility of Cerrado soils is well known with high acidity and low P and K levels being very common. Therefore, the first ameliorations required to achieve good yields are lime and P and K fertilizers. Phosphorus and K are crucial for prolonged soybean grain production in the Cerrado. One essential function of P is in energy storage and transfer where ADP and ATP (adenosine di- and triphosphates) act as energy currency within plants. This is very important for soybeans not only for plant growth, but also for promoting biological N fixation. The short supply of P may decrease nitrogenase activity and ATP concentration in the nodules impacting the ability of the plant to meet its N need. In regard to K, despite the fact that it is not associated with any compounds and functions solely as K^+ in the plant, it is related to several important functions

Visual symptoms of P deficiency in soybean. Plant growth is stunted and can have dark green coloration with necrotic spots. The deficiency ultimately delays blooming and maturity.

Dramatic contrast between two soybean fields where the only difference was the lack of application of P and K in the first year of production in a typical clay Cerrado soil in Mato Grosso State, in the Midwest region of Brazil.

such as enzyme activation, water and energy use relationships, translocation of assimilates, and protein synthesis. So, a short K supply causes a large number of problems in the plant.

Visual deficiency symptoms of P and K in soybeans are easy to identify. As both nutrients are mobile within the plant, when a deficiency occurs they are translocated from older tissues to the active meristematic regions, therefore, symptoms will generally appear in old leaves and move to younger leaves if the deficiency persists. For K, (i) irregular yellow mottling around leaflet margins during early growth stages, (ii) reddening, yellowing and dying of leaf margins on older leaves, and (iii) a ragged appearance of older leaves is typical. For P, the main symptoms are (i) slow growth, small leaflets and stunted, spindly plants, and (ii) dark green to bluish-green leaves. Conditions often associated with P and K deficiency include: low PK soil test, low soil organic matter content, sandy soils, and large P removal by previous crops.

Sound P and K management is an essential component of successful soybean production in the Cerrado. BC

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New Publication on Specialty Coffee: Managing Quality

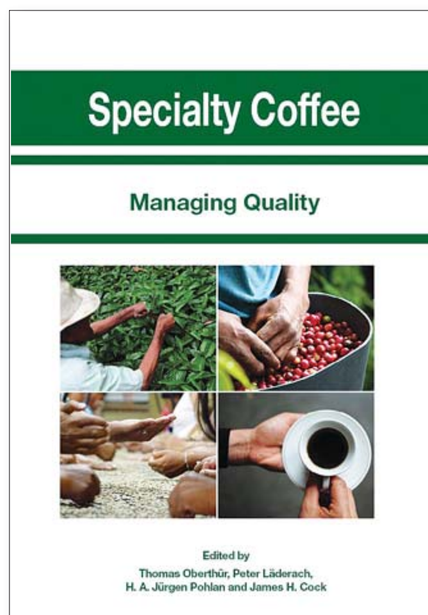
This publication developed out of a scarcity of published information on how to produce fine, high quality coffee that creates an excellent cup. The more the authors searched for information on coffee quality, the more they realized that a superb cup of coffee depends on a complex of processes along the supply chain that allows little margin for error at any stage. Furthermore, as so often occurs when personal preferences and tastes are involved in defining quality, the process of producing magnificent coffees is as much an art as a science.

Consequently, as the book evolved, the authors tried to combine hard science with art and put it into a business context …the result is a book with a wide range of styles.

> *"The authors have drawn on their long personal experience in quality coffee and their extensive network to create a resource book that covers the basic concepts of a quality market, how to manage crops for better tastes (genetics, agronomic practices, processing practices), how to structure value chains to improve relationships and incentives for quality management, and how to begin to address some of the upcoming challenges to quality coffee such as climate change."* -Don Seville, Co-Director of The Sustainable Food Lab

> *"The book has a solid scientific focus but will appeal to a broad readership. It is a compilation of 15 Chapters, each written by an eminent lead author and edited by an equally eminent team."* -Anthony Marsh, Coffee Consultant

> *"A few critical notes notwithstanding, this book is highly recommended to all stakeholders in the coffee industry as an authoritative and comprehensive source of information on several aspects of the product life cycle of coffee, the specialty arabica coffees from Meso America for the USA market in particular."* -Herbert A. M. van der Vossen, Plant breeding and Seed Consultant, Board Member of the Association for Science and Information in Coffee



This book is neither a blueprint nor a recipe for specialty coffee production. The intention is to provide information and ideas that stimulate and support creative thinking that can provide the basis for developing and adjusting the myriad processes and details of the specialty coffee supply chains that produce a multitude of coffees with distinctive traits from a diverse range of origins.

You can order your copy of this book for USD 100.00 through IPNI's on-line store at: http://info.ipni.net/COFFEE-MANAGING-QUALITY.

If you require more details on this unique publication please contact our Southeast Asia Program office at e-mail: seap@ipni.net. BC

Strategies to Mitigate Methane Emissions in Lowland Rice Fields in South Brazil

By Cimelio Bayer, Tiago Zschornack, Rogerio O. Sousa, Leandro S. da Silva,
Walkyria B. Scivittaro, Paulo R.F. da Silva, Sandro J. Giacomini, and Felipe de C. Carmona

Minimum tillage, reducing irrigation water application, and crop diversification are identified as efficient strategies to mitigate CH_4 emissions in rice fields while also increasing yield. Even though land area under rice cultivation increased 30% from 1990 to 2005 and the IPCC predicted an associated 30% increases in CH_4 emissions, introduction of minimum tillage resulted in a 4% decrease in total CH_4 emissions and a 48% decrease in emissions per unit of grain production. This is an example of how evaluation and establishment of local indexes of GHG emissions enables consideration of the impact of adopting new technologies that generalized indexes miss.

The global index proposed by IPCC for CH_4 emission predicted a 30% increase in Rio Grande do Sul State in southern Brazil (**Figure 1A**). This prediction was primarily attributed to the increase in cultivated area under flooded rice that occurred between 1990 and 2005 (Bayer et al., 2012). There is a significant chance this index has misled policy-makers and environmental monitors into maintaining a negative perception of rice production. Technologies have been developed and adopted, both in Brazil and worldwide, to increase rice yields while reducing the environmental footprint of its production. In southern Brazil, groups contributing to this science include IRGA (Rice Research Institute), EMBRAPA (Brazilian Agricultural Research Corporation) and Federal Universities (UFPel, UFSM and UFRGS). Some of these technologies and their environmental impacts are discussed below.

Minimum Tillage

Minimum tillage is an example of a new technology that is helping farmers plant their crops within periods that are better timed to minimize GHG emissions (SOSBAI, 2012). For example, systems including conventional tillage will plow the soil just before rice is sown. Thus rice straw and winter crop residues are incorporated into soil, acting as a source of labile C for CH_4 production. Conversely with minimum tillage, soil is disturbed in the fall or winter when rice residues are incorporated into soil under non-flooded conditions. Thus part of the labile C is converted into CO_2, decreasing CH_4 emission potential once the area is flooded in preparation for the next rice crop (**Figure 2**).

Minimum tillage also maintains more weeds and winter crop residues on the soil surface contributing to a lower emission of CH_4 than is observed under conventional tillage (**Figure 3**) (Costa, 2005; Zschornack, 2011; Moterle, 2011; and Buss, 2012). Conventional tillage incorporates C residues within the 0 to 20 cm depth, where soil reduction status is much higher than on the surface layer, resulting in a higher production of CH_4 by methanogenic microorganisms (Costa, 2005; Zschornack et al., 2011; Zschornack, 2011). Data collected over seven years and three sites in southern Brazil shows that soil CH_4 emissions were 33% lower under minimum tillage than conventional tillage.

Common abbreviations and notes: C = carbon; CH_4 = methane; CO_2 = carbon dioxide; N_2O = nitrous oxide; GHG = greenhouse gas; IPCC = Intergovernmental Panel on Climate Change; Gg = gigagram.

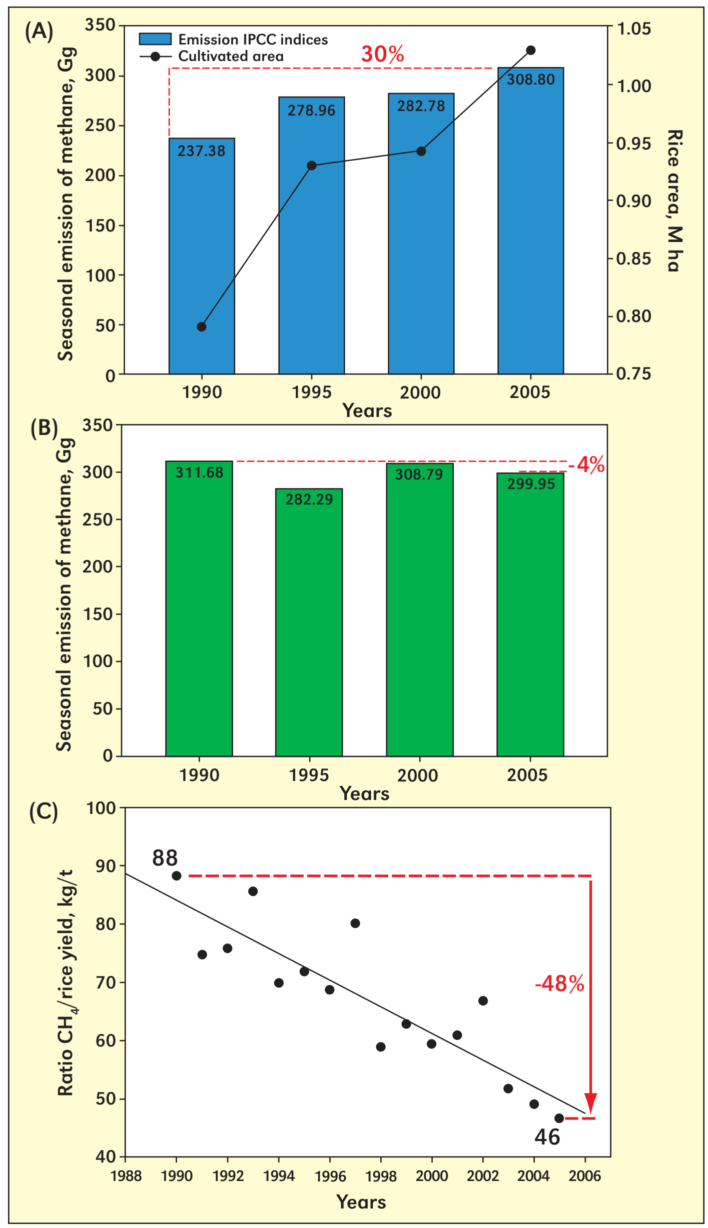


Figure 1. Changes in lowland rice area and seasonal CH_4 emission in Rio Grande do Sul State in southern Brazil based on the IPCC indexes (A), regional data for seasonal CH_4 emission considering evolution of minimum tillage adoption (B), and CH_4 emission per unit of rice production (C). Source: Bayer et al. (2012).

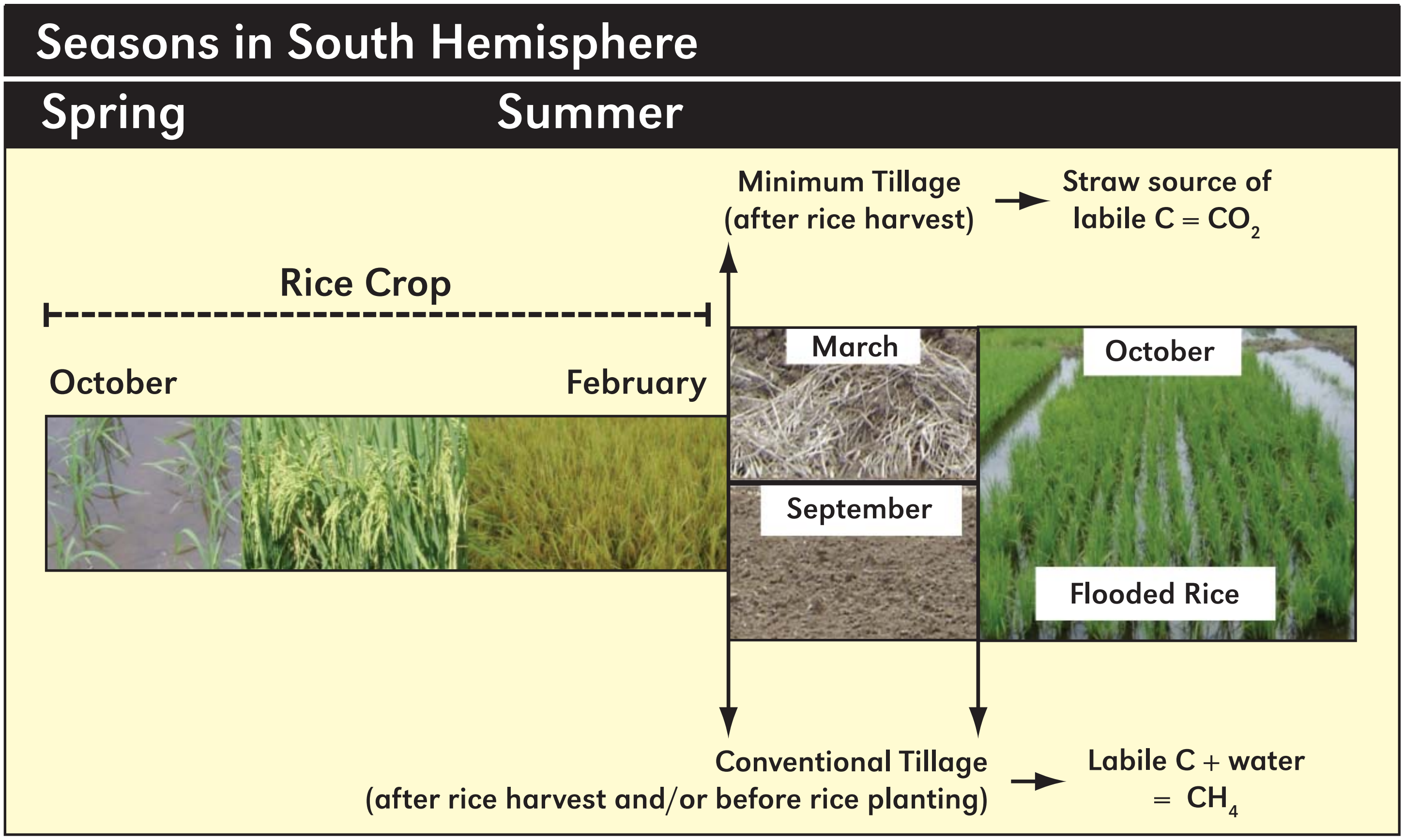


Figure 2. Conventional tillage and minimum tillage technologies adopted by southern Brazilian farmers.

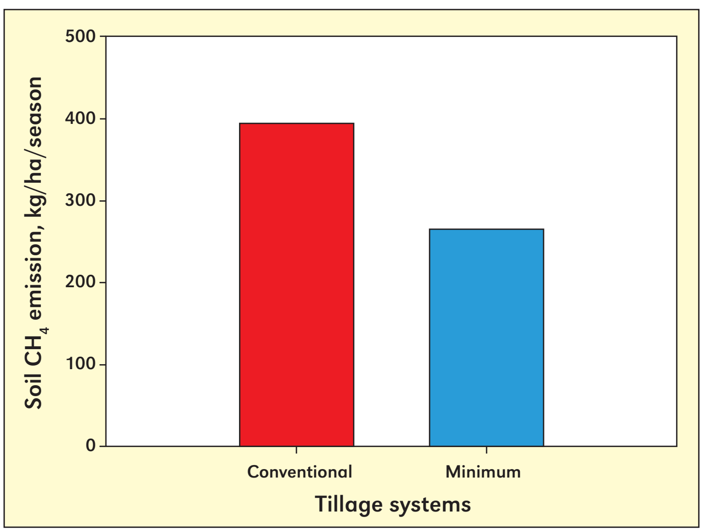


Figure 3. Seasonal methane (CH_4) emissions in flooded rice fields under conventional and minimum tillage systems in southern Brazil.

Local GHG emission data also shows that despite the 30% increase in cultivated rice area from 1990 to 2005, the estimated soil CH_4 emissions decreased by 4% (**Figure 1B**). Stable soil CH_4 emissions despite an increase in cultivated area, was the consequence of widespread adoption of minimum tillage by farmers. In 1990, about 80% of the total rice area in southern Brazil was cultivated under conventional tillage and only 20% was under minimum tillage. From 1990 to 2005, there was a continuous substitution of conventional tillage by minimum tillage, and in 2005, almost 80% of the total cultivated area was under minimum tillage. The impact of minimum tillage adoption on CH_4 emissions may not have been taken into consideration when IPCC indexes were applied.

Also, results were expressed only as per unit area, and not as per unit of food production. An increase in rice yield from 4.5 to 6.0 t/ha has occurred from 1990 to 2005 as a consequence of the introduction of new cultivars and the adoption of better soil and crop management practices. Considering this increase in yield, CH_4 emission has fallen from 88 to 46 kg of CH_4 per t of rice grain production (**Figure 1C**).

Reducing Irrigation Water Application

Areas under rice cultivation in the state of Rio Grande do Sul are traditionally irrigated by maintaining a water level during most of the life cycle of the rice plants (about 90 days). The practice consumes a large volume of water ranging from 8,000 to 10,000/m^3/ha (SOSBAI, 2012). Reducing irrigation water application to rice from continuous to intermittent use (i.e., suspending application of irrigation water at certain crop stages) has led to a 43% (9 to 77% range) reduction in soil CH_4 emission (**Figure 4**). These results are in agreement with similar studies around the world. Reducing irrigation water application also decreases the chances of iron (Fe) toxicity to rice plants.

Crop Diversification

Rice farmers in southern Brazil have recently started adopting crop diversification in paddy fields. In particular, soybean has been introduced within the rotation and this has had a positive impact on GHG emission from these poorly-drained soils. For example, partial global warming potential

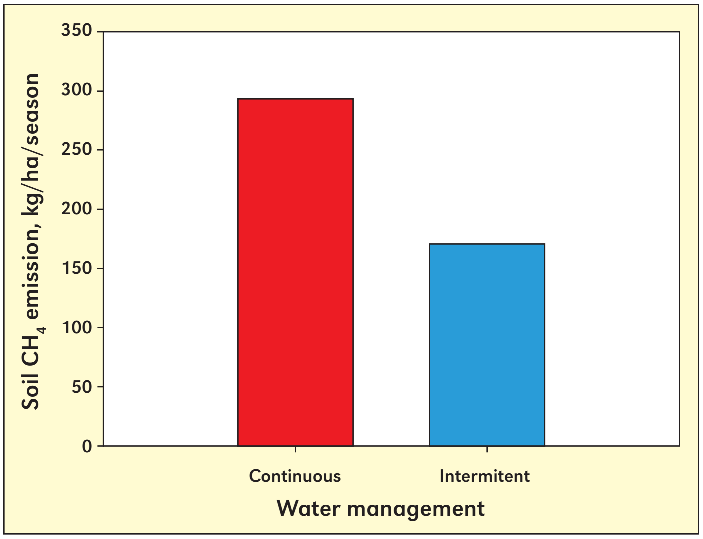


Figure 4. Potential of water saving regimes (intermittent) to mitigate soil CH_4 emissions in southern Brazilian lowland rice fields. Source: Zschornack (2011), Wesz (2012), Buss (2012), Moterle (2011), Camargo (data not published).

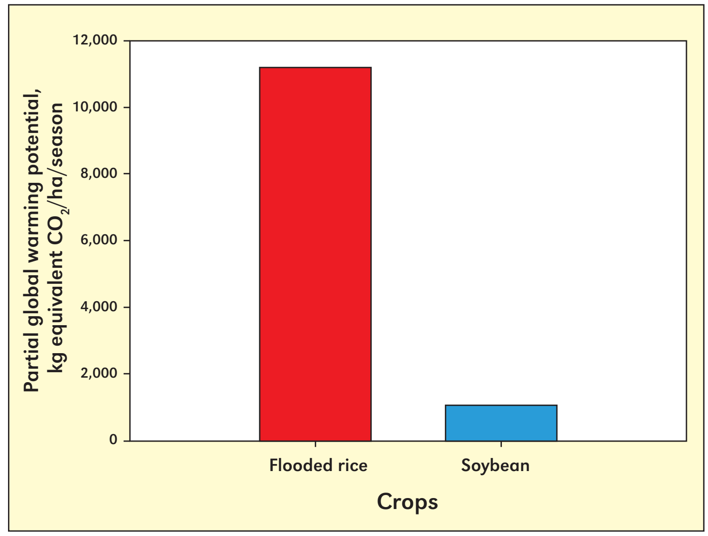


Figure 5. Partial global warming potential (CH_4+N_2O in CO_2 equivalent) in lowland fields cultivated with soybean and rice under traditional irrigation methods in southern Brazil. Source: Camargo (unpublished data).

(i.e., CH_4+N_2O in equivalent CO_2) was found to be 10-fold lower under soybean than under rice (**Figure 5**).

Summary

Development of environmental-friendly agricultural production systems with a low C footprint is a crucial strategy that will drive international agricultural markets in the near future. Thus, regional GHG research is crucial to identify or develop low C emission production systems. In flooded rice production systems, some technologies such as minimum tillage, reduction in irrigation water application, and crop diversification have been found to have the potential to mitigate CH_4 emissions in southern Brazil. BC

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Important Changes for the IPNI China Program

Dr. HE Ping

Dr. JIN Ji-yun

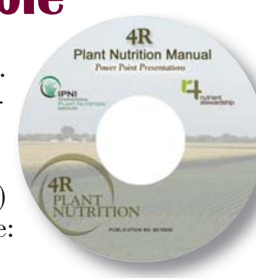
The International Plant Nutrition Institute (IPNI) has appointed Dr. HE Ping, Director of the China Program, effective January 1, 2013. She succeeds Dr. JIN Ji-yun, who served as part of the Institute's China Program since 1990 and retired from IPNI on December 31, 2012.

Dr. HE was born in Yushu County of Jilin Province, an important area for crop production. She studied soil science and plant nutrition at Jilin Agricultural University, earning a B.Sc. in 1992 and a M.Sc. in 1995. Dr. HE received her Ph.D. in Plant Nutrition Science at the Graduate School of the Chinese Academy of Agricultural Sciences (CAAS) in 1998. During 2001 to 2003, Dr. HE was chosen by the Chinese Ministry of Science and Technology and the Science and Technology Agency of Japan to work on high yield maize research at Hokkaido University as a post-doctoral fellow. As Director of the China Program, Dr. HE oversees IPNI's agronomic and educational programs in China and is responsible for the development and implementation of Nutrient Management and Optimized Fertilization programs for the Northeast (Heilongjiang, Jilin and Liaoning), and North Central regions (Hebei, Henan, Shandong, Shanxi, plus Beijing and Tianjin). In addition to her responsibilities as Director, she is also a Professor at the Institute of Agricultural Resources and Regional Planning, CAAS. Dr. HE has authored or co-authored over 70 scientific papers, and has received wide recognition for her work. In 2007, she received the Top Scientist award from the National Basic Research Program of the Ministry of Science and Technology. In 2008, Dr. HE was named as a "Top ten outstanding youth" by the State Organs Work Committee; and in 2011, she received the National Red-Banner Pacesetter award by the China Women's Federation.

Dr. JIN Ji-yun joined the PPI/PPIC (now IPNI) China Program in Beijing in 1990, as Deputy Director responsible for Northern China. In 2001, Dr. JIN became Director of the China Program. His leadership oversaw the Institute's cooperative research program growth to the national level. His pioneering research on K in northern China also changed the traditional belief that those soils were rich in K and no K fertilizer was needed. In 1995, Dr. JIN was selected by the Ministry of Agriculture for the Great Contribution Award for Young-Mid Aged Scientists. In 1997, he received the National Award for Great Contribution for Students Returned from Abroad from the National Education Commission of China. His achievements in soil testing and balanced fertilization were awarded by the Central government in 1999 and 2000. In 2001, he received the National Excellent Research Fellow Award from China Society of Agronomy. In 2004, he was presented with the First Soil Science Society Award from the Soil Science Society of China, and received the National Excellent Research Fellow Award from the China Association of Professional Societies. In 2007, Dr. JIN was awarded by the central government as one of the Model Scientists in Agricultural Technology Transfer. In 2010, he received the Norman Borlaug award from the International Fertilizer Association to recognize excellence in knowledge transfer and "last mile" delivery. Dr. JIN has published 120 scientific papers and delivered countless talks in workshops and meetings around the globe. He was involved in editing 10 proceedings and scientific books. Dr. JIN has been a council member for the Soil Science Society of China since 1987 and a council member of the Chinese Society of Plant Nutrition and Fertilizer Sciences since 1994. He has served as President of Chinese Society of Plant Nutrition and Fertilizer Sciences from 2004 to 2012. BC

Common abbreviations and notes: K = potassium.

4R Plant Nutrition Manual Slide Set Now Available



IPNI has released its *4R Plant Nutrition Slide Set* designed for use as a training and extension resource. The set is comprised of nine individual PowerPoint presentations (over 250 slides in total) that correspond to each of the chapters within our *4R Plant Nutrition Manual*. Each set is accompanied by speaker's notes. The set is currently available to order in CD format for USD 50.00.

To order please contact our Circulation Department at e-mail: circulation@ipni.net; phone: (770) 825-8082 or 825-8084 or see our 4R web portal for details on ordering directly from our on-line store: http://www.ipni.net/4R BC

Hakim Boulal Joins Staff of IPNI as Deputy Director of North Africa Program

Dr. Hakim Boulal

Dr. Hakim Boulal joined IPNI as Deputy Director of its newly established regional program in North Africa, effective February 1, 2013. Dr. Boulal joins Dr. Mohammed El Gharous, Consulting Director for IPNI North Africa, both of whom will be located in Settat, Morocco.

"The addition of Dr. Boulal to our North Africa Program completes a knowledgeable team that is well prepared to meet the research challenges facing this very important region," said IPNI President Dr. Terry Roberts. "The background and skills that Dr. Boulal brings to IPNI are vital to our plans for the North African region and will be highly valued by our members."

Dr. Boulal is a native of Youssoufia city, one of the important phosphate production sites in Morocco. He received his B.Sc. in Agricultural Sciences in 1988 from the National School of Agriculture in Meknes, Morocco. Dr. Boulal completed a Ph.D. program on Biology and Agronomy in 1996, from the National School of Agronomy of Rennes (France). In 2010, Dr. Boulal completed his second Ph.D. program from the University of Cordoba (Spain) on conservation agriculture including soil and water conservation, crops and irrigation aspects.

Dr. Boulal has an extensive work background within the North African region that began within Morocco's National Institute of Agronomic Research (INRA) where he became involved in research/development and agronomy research programs. As a research scientist with INRA, Dr. Boulal worked in various national and international projects. He made significant contributions in improving cereal crop management, to developing suitable methods of conservation agriculture, implementing decision support systems for cereal production, agro-meteorology, and leading a program on the evaluation of raised-bed planting systems for irrigated wheat in Morocco.

More recently, Dr. Boulal has worked within the International Centre of Agricultural Research in Dry Areas (ICARDA) where he coordinated research projects on improved water management for sustainable mountain agriculture; options for coping with increased water scarcity in agriculture; and development and dissemination of sustainable irrigation management in olive. BC

Conversion Factors for U.S. System and Metric

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
0.0159	kg/ha	bu/A, corn (grain)	62.7
0.0149	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.

Nutrient Balance and the Future of Land

The dollar value of agricultural land in the North American Corn Belt has reached prices few ever thought possible. High commodity prices and favorable interest rates are sited as major factors behind the increases. At the same time we see trends in nutrient balances in this region that if unchecked will erode the fertility and productivity of those same land parcels that are today so highly valued.

I spoke recently at an investors meeting on "The Future of Land" where I emphasized three points: 1) land faces challenges in every country, 2) land plays a critical role in the most significant issues of the coming decades, and 3) the future of land will reflect the success of land managers in meeting stakeholder goals (a 4R concept). It has become very clear that the marketplace today also sees land playing a critical role in the future. For example, the value of farm land in the state of Iowa in 2012 increased 24% from 2011 to an average of $8,296/A. Cropland value for the US as a whole increased 14.5% in 2012 to an average of $3,550/A and other sources indicate that this trend is not unique to North America. The value of Brazilian cropland is estimated to have increased 18% last year on top of a decade with average annual increases of 14%. In Great Britain, arable farmland increased 5% in value in 2012 and much of Central Europe has been experiencing huge increases in land value.

At the same time, a popular topic at recent meetings has been nutrient balance (nutrients being applied vs. nutrients removed in crop harvest) and IPNI's new and planned tools dealing with nutrient balance such as NuGIS, our new nutrient removal web portal (http://info.ipni.net/nutrientremoval), and mobile phone apps. These tools show us that P and K balance in much of the U.S. Corn Belt has become decidedly negative and our soil test summaries have demonstrated that these negative budgets are frequently drawing down soil fertility to less than optimal levels. Such mass balance problems cannot be corrected with biological additives. At the other extreme, are situations with highly positive nutrient balances where soil fertility is already above optimal levels and continued increases may in extreme cases negatively impact future land value.

Marc Vanacht and I heard a speaker at a recent Soil and Water Conservation Society meeting refer to a "restorative economy". Both of us immediately moved that concept into our own world as a "restorative agronomy". Shortly after the meeting, Marc expanded the concept into three terms: 1) an **extractive agronomy** that leaves the soil and the resource base worse off, 2) an **exploitive agronomy** that maintains the status quo but leaves the resource base vulnerable to extreme situations, and 3) a **restorative agronomy** that rebuilds the resource base to make it more resilient to extreme situations. As the dollar value of land increases, these terms should be front and center in our minds and plans made to assure that what we practice is indeed a restorative agronomy.

Good tools are available from IPNI and other sources to draw attention to these conflicting trends of increasing land values and inappropriate nutrient balances … tools that can help farmers, their advisers and input suppliers make appropriate adjustments to create a restorative agronomy within 4R Nutrient Stewardship programs. Such adjustments are necessary if highly valued land is to remain highly productive land.

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