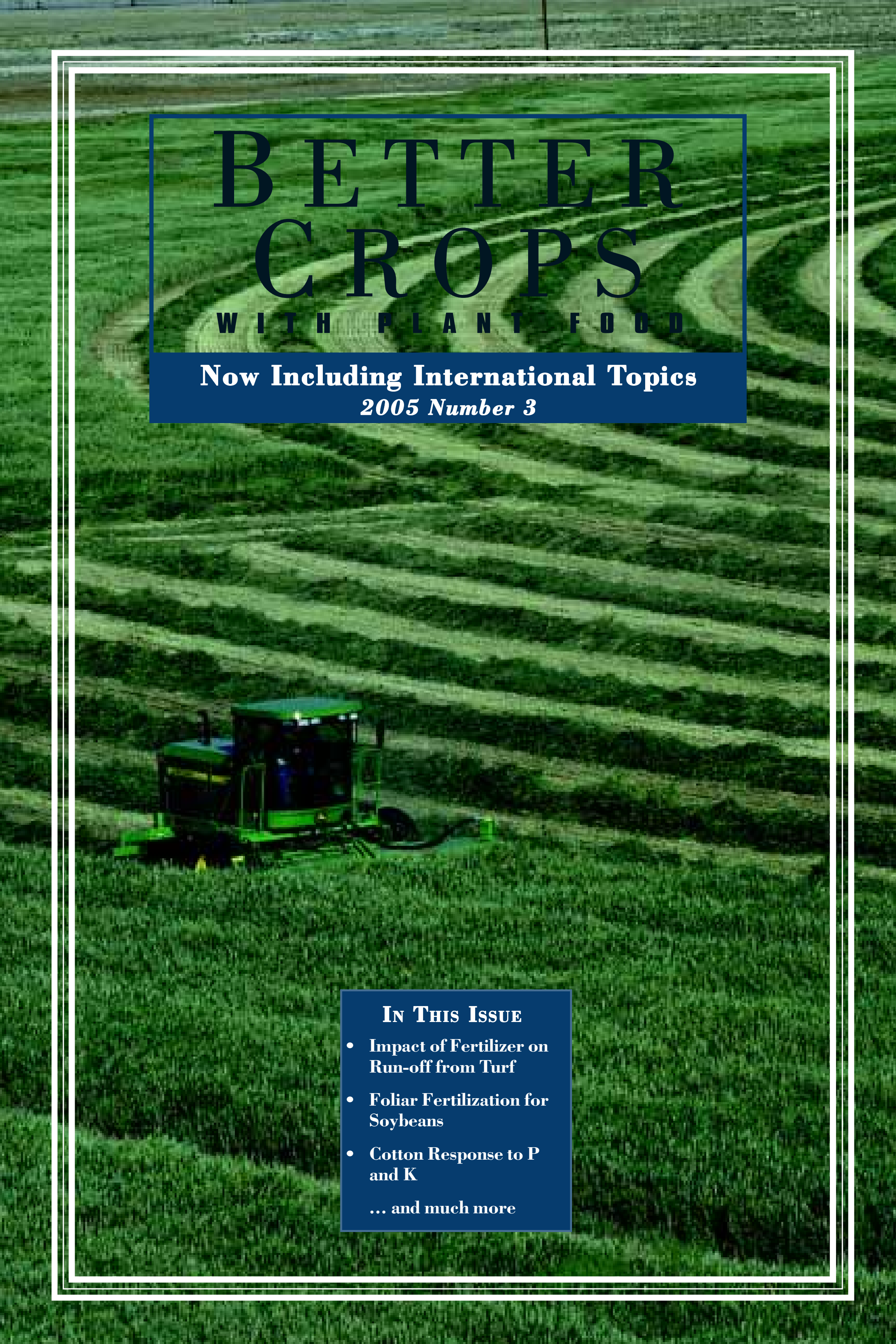

BETTER CROPS

WITH PLANT FOOD

Now Including International Topics
2005 Number 3

IN THIS ISSUE

BETTER CROPS
WITH PLANT FOOD

Vol. LXXXIX (89) 2005, No. 3

Our Cover: Windrower at work in hay field. Photo courtesy of John Deere.

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CONTENTS

INTERNATIONAL SECTION

PPI/FAR Research Database

At the end of some articles in each issue of *Better Crops with Plant Food,* a line such as "PPI/FAR Research Project SK-35" will appear. This indicates that the article is based at least in part on research supported by PPI and FAR. To find out more about the topic, readers may visit the Research Database at the website: >**www.ppi-far.org/research**<.

The icon shown here is a handy signpost to help you learn more about the various projects, including full annual reports and other publications. The Research Database contains much more detail than can be included in a typical article in this publication.

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Winners of Robert E. Wagner Award for 2005

Two outstanding scientists in agronomy and horticulture have been selected to receive the 2004-2005 Robert E. Wagner Award by PPI. The award encourages worldwide candidate nominations and has two categories... Senior Scientist and Young Scientist, under the age of 45. The recipient in each category receives $5,000 along with the award plaque.


Dr. D.G. Westfall


Dr. E.H. Simonne

Dr. Dwayne G. Westfall, Professor, Department of Soil and Crop Sciences, Colorado State University, was named winner of the Senior Scientist Award. **Dr. Eric H. Simonne,** Horticultural Sciences Department, University of Florida, receives the Young Scientist Award.

The Robert E. Wagner Award recognizes distinguished contributions to advanced crop yields though maximum yield research (MYR) and maximum economic yield (MEY) management. The award honors Dr. Wagner, President (retired) of PPI, for his many achievements and in recognition of his development of the MEY concept...for profitable, efficient agriculture.

Dr. Westfall is a well-known leader in research and education focused on efficient plant nutrient management. Throughout his career of more than 30 years, he has emphasized the goal of MEY for various production environments. His work in proper management and fertilization of no-till intensive dryland cropping systems increased annualized grain production by 75% and boosted net return by up to 40%.

Recently, Dr. Westfall has helped build an interdisciplinary, interagency agriculture team that is comprised of 12 scientists and extension specialists, including soil fertility, entomology, weed science, plant pathology, irrigation, remote sensing, spatial statistics, economics, and extension. He is widely known as a highly productive scientist who has successfully translated his research findings into farmer-level application. Among other awards and honors, Dr. Westfall is a Fellow of the American Society of Agronomy (ASA) and Soil Science Society of America. He received the Agronomic Achievement Award from ASA in 1987. He is author or co-author of more than 430 publications and abstracts. Dr. Westfall completed his Ph.D. in Soil Science at Washington State University in 1968.

Dr. Simonne leads a research/extension program in the Horticultural Sciences Department at the University of Florida, with focus on the integration of mineral nutrition with irrigation. The goal is to maintain the competitiveness of the $1.8 billion Florida vegetable industry while preserving natural resources, especially water. He has been actively involved in drafting and modifying the best management practices (BMP) manual for vegetables grown in Florida. Dr. Simonne's extension work has been unique in developing and conducting dye tests to help growers visualize how their irrigation schedules affect movement of soluble nutrients in the soil profile. Use of soil moisture measuring devices by growers has reduced irrigation amounts by 15 to 50%, and the on-farm dye demonstrations are credited with reducing nutrient leaching. Dr. Simonne is active in the American Society for Horticultural Science, and is involved in the review and publication process of two international journals that focus on plant nutrition. He earned his Ph.D. degree in Horticulture at the University of Georgia in 1993. BC

J. Fielding Reed PPI Fellowships Awarded To Seven Graduate Students

Seven outstanding graduate students have been announced as the 2005 winners of the J. Fielding Reed PPI Fellowships. Grants of $2,500 each are presented to the individuals. All are candidates for either the Master of Science (M.S.) or the Doctor of Philosophy (Ph.D.) degree in soil fertility and related fields. The winners for 2005 are:

- **Nancy L. Bohl**, University of Wisconsin-Madison
- **Ines C. Daverede**, University of Illinois
- **Fabian G. Fernandez**, Purdue University
- **Amy L. Shober**, University of Delaware
- **Douglas J. Soldat**, Cornell University
- **John T. Spargo**, Virginia Tech
- **Kristin E. Staats**, University of Delaware

"Each year, we have the privilege of recognizing these excellent young individuals who represent such strong qualifications and dedication in agronomic sciences. Since these awards began in 1980, more than 150 graduate students have received Fellowships from the Institute," said Dr. David W. Dibb, President of PPI.

Funding for the Fellowships is provided through support of potash and phosphate producers who are member companies of PPI. Scholastic record, leadership, and excellence in original research are among the important criteria evaluated for the Fellowships. Following is a brief summary of information for each of the 2005 recipients.


Nancy L. Bohl

Nancy L. Bohl is working toward her M.S. degree in Soil Fertility at the University of Wisconsin-Madison. Her thesis title is "Assessing Phosphorus Losses in Run-off at Plot and Sub-Watershed Scales in Wisconsin Cropping Systems." A native of Wisconsin, she completed her B.S. degree at Iowa State University in 2004. For the future, she hopes to use her background in soil fertility and agricultural education in working with landowners and farmers in nutrient management planning.


Ines C. Daverede

Ines C. Daverede is pursuing a Ph.D. degree in Soil Fertility at the University of Illinois-Urbana/Champaign. With the thesis title of "Swine Manure and Fertilizer Nitrogen Transformations in Soil and Corn Uptake," a portion of her work involves tracing the fate of labeled N from the corn kernel, through the animal, into manure storage facilities, and finally back to the soil and into corn grain. A native of Argentina, she completed her B.S. degree at the University of Buenos Aires in 1999 and her M.S. at Illinois in 2001.


Fabian G. Fernandez

Fabian G. Fernandez is completing the requirements for his Ph.D. degree in Soil Fertility and Plant Nutrition at Purdue University in West Lafayette, Indiana. His dissertation title is "Potassium Acquisition by No-Till Soybeans Affected by Stratified Soil Potassium, Growth Stage, and Soil Water Content," which seeks to advance understanding of interactions between soil water status, soil K availability, soybean root development, and soybean K requirements in rain-fed production with stratified soil test K. Born in Argentina, Mr. Fernandez completed his M.S. and B.S. degrees at Brigham Young University.

Amy L. Shober

Amy L. Shober is finishing the program for her Ph.D. degree in Soil Science at the University of Delaware. Her dissertation title is "Phosphorus (P) Speciation and Solubility in Soils Amended with Animal Manures and Municipal Biosolids: Implications for Water Quality." Her research incorporates laboratory and molecular scale research to determine how the chemical forms of P differ between organic P sources, and how these differences will affect P solubility and bioavailability when they are incorporated into the soil. A native of New Jersey, Ms. Shober earned her B.S. degree at Virginia Tech in 1998 and M.S. at Pennsylvania State University in 2002. Her future plans include a career as a research soil scientist.

Douglas J. Soldat

Douglas J. Soldat is working toward a Ph.D. degree in Horticulture/Plant Science at Cornell University in Ithaca, New York. With a dissertation title of "The Source of Phosphorus in Runoff from Turfgrass," his research has examined the relationship between soil test P levels and P losses from turfgrass areas. In identifying the major sources of this loss, his hypothesis is that microbial decomposition of clippings is a major factor. Born in Wisconsin, Mr. Soldat earned his B.S. and M.S. degrees at the University of Wisconsin-Madison. In the future, he hopes to work in teaching and research with a university and contribute further to the understanding of how P and K cycle in turfgrass systems.

John T. Spargo

John T. Spargo recently began working toward his Ph.D. degree in Soil Fertility at Virginia Tech. His dissertation title will be "Nitrogen Cycling in Long-Term No-Till Coastal Plain Soils of the Mid-Atlantic," with the objective of determining fertilizer N recoveries/losses and sequestration in areas of the region that have been in no-till for several years. Improved understanding of N dynamics in no-till soils of the area will allow increased agronomic efficacy of N applications and limit any negative environmental impact. Born in Washington, DC, Mr. Spargo earned his B.S. at Texas A&M and his M.S. at Virginia Tech.

Kristin E. Staats

Kristin E. Staats is completing her M.S. degree at the University of Delaware with a major in Plant and Soil Sciences. With a thesis title of "Phosphorus in Alum-Amended Poultry Litter Systems: Distribution, Speciation, and Interactions with Aluminum Oxides", she is using innovative laboratory techniques to investigate the efficacy of alum as a best management practice for poultry litter. Improved understanding of animal manure chemistry is important for environmental preservation and improvement. Ms. Staats will begin a Ph.D. program at Virginia Tech in fall 2005.

The PPI Fellowships are named in honor of Dr. J. Fielding Reed, who served as president of the Institute from 1964 to 1975. Dr. Reed, who passed away in 1999, was well-known for inspiring advanced study and for encouragement of students and teachers. BC

Humic Materials for Agriculture

By R.L. Mikkelsen

Humic materials...very large and complex molecules extracted from organic matter...have been used in many ways for plant production. There are numerous reports of plant response and also of no response to these materials. This article reviews their use in agriculture and points to consider before using humic materials.

Few agricultural products have been subject to more confusion and conflicting information than humic-type additives. The scientific literature is full of reports where humic additives have directly or indirectly stimulated plant growth. There are also many reports where no response was found following the use of humic substances.

Unlike fertilizer, which has a long history of documented research and university recommendations, humic acid is widely sold and used without as much detailed research. This brief review will cover the nature of humic substances and how they are currently being used in crop production.

Humic material can be extracted from soft brown coal-like deposits called leonardite, found with lignite coal.

What Are Humic Substances?

There is no one single chemical known as humic acid, since the chemical structure has never been completely defined. These materials are composed of complicated organic mixtures which are linked together in a random manner, resulting in extraordinarily complex materials (**Figure 1**). It has been suggested that no two molecules of humus are exactly the same. The special properties of humic materials result from this extreme heterogeneity and their high chemical reactivity.

Humic materials have an abundance of carboxyl groups and weakly acidic phenolic groups, which contribute to their complexation and ion-exchange properties. They exhibit both hydrophobic and hydrophilic characteristics and can bind to soil mineral surfaces.

Over the years, many methods have been used to extract humic acids from stable organic matter. Most commercially

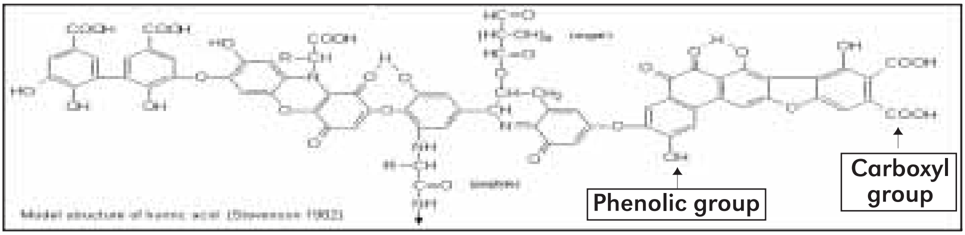

Figure 1. A simplified example of the structure of humic acid extracted from soil.

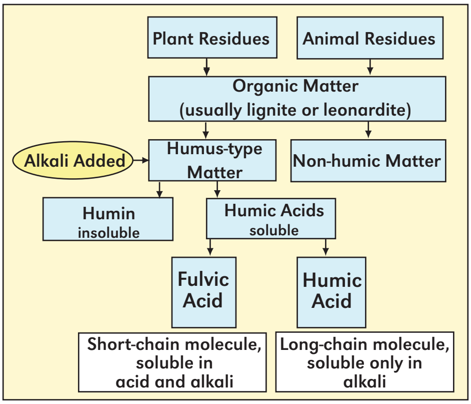

Figure 2. Common chemical extraction technique for extracting organic materials into various fractions commonly applied for crops.

available humic material is extracted from soft brown coal-like deposits with an alkali solution (**Figure 2**). Following extraction, it may be subjected to many secondary processes for stabilization and enhancement, including addition of nutrients. Given the wide range of extraction methods and processes used to produce commercial products, it is frequently difficult to compare specific materials.

With their high pH-dependent charge, when the cation exchange sites are filled primarily with hydrogen (H) ions, the material is considered an acid and is called humic acid. This material has no great effect on soil pH because this acid form is insoluble in water. When a cation other than H dominates the exchange sites, the material is technically called humate (a salt of humic acid). **Humic materials are not fertilizers, since they contain only small amounts of plant nutrients, but their potential usage has been classified as providing soil physical, chemical, and biological benefits.**

Use of Humic Substances

Physical benefits—The conditioning value of high rates of organic matter added to soil has long been known. Both fresh and stable organic matter provide benefits such as improved tilth, water retention, and a nutrient reservoir. However, consider that a soil containing just 1% organic matter has over 20,000 lb/A of organic matter.

Clearly, massive amounts of organic matter addition are required to make significant changes in this soil property, and usually this is a very long-term process. However, it may be feasible to make important changes in localized soil zones, such as the seedbed or in a fertilizer band.

Soil chemical benefits—Humic materials are able to complex various cations (pseudo-chelation) and serve as a sink for polyvalent cations in the soil. They have a negative surface charge at all pH values where crop growth occurs. Reports of improved cation availability following addition of humic materials are common. Detailed reviews of this phenomenon have been published elsewhere.

Essential micronutrient cations that might normally be expected to precipitate at pH ranges found in most soils are maintained in solution through complexation with many organic compounds. Enhanced plant growth following addition of humic materials has sometimes been related to increased micronutrient availability…especially iron (Fe) and zinc (Zn). There are also numerous reports of metal concentrations being reduced to non-toxic levels following addition of complexing organic matter.

Organic substances have been demonstrated to enhance the solubility of soil phosphorus (P) through complexation of Fe and aluminum (Al) in acid soils and calcium (Ca) in calcareous soils. For example, researchers at the University of Idaho showed positive yield and quality responses of potatoes to humic acid added to band-applied P in a calcareous soil. Other researchers have noted similar increases in nutrient availability for plants following the use of humic substances, although there is still much to learn about these reactions.

Biological benefits—-Numerous reasons have been proposed for the stimulatory plant responses sometimes seen following addition of humic materials.

(continued on page 10)

Do Contemporary Cotton Cultivars Respond Differently to Potassium Fertilization?

By C. Owen Gwathmey

Contemporary upland cotton cultivars may differ in their potassium (K) nutrition requirements to achieve optimum yields. Researchers have offered several possible explanations for varietal differences in yield response to K, including differences in earliness of maturity and in partitioning of the products of photosynthesis within the plant. This article summarizes some Tennessee research in progress to investigate these relationships.

Earliness of maturity is important to the adaptation of cultivars to different parts of the U.S. cotton belt, especially where season length is marginal for cotton, as in the North Mississippi River Delta. Earliness is enhanced when a greater proportion of new photosynthate is partitioned to bolls instead of more vegetative growth. This reduces the number of new fruiting sites, thus limiting the number of late-set bolls. By contrast, cultivars that continue to grow vegetatively during boll filling are said to be physiologically indeterminate. Production of new fruiting sites and foliage late in the season delays their maturity and harvest.

Role of K—Potassium is an essential nutrient for many physiological processes, most notably for the transport of the products of photosynthesis within the plant. It does this by regulating the salt balance across cell membranes. Improved transport of photosynthate to active growing points may be expected to promote vegetative growth. We wondered if increasing K fertility might promote late-season vegetative growth more in an indeterminate cultivar than in a more determinate cultivar.

Field research—A field study was conducted in 2003 and 2004 on a no-till Loring (thermic Oxyaquic Fragiudalf) silt loam at the West Tennessee Experiment Station in Jackson, Tennessee, to determine effects of K nutrition on lint yield, earliness, and dry matter partitioning of two contrasting cultivars. Replicated, long-term K plots were maintained by broadcasting 60 or 120 lb K_2O/A as KCl before planting each year. Residual K fertility of each plot was estimated by soil sampling and analysis by Mehlich 1 procedures prior to annual K fertilization. Plots were also fertilized with 80 lb nitrogen (N) and 60 lb P_2O_5/A. Cultivars were the early-maturing PM 1218 BG/RR and the later, more indeterminate DP 555 BG/RR. Aboveground portions of eight plants per plot were harvested at early bloom and after cutout. These plants were dissected, dried, and weighed to measure biomass partitioning. Later, plots were spindle-picked twice to determine lint yields. Earliness was calculated as the percent of total yield picked at first harvest.

Soil test K—In plots receiving 60 lb K_2O/A/year, residual soil test K averaged 204 and 219 lb K/A in 2003 and 2004, respectively. These Mehlich 1 soil K levels correspond to the recommended K fertilization rate of 60 lb K_2O/A, according to the University of Tennessee Extension Service. Plots receiving 120 lb K_2O/A/year had residual soil test of 301 and 395 lb

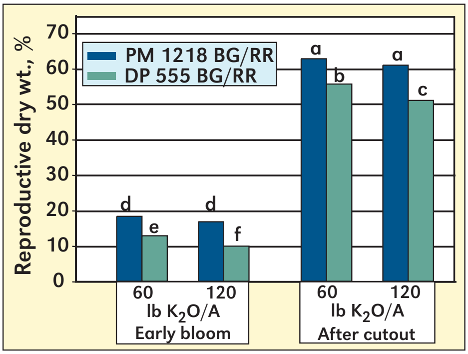

Figure. 1. Effect of K nutrition on proportion of biomass in reproductive tissue at early bloom and after cutout of two cotton cultivars at Jackson, Tennessee, 2003-04.

K/A in 2003 and 2004, respectively. These soil K levels correspond to recommended rates of 60 and 0 lb K_2O/A, respectively, indicating that these plots received K above the agronomic optimum.

Biomass partitioning—Figure 1 shows the effect of K regime on the proportion of biomass in reproductive tissue of the two cultivars in 2003-04. As expected, the earlier cultivar partitioned more aboveground biomass to reproductive tissue than the later, indeterminate cultivar did. Potassium nutrition did not significantly alter the reproductive partitioning of PM 1218 BG/RR, but DP 555 BG/RR partitioned a smaller proportion of biomass to reproductive tissue at the higher K rate than it did at the lower K rate, both at early bloom and after cutout. This result suggests the additional K promoted more vegetative growth in the indeterminate cultivar.

Lint yield and earliness—Figure 2 shows the effect of K regime on 2-year average lint yield and earliness of the two cultivars. Yield of the earlier cultivar increased 11% in response to the additional K, while yield of the later cultivar did not increase significantly. This result is consistent with the different partitioning responses to K shown in **Figure 1**. Evidently, partitioning to vegetative growth in DP 555 BG/RR did not promote additional yield formation at the higher K rate. Bolls set very late in the season are not expected to contribute much to yield in Tennessee, due to lack of heat units needed for them to mature. **Figure 2** also shows the relative earliness of maturity of each cultivar in response to K. The expected cultivar difference in maturity is evident, but the delayed maturity in response to additional K was not statistically significant. Differences in cultivar maturity were also evident in canopy appearance late in the growing season (**Figure 3**).

Contemporary cotton cultivars that differ in earliness and growth habit may respond differently to annual K fertilization that exceeds recommended rates. If the additional K promotes the partitioning of photosynthetic products to vegetative growth instead of reproductive parts, then lint yield formation may not be enhanced. Additional research is needed to determine the role of K in the storage and

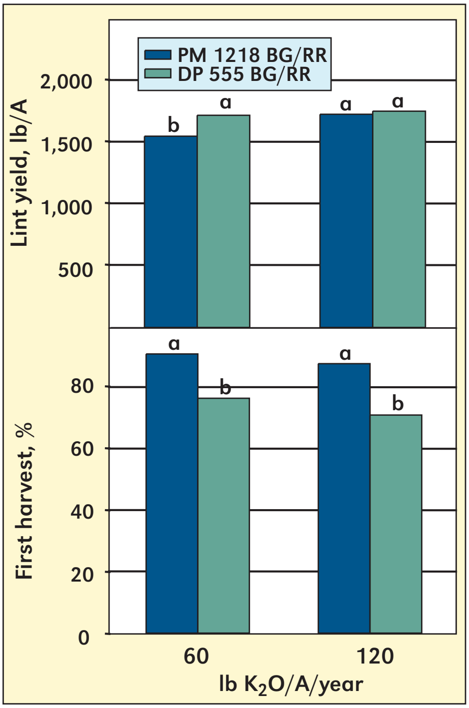

Figure. 2. Effect of K nutrition on lint yield and earliness of two cotton cultivars at Jackson, Tennessee, 2003-04.

Figure 3. Cultivar differences in canopy appearance at 114 days after planting in 2004 at Jackson, Tennessee.

remobilization of carbohydrates in these cultivars, to improve their efficiency.

In short season environments like Tennessee, the likelihood of a satisfactory cotton crop is promoted by planting well-adapted, early maturing cultivars and managing them for earliness. **An important element in earliness management is a K fertility maintenance program based on annual soil test results and local extension recommendations.** BC

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Acknowledgment

Donation of planting seed by Delta and Pine Land Co. is appreciated.

PPI/FAR Research Project TN-19F

Humic Materials...from page 7

However, there is currently not enough research to explain possible mechanisms and accurately predict when humic materials might prove beneficial. There are reports of growth and yield responses from various conditions...from soil and foliar application...banded, broadcast, and fertigated applications...and solid and liquid humic formulation. Thus, defining the positive effect is difficult.

A benefit sometimes mentioned regarding humic material is that it can provide a carbon (C) source for soil microorganisms. This mechanism does not appear to be likely, since a typical application of 5 to 20 gal/A of humic material will supply only 3 to 15 lb C/A. Compare this with more than 4,000 lb of C/A returned in the residue of a typical corn crop. The hormonal effect of humic materials on plant growth has also been carefully studied and largely negated. Humic acids have been shown to function as a urease inhibitor and a nitrification inhibitor in some circumstances. The search for a biological explanation for the plant responses to humic materials will continue and will not be simple.

The use of humic materials in production agriculture continues to grow. There are numerous reports of both successful and unsuccessful use of these materials. Due to the wide variation in their raw materials and processing methods, it is difficult to accurately compare the efficacy of specific commercial products without careful study. Due to the range of recommendations for use, it is not easy to define a mode of action that can be applied across many crops, soils, and growing conditions.

Users of humic materials should keep careful records and conduct on-farm field trials to determine product effectiveness. Research organizations should continue to study the value of this expanding agricultural input. Remember that no additive will compensate for poor management and inadequate crop nutrition. BC

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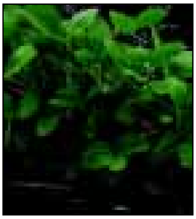
IOWA

Early Season Foliar Fertilization of Soybeans



By A.P. Mallarino, M.U. Haq, and T.S. Murrell

Based on 74 site-years of investigation of foliar fertilization at early vegetative growth stages, foliar fertilization combinations had relatively low probabilities of increasing soybean yields in Iowa.

Prior to the middle to late 1990s, little research had been conducted on foliar fertilization of soybeans at early vegetative stages. Foliar fertilization at these stages could increase phosphorus (P) and potassium (K) supplies at a time when root systems are not well developed.

This article summarizes work performed across 74 site-years from 1994 to 1998 (Haq and Mallarino, 1998; Haq and Mallarino, 2000; Mallarino et al., 2001). The objective was to evaluate the grain yield response of soybean to early season foliar fertilization. Most soybean varieties used were glyphosate resistant. Products tested include 3-18-18 [nitrogen (N)-P_2O_5-K_2O] and 10-10-10. Additionally, 10-10-10 was examined with the addition of sulfur (S) and S plus the micronutrients boron (B), iron (Fe), and zinc (Zn)…denoted 10-10-10-1S-M. The products used to formulate the 3-18-18 and 10-10-10 were urea, aqueous ammonia, phosphoric acid, and potassium hydroxide. Sulfur was supplied as ammonium sulfate and micronutrients as iron chloride, zinc chloride, and sodium borate. Potassium nitrate was used to formulate the 8-0-8.

Product rates ranged from 2 to 6 gal/A (**Table 1**). Some treatments consisted of a second application, 8 to 10 days after the initial one (denoted by a "+" between rates). The single or first foliar fertilizer applications were made at the V5 to V6 growth stage. For 66 conventional plot trials, the fertilizers were not mixed with

Table 1. Trials, treatment sets, and rates of nutrients applied with foliar fertilization.

Trials and treatment sets	Formulation	Product rate, gal/A	Nutrient rate, lb/A N	P_2O_5	K_2O	S	B	Fe	Zn
3-18-18	3-18-18	2	0.7	4.3	4.2	–	–	–	–
	3-18-18	3	1.1	6.3	6.3	–	–	–	–
	3-18-18	4	1.4	8.6	8.4	–	–	–	–
	3-18-18	2+2	1.4	8.6	8.4	–	–	–	–
	3-18-18	3+3	2.2	12.6	12.6	–	–	–	–
3-18-18 strip trials	3-18-18	3	1.1	6.3	6.3	–	–	–	–
N-P-K various	3-18-18	3	1.1	6.3	6.3	–	–	–	–
	3-18-18	2+2	1.4	8.6	8.4	–	–	–	–
	10-10-10	3	3.1	3.1	3.1	–	–	–	–
	10-10-10	6	6.2	6.2	6.2	–	–	–	–
	8-0-8	4.5	3.4	0.0	3.4	–	–	–	–
N-P-K-S various and micronutrients	3-18-18	3	1.1	6.3	6.3	–	–	–	–
	10-10-10	3	3.1	3.1	3.1	–	–	–	–
	3-18-18-1S	3	1.1	6.3	6.3	0.3	–	–	–
	10-10-10-1S	3	3.1	3.1	3.1	0.3	–	–	–
	10-10-10-1S-M	3	3.1	3.1	3.1	0.3	0.03	0.12	0.02

glyphosate or any other herbicide. The 3-18-18 was mixed with glyphosate in eight replicated strip trials. Some of these strip trials were conducted in the same fields where conventional plots were established. The results suggested no interaction between foliar fertilization with 3-18-18 and glyphosate application, which agrees with industry research and product labels allowing for tank mixtures of these products. Further investigations are needed into yield impacts of possible interactions of other products with glyphosate.

Tillage systems of the studies included no-till, ridge-till, as well as chisel plow tillage. Soybean row spacing of the no-till fields was 7.5 in., while the no-till and ridge-till sites had 30 to 38 in. spacings. Most sites had P and K fertilizer applied in the fall before the previous season's corn crop; however, some sites did have these nutrients applied in the fall before the soybean crop. Soil tests of 0 to 6 in. samples were taken in the spring of the soybean cropping year. Bray P-1 (colorimetric) soil test levels indicated that 1.4, 12.2, 8.1, 18.9, and 59.5% of the fields were very low, low, optimum, high, and very high, respectively. Ammonium acetate extractable soil test K levels indicated that 2.7, 31.1, 24.3, 16.2, and 25.7% of the fields were very low, low, optimum, high, and very high, respectively. Iowa State University does not provide micronutrient soil test interpretations for soybeans, although all the sites where micronutrients were applied had soil test Zn levels considered adequate for corn.

Leaf injury from foliar applications sometimes occurred with applications of 10-10-10-1S and 10-10-10-1S-M (at 3 gal/A) or when 10-10-10 was applied at the higher rate of 6 gal/A. Injury usually affected 5% or less of the leaf area; however, up to 10% of the leaf area was affected at two sites where 6 gal/A of 10-10-10 had been applied. Injury to the leaves did not result in statistically significant yield decreases. Treatments that did not produce significant foliar injury sometimes decreased yields. Consequently, leaf injury was not related to soybean yield response.

Table 2 summarizes yield responses from the studies. The same treatments were not evaluated in all 74 trials. The number of site-years in which a specific set of fertilizers and rates were compared to a non-fertilized control ranged from 18 to 74. Across all locations, years, fertilizer products, and application rates, the average relative frequency of positive and negative responses was 16 and 5%, respectively. The increase in yield at the 12 sites with positive responses ranged from 1 to 8% and averaged 6%. At the few sites (4) where yields were significantly decreased with foliar fertilization, yield losses ranged from 6 to 10%, and averaged 9%.

Positive responses to foliar fertilization were more likely with low rainfall in late spring to midsummer and when growing

Table 2. Effects of early season foliar fertilization on grain yield of soybean.

Trial and treatment set	Number of site-years studied	Site-years with statistically significant positive yield responses[1]	Positive response frequency	Avg. positive yield response	Site-years with statistically significant negative yield responses[2]	Negative response frequency	Avg. negative yield response
			%	%		%	%
3-18-18	21	6	29	7	1	5	6
3-18-18 strip trials	8	1	13	1	–	–	–
N-P-K various	27	3	11	8	3	11	10
N-P-K-S various and micronutrients	18	2	11	7	–	–	–
All trials	74	12	16	6	4	5	9

[1] Some or all treatments increased yield compared with the non-fertilized control.

[2] Some or all treatments decreased yield and none increased yield compared with the non-fertilized control.

conditions resulted in low N, P, and K uptake. Across most sites, no significant relationship was seen between yield response and soil nutrient levels, soil pH, or soil series. One site (no-till) did show a significantly positive response to 3-18-18 (3 gal/A) in acidic (pH 5.7-6.0) areas of the field.

However, other sites did not exhibit this relationship. It must be noted that the vast majority of the sites tested optimum or higher according to current P and K soil test interpretations for soybean in Iowa. As a matter of fact, the two largest yield responses were observed in high-testing soils. These two sites were managed with no-tillage or ridge-tillage, but there was no clear overall trend toward higher frequency of responses in these tillage systems compared to a conventional tillage system.

Statistical analyses of specific formulations and rates revealed no consistent trends in yield response (positive or negative) to the different treatments. However, study of yield differences that were statistically significant as well as examination of general agronomic trends across trials indicated a few results of interest. Split applications (V4 toV5 plus another application 8 to 10 days later) increased only slightly the probability of yield response. Inconsistent and small yield responses from one-time (V5-V6 growth stage) foliar applications, combined with application costs, led us to conclude that any economically advantageous yield response was achieved with only a single application. Use of 10-10-10 and 8-0-8 formulations had, on average, a lower probability of producing a positive response than did 3-18-18 at the sites studied. The chance of a statistically significant yield loss from these treatments was nearly the same as the chance of a significant yield gain, and average yield losses were about the same as average yield gains. The inclusion of S provided an advantage at one site. These formulations sometimes resulted in leaf burning, mainly at the high rate of 10-10-10 and 10-10-10-1S, but yield decreases were not clearly related to leaf burning. Adding the mix of the micronutrients B, Fe, and Zn did not provide any additional advantages.

The 3-18-18 formulation at 3 gal/A had the most consistent set of positive responses across all trials in which it was compared to other formulations, although this superiority could not be confirmed at the usual probability level used in research ($p \leq 0.05$). Higher consistency in producing responses combined with no leaf burning and compatibility with glyphosate suggest that 3-18-18 could be the formulation of choice for foliar fertilization of soybeans at early growth stages.

Summary

All foliar fertilization combinations had relatively low probabilities of increasing soybean yields. Of the formulation and rate combinations studied, 3-18-18 had the best chances of increasing yields while minimizing chances of yield losses. Generally in these studies, foliar fertilization has not proven to be a cost-effective management practice when used across all fields and conditions. However, the probability of an economically positive response may be increased by targeting foliar applications to fields in which visual observation of early growth suggests stress. Combining fertilizer with glyphosate applications at the V5 to V6 growth stage may improve the economics of foliar fertilization practices. BC

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WESTERN CANADA

Impact of Crop Residue Type on Potassium Release

By N.Z. Lupwayi, G.W. Clayton, K.N. Harker, T.K. Turkington, and A.M. Johnston

Greater than 90% of crop residue potassium (K) was released to the soil within one year of addition. Tillage system had no effect on the release of K from the crop residues.

It is generally assumed that crop residues will decompose more slowly under no-till than under conventional tillage management. With a reduced rate of decomposition, we would expect less nutrients to be released in a given time period. This assumption may not always be correct, given that the amount of a nutrient released from crop residue depends not only on the decomposition rate, but also on the nutrient concentration in the original crop residue. This could be affected more by crop type than any management input.

To address these questions, a study was initiated in an established long-term tillage and crop rotation experiment. The objective was to quantify how much K is released from red clover, field pea, canola, and spring wheat residues under conventional and no-till seeding systems.

The trial was conducted at Fort Vermilion in northwestern Alberta in 1998-1999 and 1999-2000, using an established study evaluating two tillage systems: conventional tillage (CT) and no-till (NT), and four different crop rotations that included red clover green manure (GM), field peas, canola, and wheat. In 1998-1999, the red clover did not survive the winter and was replaced with a field pea green manure crop. Crops were grown on soils that had soil test levels of 150 parts per million (ppm) K (0.5M $NaHCO_3$-extractable), and no fertilizer K was added. Crop residues of the green manure, field peas, wheat, and canola were collected at harvest, weighed, and analyzed for K to determine the amount of K being returned to the plot. The residues were then placed in decomposition-resistant litter bags with 1 mm mesh and either buried in the soil (CT), or placed on the soil surface (NT). The bags were sampled periodically over a 12-month period and the residues analyzed for K to determine how much K still remained in the decomposing residues and, by difference from the amounts applied, how much K had been released.

Table 1. Impact of previous crop on the input and release of K from green manure, field pea, canola, and wheat crop residues, 1998-1999.

	Residue applied		K released			% K
Crop residue	DM	K	2 wk	5 wk	52 wk	released
	lb/A					
Field pea GM	3,105a[1]	32.4a	30.3a[2]	29.6a	30.2a	93
Field pea	2,061bc	28.3a	12.9b	21.5a	26.6a	94
Canola	2,610ab	35.9a	17.4c	28.6b	34.2a	95
Wheat	1,458c	22.8a	8.3b	18.4a	20.9a	92

[1] For residue applied (dry matter and K) numbers in columns followed by the same letter are not significantly different.

[2] For K released, numbers in rows followed by the same letter are not significantly different.

Crop residue dry matter returned to the soil by the

Table 2. Impact of previous crop on the input and release of K from green manure, field pea, canola, and wheat crop residues, 1999-2000.

	Residue applied		K released			% K
Crop residue	DM	K	2 wk	5 wk	52 wk	released
	lb/A					
Red clover GM	4,788a[1]	94.2a	32.1b[2]	81.0a	91.4a	97
Field pea	5,445a	73.8ab	37.7b	45.1b	66.3a	90
Canola	4,581a	53.3bc	38.8b	43.5ab	49.1a	92
Wheat	1,962b	31.5c	13.0b	16.4b	30.0a	95

[1] For residue (applied dry matter and K) numbers in columns followed by the same letter are not significantly different.

[2] For K released, numbers in rows followed by the same letter are not significantly different.

different crops was considerably higher in 1999-2000 relative to 1998-1999, reflecting the higher crop production during the 1999 growing season (**Tables 1** and **2**). However, crop residue yield resulted in a large difference between the two study periods in the amount of total K being returned to the field. While the total amount of K returned varied by crop grown, all crop types released at least 90% of their K in 52 weeks. Wheat produced the least amount of crop residue and lowest residue K returned to the field in both years. The amounts of residues produced and added to the soil did not differ significantly between tillage treatments, and there were no significant interactions between tillage and crop residues in residue DM produced or K returned to the field (data not shown).

During the 52 weeks that residue samples were monitored in this study, the amount of K released was very similar to that which had been applied with the residues (**Tables 1 and 2**). Unlike the release of phosphorus (P), where green manure crops released the largest proportion of the residue P (70 to 78%), all crop types released 90% or more of their residue K. The reason for the difference is that, unlike N and P, K is not a structural component of plant tissue. This release of K was rapid, with most of the K returned to the soil within 5 weeks of application. Whether the residue was buried with CT or left on the surface with NT, there was no effect on K release recorded. However, there were significant interactions between tillage and sampling time under canola residues in 1998-1999 and pea residues in 1999-2000 (interaction data not shown). In both cases, more K was released under zero tillage than under conventional tillage in the first 5 weeks of decomposition. The reason is that canola residues contained more K under zero tillage than conventional tillage in 1998-1999, and the same was true for pea residues in 1999-2000.

The results of this study illustrate that all crop residues considered released more than 90% of their accumulated K in the 52-week period. The rapid and large release of residue K can be expected to contribute to plant K supply when these fields are recropped. Given the very small proportion of plant K that is removed from the field in grain harvest, the return of residue K shown here will help to maintain soil test K levels. The use of no-till seeding systems, relative to conventional tillage, had no effect on the K released by the crop residues. However, sometimes residues returned more K to the field under zero tillage than under conventional tillage. BC

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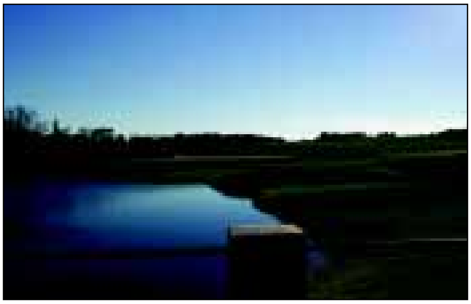
Impact of Organic and Mineral Fertilizers on Run-off from Turf

By Z.M. Easton and A.M. Petrovic

Turfgrass is an effective filter, slowing run-off and cutting sediment loss. Fertilizing it appropriately can reduce losses of nutrients in run-off.

Residential lawns comprise 82% of New York state's 3.4 million (M) acres of turfgrass, according to a recent survey. On average, homeowners spent just $31/A on fertilizers for these lawns, so it appears that rates applied fall well below rates recommended to maintain optimum quality turf.

Excesses of nutrients, particularly nitrogen (N) and phosphorus (P), can impair water quality. However, when turfgrass is fertilized with these two essential nutrients, the impact on their losses to surface water and groundwater is often unclear. Because turfgrass can reduce run-off and absorb nutrients, enhancing its growth may reduce nutrient losses, in spite of their added input.



Turf that is fertilized correctly ultimately results in less water contamination.

We conducted research to compare three organic and two mineral sources of nutrients for their impact on nutrient losses in run-off. Each of the five fertilizers (see **Table 1**) provided a total of 4 lb of N/1,000 ft^2 each year. The total was split into four applications in each calendar year, starting with seeding on July 18, 2000. Applying the treatments to 3 ft. by 6 ft. plots on an Arkport sandy loam in New York, we monitored both the establishment year and the year following. We collected run-off water from 33 precipitation events. The soil

Table 1. Fertilizers applied to turfgrass, and total clippings removed.

Fertilizer	Source	Analysis[3], %	P_2O_5 applied, lb/1,000 ft^2/yr	Clippings, % of check
Organic				
Swine compost	Bion Technologies	4.25 - 2 - 0	1.9	210
Dairy compost	Bion Technologies	0.8 - 0.3 - 0	1.5	160
Biosolid	Milorganite	6 - 2 - 0	1.4	190
Mineral				
Controlled-release[2]	SCU + Urea + MAP + MOP[1]	24 - 5 - 11	0.9	300
Soluble	Urea + MAP + MOP[1]	35 - 3 - 5	0.4	240

[1] MAP=monoammonium phosphate; MOP=muriate of potash; SCU=sulfur-coated urea

[2] Controlled-release had 45% of the N as SCU

[3] $N\text{-}P_2O_5\text{-}K_2O$

test level for P was considered adequate.

Table 2. Losses of P and NO_3-N by run-off.

	Total losses in run-off, lb/A			
	July – December 2000 (8 run-off events)		January – November 2001 (25 run-off events)	
Fertilizer	Phosphate-P	Nitrate-N	Phosphate-P	Nitrate-N
Swine compost	0.7	7	0.9	3
Dairy compost	0.4	2	0.6	3
Biosolid	0.4	8	0.9	4
Controlled-release	0.4	7	0.5	4
Soluble	0.2	10	0.5	3
Control	0.2	5	1.2	3

We found that fertilization increased shoot density. In our study, as shoot density doubled, water infiltration increased and reduced run-off by threefold. Thus, fertilizer treatments that promoted high shoot density tended to reduce the volume of run-off, chiefly after establishment. Fertilization also boosted the yield of clippings, and thus nutrients removed, relative to the unfertilized check (see **Table 1**).

At establishment, sediment clouded the run-off from all treatments. Following establishment, sediment was observed regularly in run-off only in the control treatment. Since the run-off samples were filtered through 2-micron cellulose, the P measured did not include all the particulate P that might have moved from the plots, and thus we may have underestimated total losses from the unfertilized control.

During the first 5 months after seeding, losses of P in run-off were proportional to the amount applied in fertilizer (see **Table 2**), and nitrate (NO_3^-) losses were greatest where the most soluble N source (urea) was applied.

Following the establishment period, NO_3^- losses decreased dramatically (**Table 2**). The 25 run-off events in 2001 caused less total run-off loss of NO_3^- than the eight events of 2000, and the fertilized treatments did not differ from the control. However, P losses in run-off from the control plot increased and exceeded those from all fertilized plots.

The organic fertilizer sources—particularly the swine compost and the biosolid—produced the highest losses of P. This was not surprising, since these sources supplied considerably more P than the mineral fertilizers. The low ratio of N:P thus becomes a limitation for use of organic fertilizer sources for turf, if minimizing losses of nutrients in run-off is a management goal.

Since the run-off losses we measured were immediately adjacent to small-scale plots on slopes of 7 to 9%, it should not be presumed that similar amounts would be delivered to surface waters from all turf. Landscape processes can alter nutrient losses. Slope and distance to watercourse are important factors.

Our results suggest that fertilization during establishment poses the most serious threat to water quality. During this phase it is important to apply just the right rate of nutrients needed to quickly establish the turf to enhance infiltration and reduce sediment and run-off loss.

Nutrient sources should be chosen that match the ratio of required nutrients. If P deficiency limits the speed of establishment, it may also result in increased nutrient losses in both the sediment and soluble forms. On the other hand, excessive applications could also increase losses.

Dense growth obtained by fertilizing can help reduce water contamination from N and P. The importance of accurately managing fertility for optimum environmental performance of turf is underscored. BC

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Cotton Response to Multiple Applications of Phosphorus Fertilizer

By W.M. Stewart, J.S. Reiter, and D.R. Krieg

Texas is the largest cotton-producing state in the U.S. Most of the state's cotton is produced on the High Plains. Water supply, growing season length, and nutrient supply are generally the most limiting factors in cotton production in this region. This study evaluated different methods of phosphorus (P) fertilizer application to cotton, and nitrogen (N) to P ratio in fertigation. Phosphorus fertilizer significantly increased yield. Multiple applications through fertigation was the most effective method of delivery. The companion fertigation study, where N:P_2O_5 ratio was investigated, showed that cotton response to P fertilizer is largely determined by water supply.

The Southern Great Plains of Texas is the largest contiguous cotton-producing region in the world, with about 3.8 million (M) acres planted each year. Approximately one-half of the area's total cotton acreage receives some supplemental irrigation. Cotton producers on the High Plains have made great strides in increasing yield in recent years. In fact, reports of yields in excess of 5 bales/A are no longer uncommon in irrigated production when water is adequate. Cotton production in this region hit record levels in 2004...preliminary estimates indicate that total production was about 4.88 M bales on 3.27 M harvested acres...an average of about 1.5 bales/A.

Water supply, growing season length, and nutrient supply are generally the most limiting factors in cotton production on the South Plains. In irrigated production supply is often considerably less than demand, hence deficit water management is routine. The use of LEPA (low energy precision application) rather than spray application of the irrigation water is common, reducing the evaporation losses of applied water. Growing season length is limited by heat unit accumulation rather than frost-free days since both spring and fall can be rather cool at night. The major yield factor left to the producer's control is crop nutrition.

Nutrient management can affect cotton yield determinates such as fruit retention and boll size, which in turn influences water use efficiency. Nitrogen requirements and application timing relative to water supply have been established for the region in previous work conducted at Texas Tech University. The development of efficient P fertilizer management strategies has not been advanced to the same degree as N strategies. A major concern with P fertilization is the potential for formation of sparingly soluble calcium phosphate reversion products in the alkaline and alkaline-

LEPA (low energy precision application) greatly reduces evaporation losses when irrigating cotton.

calcareous soils of the region. Multiple applications of a balanced nutrient blend in small amounts through the irrigation water during the time of peak crop use is a reasonable approach to increasing the use efficiency of water and nutrients, including P.

This study compared different methods of P fertilizer application (pre-plant banded, side-dressed, fertigation, and no P control) to cotton. In a companion study, the ratio of $N:P_2O_5$ in fertigation was investigated to determine the proper balance between these nutrients. The ratios were 5:0, 5:1, 5:2, and 5:3 (lb N:lb P_2O_5 per in. of total water).

The experiment was conducted over a 3-year period at the Crop Production Research Lab near Brownfield in Terry County. The soil is an Amarillo fine sandy loam with a pH of 7.7. The initial soil test P level at the site was high…27 parts per million (ppm), Olsen method. The center pivot irrigation system used in the study was equipped with LEPA application technology and nozzled to apply 2, 3, and 5 gallons per minute per acre (GPMA), which corresponds with 33%, 50%, and 90% potential evapotranspiration (PET) replacement, respectively. These water supplies are representative of the irrigation capabilities of the region. The irrigation frequency was on a 5-day schedule starting at first square and adjusted according to rainfall. Application method treatments and $N:P_2O_5$ fertigation ratio treatments were applied in blocks within each water supply. The N to water ratio was 10 lb N/in. of irrigation water. Pre-plant P was banded (3 to 6 in. deep and 8 in. from row) with a knife rig 4 weeks prior to planting. Side-dressed P was banded (3 to 6 in. deep and 8 in. from row) with the knife rig and split into three equal applications at pre-plant, first square, and first flower. Ammonium polyphosphate (10-34-0) was used in the side-dress and pre-plant treatments. The P rates used in the pre-plant and side-dress treatments were adjusted according to expected yield based on water supply. The ratio used was 10 lb P_2O_5 per 1 GPMA (2 GPMA=20 lb P_2O_5; 3 GPMA=30 lb P_2O_5; 5 GPMA=50 lb P_2O_5). Fertigation was started at first square and continued through peak bloom. Fertilizer sources used in fertigation blends included 10-34-0, urea-ammonium nitrate (32-0-0), and ammonium thiosulfate (12-0-0-26). Cotton development and boll distribution were monitored during the season by plant mapping at first flower, peak bloom, and at harvest. Yields were determined by hand harvesting samples and ginned in a plot gin. Lint samples were taken for fiber quality measurements at the International Textile Center in Lubbock.

Table 1. Planting dates, rainfall, and heat unit accumulation.

	1997	1998	1999
Planting date	May 19	May 12	June 15[1]
Rainfall, in.	8.5	5.4	6.3
Heat units[2], °F	2,121	2,811	1,871

[1] Replanted due to hail.

[2] Heat unit = [(daily maximum temperature + daily minimum temperature) ÷ 2] - 60

The weather throughout the 3-year study provided a range of conditions representative for the area. Heat unit accumulation, rainfall, and planting date varied considerably from year to year (**Table 1**). Total water applied in the irrigation treatments is shown in **Table 2**.

The application method comparison showed that fertigation is effective in supplying P to the cotton crop and increases lint yield (**Figure 1**). Fertigation allowed pulse feeding of a balanced nutrient blend in a moist soil region where a large percentage of plant roots are located and proved to be the most consistent method of increasing yield across the 3 years of the study. Banded pre-plant application of P

Table 2. Total water supply per irrigation treatment.

	1997			1998			1999		
GPMA	2	3	5	2	3	5	2	3	5
Irrigation, in.	3.2	4.7	7.6	6.2	8.9	14	3.1	4.7	7.7
Total, in.	12	13	16	12	14	19	9	11	14

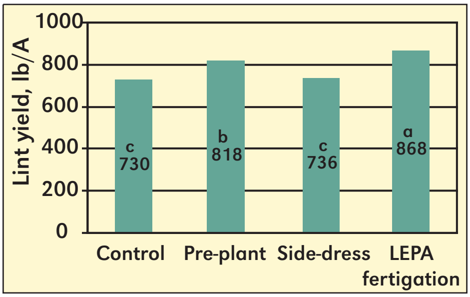

Figure 1. Effect of P fertilizer application method on irrigated cotton lint yield (3-year average across all water supplies).

produced more cotton than the control and side-dress method. Late season cultivation negated the benefits of multiple nutrient applications by side-dressing due to severe root pruning that interrupted water uptake at the critical flowering stage of development. Lint yield increase from P fertilization was due to an increased number of bolls and boll size. The increased boll size observed with P fertilization was a function of increased micronaire (**Figure 2**). In fact, P fertilization increased micronaire into the premium range, demonstrating the impact that nutrient management can have on crop quality.

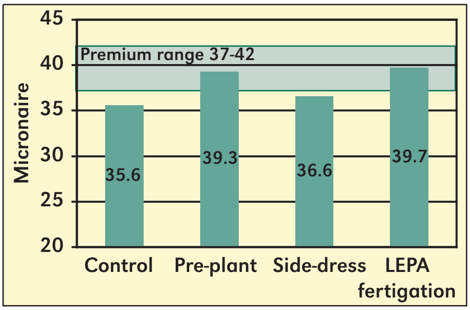

Figure 2. Effect of P fertilizer and delivery method on micronaire of irrigated cotton (3-year average). The horizontal green bar represents the premium range for micronaire (37 to 42).

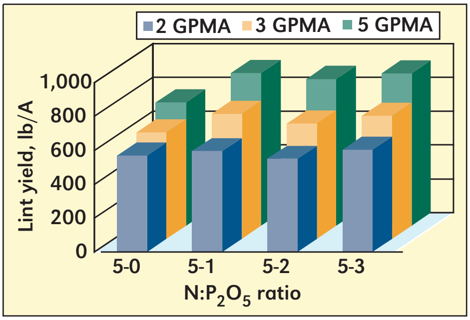

Figure 3. Effect of $N:P_2O_5$ ratio on irrigated cotton lint yield. All N and P were applied through fertigation (3-year average).

The companion fertigation study, where $N:P_2O_5$ ratio was investigated, showed that cotton response to P fertilizer is largely determined by water supply (**Figure 3**). The 2 GPMA water supply did not respond to added P since water was the most limiting factor. At the 3 and 5 GPMA water supply, lint yield responded to added P; however, the higher P rates did not significantly affect lint yield above the 5:1 ratio. The lack of a significant yield response to higher levels of P relative to N was consistent with boll number response. Increasing P did increase the boll size and micronaire, owing to more mature fibers in the bolls.

This 3-year project has shown that fertigation is an effective method of applying P to cotton. However, before attempting P fertigation, measures should be taken to ensure that the irrigation system and water are compatible with this practice. **Using fertigation to apply P fertilizer, where compatible with water quality, gives producers added flexibility in managing this important input.**

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International Section

INDIA

Most Profitable Sugarcane Production in Maharashtra

By D.B. Phonde, Y.S. Nerkar, N.A. Zende, R.V. Chavan, and K.N. Tiwari

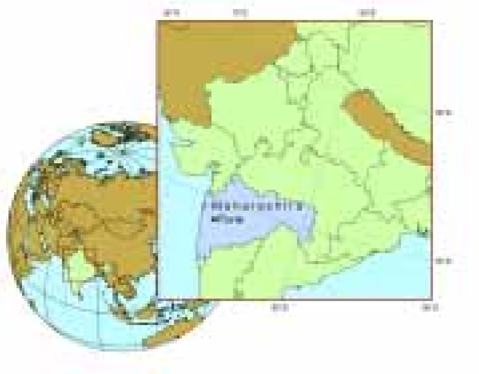
A comprehensive site-specific nutrient management (SSNM) strategy was by far the best option for plantations if compared to traditional farmer practice and available fertilizer recommendation systems.

The state of Maharashtra provides a clear example of a region which is falling considerably short of its sugar production potential. The region's climate is well-suited to sugarcane production. Its main limitations include a lack of emphasis on soil fertility through proper nutrient management.

Despite having higher fertilizer inputs than most of the surrounding states (excluding Andhra Pradesh), nutrient application rates can be considered low and imbalanced with total nitrogen (N), phosphorus (P), and potassium (K) consumption estimated at 88 kg/ha, consisting of an average application of 51-25-12 kg N-P_2O_5-K_2O/ha. Average sugarcane yields in Maharashtra hover around 90 t/ha. India's highest state-wise productivity of 108 t/ha occurs to the southeast in Andhra Pradesh, where average NPK consumption is higher at 80-33-16 kg/ha. Besides NPK deficiencies, emerging secondary and micronutrient deficiencies also provide significant constraints to high yields in Maharashtra. Little to no consideration is given to anything beyond the basic NPK needs of sugarcane and it is apparent that the potential of its production systems is largely being overlooked.

This study examined the available options for fertilizer recommendations (i.e., state fertilizer recommendation, state soil testing lab recommendation, typical farmer practice) and compared them with a SSNM strategy—a complete, soil analysis-based approach which fully considers all soil nutrient deficiencies and the corrective fertilization required to achieve a high yield goal.

A field experiment comprised of treatments outlined in **Table 1** was initiated in 2003 during suru season (January planting) at the Research and Demonstration Farm of Vasant Dada Sugar Institute, Pune. The test soil was described as a medium black clay. The initial soil analysis found low levels of available N, moderate P and K



The sugarcane research and education site is in Pune, Maharashtra.

levels, and deficiencies for sulfur (S), zinc (Zn), iron (Fe), and manganese (Mn). Besides cane yield data, sugar recovery and relative economic benefit were calculated.

Table 1. Treatments applied to sugarcane, Pune, India.

Treatment	N	P_2O_5	K_2O	S	Zn	Fe	Mn
no.	kg/ha				Sulfate salts, kg/ha		
State soil test	312	115	115				
State general	250	115	115				
Farmer practice	255	80	60				
T1	180	180	120	20	20	50	10
T2	180	120	120	20	20	50	10
T3	180	60	120	20	20	50	10
T4	180	0	120	20	20	50	10
T5	180	180	60	20	20	50	10
T6	180	180	0	20	20	50	10
T7	180	180	120	20	20	50	0
T8	180	180	120	20	20	0	10
T9	180	180	120	20	0	50	10
T10	180	180	120	0	20	50	10
T11	180	180	120	0	0	0	0

SSNM produced significantly higher yields compared to the generalized state recommendation, state lab soil test based recommendation, and farmer practice **(Figure 1)**. Cane yield was significantly influenced by both P and K (**Figure 2**). A yield of 150.6 t cane/ha was recorded with 180 kg P_2O_5/ha, but this was statistically equal to the 148.6 t/ha produced with 120 kg P_2O_5/ha. Yields produced with 0 and 60 kg P_2O_5/ha were 125 and 130 t/ha, respectively. The cane yield response to 0, 60, and 120 kg K_2O/ha appeared to be linear, suggesting that even greater productivity may be achieved under K application rates beyond 120 kg K_2O/ha.

Sulfur and micronutrients were an integral part of the SSNM package **(Figure 3)**. Cane yields were significantly higher with application of S, Zn, and Fe applications of 20, 20, and 50 kg/ha, respectively. The yield response to Mn applied at 10 kg/ha was not significant.

Juice quality indicators, including brix, pol, purity, and commercial cane sugar percentage (CSS%) were not significantly affected by any fertilizer application treatment (data not shown). However, as a result of the large cane yield increase due to SSNM, commercial cane sugar yield was highest at 18.9 t/ha, which greatly improved crop value.

Figure 4 illustrates the relative influence of individual nutrient omission on profitability. The highest benefit-to-cost ratio of 2.64 was provided

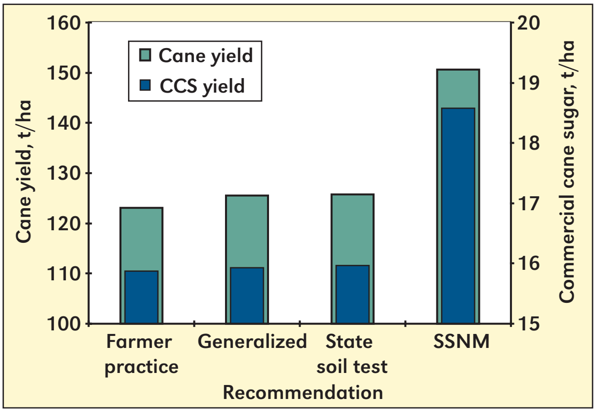


Figure 1. Effect of varying fertilizer recommendations on cane and sugar yield.

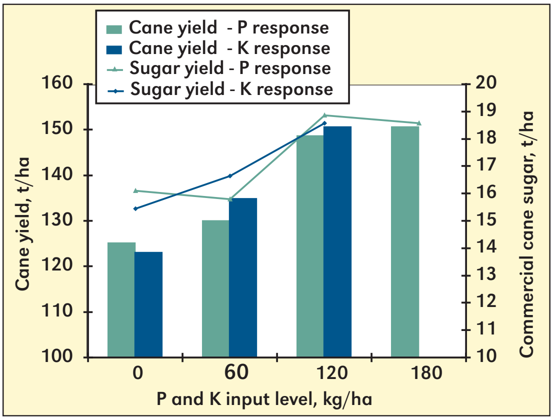


Figure 2. Effect of P and K levels on cane and sugar yield.

with SSNM. The accrued benefit was reduced by 18, 29, 19, 20, 27, and 6%, if P, K, S, Zn, Fe, or Mn was omitted from the complete SSNM treatment.

Conclusion

Opportunity for maximum economic yield and improved sugar recovery is ensured through application of the principles of SSNM. The range of economic nutrient responses revealed the importance of considering secondary and micronutrients along with NPK fertilization. The generalized state fertilizer recommendation and even state soil testing lab recommendations are providing sub-optimal solutions for farmers and continue to promote low profitability. BC

Mr. Phonde and Dr. Zende are Scientists, Mr. Nerkar is Director, and Mr. Chavan is Research Associate, all with Vasant Dada Sugar Institute in Pune. Dr. Tiwari is Director, PPI/PPIC-India Programme, Gurgaon, Haryana; e-mail: kntiwari@ppi-ppic.org.

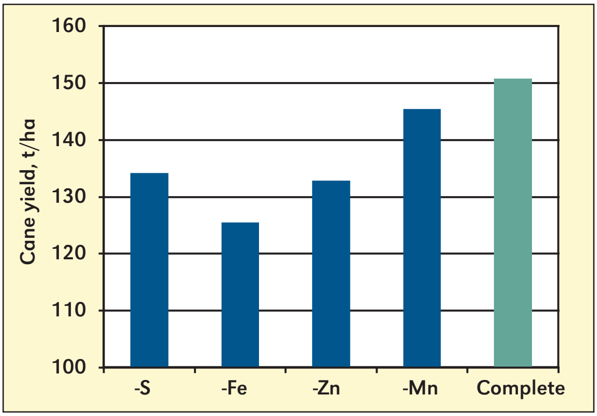


Figure 3. Effect of secondary and micronutrients on cane yield.

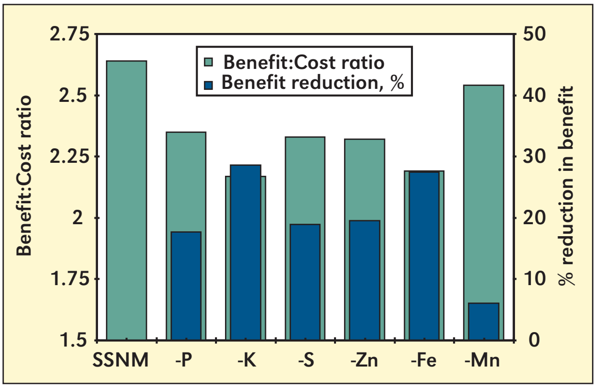


Figure 4. Cane yield profitability due to SSNM.

Correction for Table in *Better Crops* No. 2, 2005

In *Better Crops with Plant Food* Issue No. 2 of 2005 (Vol. 89), the unit indicated for free amino acids in Table 2 on page 26 was shown incorrectly. The table is part of the article titled *"Balanced Fertilization for Tea Production in Yunnan."* The unit was indicated as **percent (%)**, but should be expressed as **mg/g**. The table with the corrected unit appears below.

Table 2. Treatment effect on amino acid, protein, and water extractable compounds in tea leaf tissue, Yunnan.

	Amino acid, mg/g			Protein, %			Water extractable compounds, %		
Treatment	Menghai	Simao	Eshan	Menghai	Simao	Eshan	Menghai	Simao	Eshan
1. $NP_1K_0S_1Mg_1Mn_1$	16.03	18.35	18.20	25.74	28.45	27.16	52.99	55.75	54.51
2. $NP_1K_1S_1Mg_1Mn_1$	17.93	19.19	18.41	24.91	28.33	27.48	53.05	56.45	54.72
3. $NP_1K_2S_1Mg_1Mn_1$	18.24	19.24	18.85	26.63	28.57	28.13	53.25	56.32	55.20
4. $NP_1K_3S_1Mg_1Mn_1$	17.11	18.31	17.01	23.97	27.82	26.92	53.90	56.91	55.24
5. $NP_2K_2S_1Mg_1Mn_1$	18.78	19.56	18.77	24.90	28.39	27.16	55.04	56.74	57.13
6. $NP_1K_2S_0Mg_1Mn_0$	16.64	19.01	19.20	25.57	28.67	27.92	53.11	56.29	56.82
7. $NP_1K_2S_1Mg_0Mn_1$	17.81	18.20	17.86	26.24	28.48	26.95	53.06	55.88	55.03
8. $NP_1K_2S_1Mg_1Mn_1$	17.71	19.89	21.98	25.57	28.26	27.32	54.26	56.33	56.60

Selected fertilizers were urea, monoammonium phosphate, single superphosphate, KCl, K_2SO_4 (treatment 8), gypsum, magnesium chloride, magnesium sulfate, and manganese sulfate.
Note: Only the Simao site received Mn, and no S.

SOUTHWEST CHINA

Better Sugarcane Production for Acidic Red Soils

By Tan Hongwei, Zhou Liuqiang, Xie Rulin, and Huang Meifu

The region would benefit greatly by considering a fertilization strategy that extends beyond traditional practice.

Sugarcane plantings in the southern sub-tropical province of Guangxi have experienced rapid expansion. Recent estimates place the harvested area at well over 0.5 million (M) ha. This region is well suited for sugarcane production, particularly in the central parts of the province. However, low fertilizer input and poor fertilizer management have limited cane yields to only about 45 to 60 t/ha. Sugarcane yields in the region have the potential to reach 90 to 150 t/ha. This study determined balanced fertilization's contribution towards reaching high yield and quality goals.

Two field trials were situated within the sugarcane production base, one in the suburb of Nanning and one in Laibin County. Soils at the two sites were derived from quaternary red earth. At Laibin, the test soil was siliceous and silty, while in Nanning the soil is described as red. Six treatments (**Table 1**) were each applied to a 5.5 m by 4.0 m area. Plant nutrient sources included urea, diammonium phosphate, single superphosphate, potassium chloride (KCl), K-Mag™ ($K_2SO_4 \cdot 2MgSO_4$), calcium (Ca)-magnesium (Mg) phosphate, and Mg sulfate. Nitrogen (N) and potassium (K) were applied in four splits providing 5%, 15%, 25%, and 50% of the total treatment during the basal dressing, seeding, tillering, and cane elongation stages. The other fertilizers were applied basally. Guitang and Taitang crop cultivars were established at 5,000 seed-plants/ha. Sugarcane biomass was recorded at maturity along with percent fiber, sucrose, reducing sugars, and total sugar yield.

Study sites are indicated in the southern province of Guangxi.

Soil nutrient analysis found fertility to be relatively low in both soils (**Table 2**). The soil near Nanning was acidic and deficient in N, phosphorus (P), K, and Mg.

Soil analysis in Laibin found the site to be near neutral, and deficient in N, K, sulfur (S), and Mg. This soil test data was well supported by subsequent pot trials which used sorghum as the indicator plant (Portch and Hunter, 2002). The trials found the relative severity of deficiency for the two locations to be similar at: N > K > P > Mg > S (**Figure 1**).

Table 1. Nutrient application rates (kg/ha) used at Nanning and Laibin, Guangxi.

	N	P_2O_5	K_2O	Mg	S
NP	375	120	–	–	–
NPK	375	120	330	–	–
NPKMg	375	120	330	36	–
NPKMgS	375	120	330	36	60
NPK_2MgS	375	120	660	36	60
NPK_3MgS	375	120	990	36	60

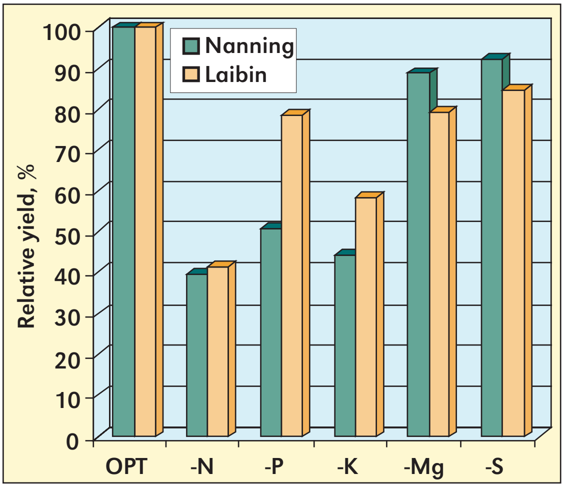


Figure 1. Relative yield of sorghum grown in pot trials using soils from two study sites.

The impact of balanced fertilization on plant growth was most evident during the fast-growing stage (July to August). Given adequate K, the inclusion of Mg and S allowed for higher plant growth at both locations, as illustrated by data from Laiban (**Figure 2**).

All aspects of cane quality, including single cane weight, cane length, and effective (harvestable) cane number, were positively affected by K, Mg, and S fertilization. But once again, adequate K appeared key to maximizing the response (**Table 3**). In Nanning, cane weight and length were equally as high under complete treatments using either the low (330 kg K_2O/ha) or intermediate (660 kg K_2O/ha) K rates. Effective cane number was significantly higher with the intermediate K rate. In Laiban, the advantage from applying the intermediate rate of K was perhaps even clearer. Given the N, P, Mg, and S rates tested, no advantage was found beyond 660 kg K_2O/ha.

The complete treatment supplying 660 kg K_2O/ha produced the highest cane yield at both sites (**Table 4**). An analysis of the incremental yield response to fertilizer reveals that K alone produced an additional 3.2 t/ha in Nanning and 6.9 t/ha in Laibin. Addition of Mg produced slightly more (0.7 t/ha) in Nanning, but was more significant (2.5 t/ha) in Laibin. The combination of Mg and S increased yield by 3.3 t/ha in Nanning and 5.0 t/ha in Laibin. Lastly, yields were maximized by raising the K rate to 660 kg K_2O/ha, which produced a total yield of 78.8 t/ha in Nanning and 99.9 t/ha in Laiban. Data from

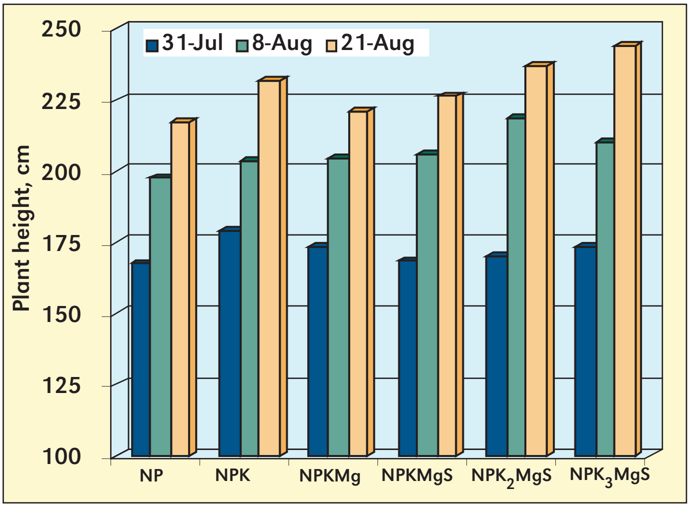


Figure 2. Plant heights measurements from late July to August, Liabin.

Table 2. Soil nutrient status at two sugarcane field sites, Guangxi.

			Available nutrient content, mg/kg					
	pH	O.M., %	N	P	K	S	B	Mg
Nanning	5.0	2.19	47.4	11.6	43.0	18.8	0.21	62.0
Laibin	6.8	1.58	13.7	14.5	70.4	8.0	0.24	100.5

Table 3. Size and numbers of harvestable canes, Guangxi.

	wt/cane, g		Cane diameter, mm		Effective canes/ha	
	Nanning	Laibin	Nanning	Laibin	Nanning	Laibin
NP	1,009	1,770	23.6	26.3	61,800	40,695
NPK	1,102	1,810	24.2	27.3	61,995	43,500
NPKMg	1,206	1,837	24.9	27.6	60,240	44,745
NPKMgS	1,260	1,850	24.9	27.8	58,320	43,245
NPK$_2$MgS	1,261	1,910	24.9	28.0	63,705	46,275
NPK$_3$MgS	1,243	1,815	25.1	27.9	59,145	44,250

Table 4. Sugarcane yield and yield increases, Guangxi.

	Nanning		Laibin	
	Yield, t/ha (2-year average)	Yield increase, %	Yield, t/ha (2-year average)	Yield increase, %
NP	66.1	-	80.7	-
NPK	69.3	4.8*	87.6	8.6*
NPKMg	70.0	5.9*	90.1	11.6**
NPKMgS	72.6	9.8**	92.6	14.7**
NPK_2MgS	78.8	19.2**	99.9	23.8**
NPK_3MgS	73.0	10.4**	91.4	13.3**

*, ** Means significantly differ at p=0.05 and p=0.01, respectively.

Table 5. Sugarcane crop quality traits, Laibin.

	Sucrose, %	Fiber, %	Reducing sugars, %	Sugar yield, t/ha
NP	13.60	11.26	2.38	10.97
NPK	14.88	11.54	2.44	13.04
NPKMg	14.95	11.56	1.71	13.47
NPKMgS	14.41	11.46	2.16	13.34
NPK_2MgS	13.86	11.57	2.14	13.85
NPK_3MgS	15.30	11.42	2.26	13.99

Laiban indicate that K had the largest influence on cane sucrose, fiber, and reducing sugar contents (**Table 5**). The effect of Mg and/or S fertilization was more subtle. Although their inclusion did not enhance product quality traits, Mg and S influence on plant growth and yield did result in improved commercial sugar yields. Sucrose content was maximized under the complete treatment using the highest K rate. Ultimately, this treatment produced the highest sugar yield, near 14 t/ha.

There was a steady improvement in net income despite the higher fertilizer costs due to K, Mg, and S input (**Figure 3**). Two years of data from both sites indicate that the complete treatment with 660 kg K_2O/ha is the most profitable. Net income was increased by US$256/ha, or 15%, in Nanning and US$456/ha, or 21%, in Laibin. Any further increase in K application was not justified at these sites due to the combined effect of lower yields and higher input cost.

Fields in southern China respond to significantly higher K application rates for sugarcane. **This research strongly suggests that adequate K in combination with Mg and S improved crop yield, harvestable sugar, and…most importantly…farmer profit margins.**

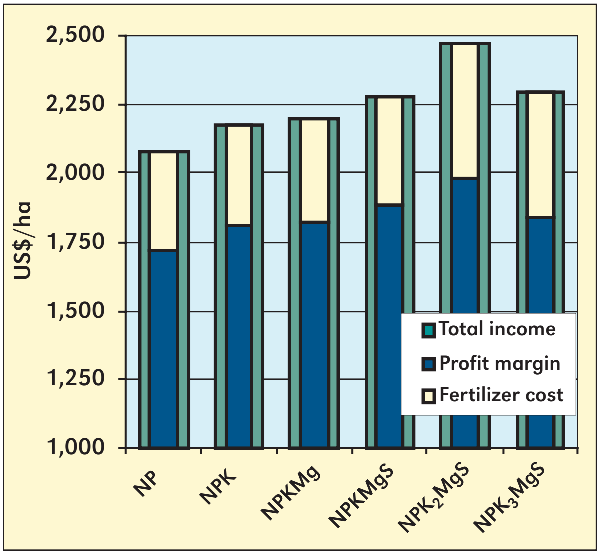


Figure 3. Profit margin comparison (average of 2 years and sites), Guangxi.

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Key Principles of Crop and Nutrient Management in Oil Palm

By C. Witt, T.H. Fairhurst, and W. Griffiths

There are substantial opportunities for the oil palm industry to increase productivity on planted land, considering the scarcity of suitable land for further expansion in Southeast Asia. We propose a framework for an ecological intensification of oil palm production, summarizing key crop and nutrient management principles.

Driven by an increasing demand for oil palm products, crude palm and kernel oil production in Malaysia, Indonesia, and Thailand increased by 92% from 12.5 million metric tons (M t) in 1993 to 24.0 M t in 2002 (FAOSTAT). Production increases were largely caused by an expansion in the area under harvest in Malaysia and Indonesia, while crude palm oil yields have stagnated in the two countries in the last 20 years (**Figure 1**).

Major environmental challenges in further increasing palm oil production in Southeast Asia include limitations in area expansion and an increasing scrutiny by the public demanding ecological palm oil production. Future productivity increases must be achieved from crop management intensification on land already under oil palm because area expansion is now only possible in less favorable environments, both in terms of resource quality and infrastructure.

Changes in palm oil demand, environment, and socio-economic conditions are expected to drive changes in the management of oil palm estates in Southeast Asia. The rapid development of oil palm production in the region has revealed a shortage of qualified management staff, an apparent scarcity of labor due to alternative employment opportunities and associated increases in labor cost, and the requirement for

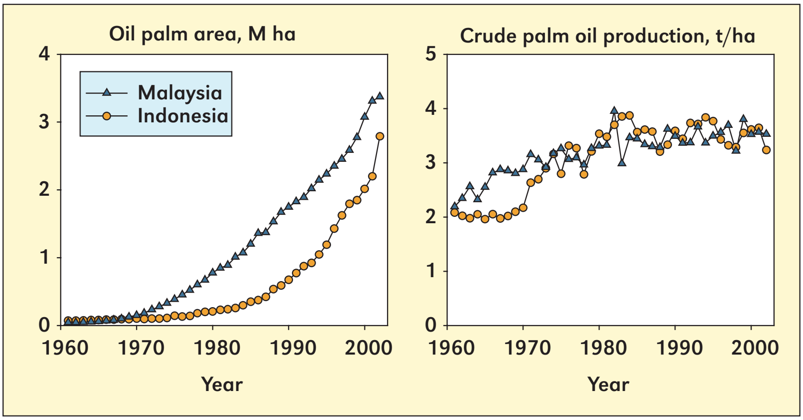


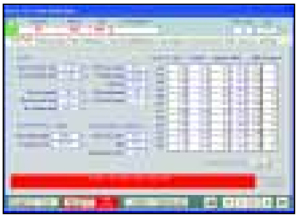
Figure 1. Oil palm area and production of crude palm oil in Malaysia and Indonesia in 1960-2002. Data source: FAO (www.fao.org).

regional migration of labor. To maintain regional productivity advantages in palm oil production compared to the global production of other vegetable oils, sizes of cooperatives or estates are likely to increase while a smaller, more knowledgeable work force will need to employ more advanced technologies.

Oil palm growers and researchers have made substantial progress in recent years to develop standardized, optimal crop and nutrient management practices that promise high productivity and profitability through efficient and effective use of inputs and resources. These practices and associated readily available, more 'knowledge-intensive' technologies have recently been summarized into five major crop and nutrient management principles (Witt et al., 2005).

Principle 1:

Decision making based on relevant information.



The key to optimal resource management is to understand the spatial and temporal variability of factors that influence production. The contribution of factors to productivity needs to be quantified and analyzed in time and space to identify the variability in fruit bunch production that can be managed. The proposed framework for an ecological intensification therefore aims to guide decision makers in their identification of key constraints to increasing productivity through quantification of relevant production indices and consequent analysis of gathered data. Thus the Agronomic Management Information System (AMIS) is used to devise strategies than can evolve as constraints to productivity increases are removed. AMIS requires tools for data collection, an adequate database management system, integrated analytical procedures, and mapping facilities to analyze data over time and space. Outputs include reports, maps, tools, and guidelines for a step-wise implementation of strategies for productivity enhancement based on need or capacity. Complete documentation is further required to obtain the international certification for ISO 9001 and 14001 for Quality and Environmental Management Systems.

Principle 2:

Development of management units based on soil and plant surveys.

It is a standard practice in oil palm plantation management to extrapolate estimates of relevant plant and soil parameters measured below the block scale to larger areas or management units. Sampling requirements for estimating the values of relevant parameters depend on the homogeneity of the management unit of interest and have been well established, for example, for leaf sampling units (Foster, 2003). The first step in the development of management units is a proper land and soil survey providing information on the expected site-specific yield potential affected by the soil resource base, the occurrence and extent of soil problems, and the likely cost of corrective measures. A detailed summary of a land evaluation classification system for oil palm providing the criteria and class limits for land and soil is provided by Paramananthan (2003). Boundaries of management units for fertilizer application would need to be defined based on a minimum set of available biophysical characteristics that determine uniformity of yield potential, yield stability, indigenous nutrient supply, soil constraints, leaf nutrient status and deficiency symptoms, and an expected response to fertilizer within the management unit. We propose to use soil maps (e.g., soil texture), topography, watershed, block boundaries, (long-term) yield statistics, palm age, drainage, and other existing and readily available information as a starting point for the delineation of management units.

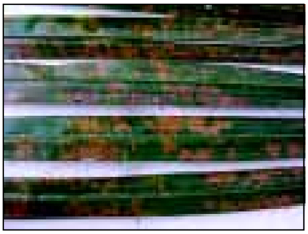
Principle 3:

Best management practices for optimal economic yield.

A limited number of blocks with best management practices (BMPs) strategically placed in a plantation provide a useful tool to: i) determine site-specific attainable yield under optimal management conditions (Griffiths et al., 2002), ii) estimate peak crop production (% annual crop in a single month) for planning mill capacity requirements, iii) demonstrate the effect of management practices on crop performance and soil improvement, iv) train staff on the implementation of new practices, and v) test new technologies. Under BMP conditions, yield is only limited by climate, planting material, and site-specific natural resources such as soil texture, rooting depth, or water. Priorities need to be identified based on a proper inventory of planting conditions, and management practices are rated according to the greatest impact expected. Changing a limited number of management practices in BMP blocks allows a quantitative analysis of the interaction of different management factors on yield. Yield gaps between BMP and surrounding blocks can be directly linked to differences in crop recovery, canopy and nutrient management, drainage, and other BMPs. The BMP blocks serve both as benchmark and demonstration for training and required standards of field upkeep and maintenance in line with standards described in the oil palm publications by the Southeast Asia Program (SEAP) of PPI/PPIC-IPI >website: www.seap.sg<.

Principle 4:

Plant-based determination of nutrient needs.



Nutrient deficiencies and associated nutrient needs of oil palms are largely based on an evaluation of the current nutritional status from plant tissue analysis. Such fertilizer systems ...including the choice of tissue for sampling, leaf sampling units, palms for sampling, and time of sampling...have been described in great detail elsewhere (Foster, 2003; Fairhurst et al., 2005). Foster (2003) provides an extensive review of the interpretation of leaf analysis results including the problem of variation in optimum leaf nutrient levels, the prediction of optimum leaf nutrient levels, the relationship of total leaf cations and palm age, and the prediction of yield response from leaf nutrient analysis results.

We propose to integrate the examination of foliar tissue analysis with other plant based indicators of nutrient deficiencies over time and space such as leaf deficiency symptoms, yield, vegetative growth, and ground vegetation. Such opportunities arise only when relevant data have been carefully stored in an adequate database management system with associated analytical tools (e.g., OMP 8, www.agrisoft-systems.de) providing the decisionmaker with rapid overviews of likely nutrient deficiencies.

Principle 5:

'Need-based' fertilizer use for effective use of nutrients.

The key objective in 'need-based' fertilizer management is the effective use of nutrients. That requires both preventive and corrective measures to manage nutrients efficiently, sustain the soil resource base, and increase the profitability of palm oil production. Much progress has been made in recent years to develop site-specific solutions as compared to blanket fertilizer applications (Goh et al., 2003). Research has largely focused on improving the foliar diagnosis of oil palm, which has become the most widely used strategy to detect and overcome nutrient deficiencies. For specific-site conditions, reliable predictions of nutrient needs can be made because yield responses to individual fertilizers are highly correlated with nutrient levels, except for boron (B). Generic concepts have been devised for the interpretation of leaf analysis results, particularly in identifying optimal leaf nutrient levels and yield responses from leaf analysis considering the interaction of nutrients. Fertilizer recommendations are then developed based on foliar diagnosis supported by multi-factorial fertilizer trials. The major purpose of multi-factorial fertilizer response trials is to obtain estimates of yield responses to nutrients, to observe changes in leaf nutrient status, to estimate recovery efficiencies of applied fertilizer nutrients, and to evaluate the nutrient interaction when more than one nutrient is included in the trial. While multi-factorial fertilizer trials will be required to obtain more detailed information on nutrient interactions and nutrient use efficiencies, smaller estates might seek alternative approaches to fine-tune fertilizer nutrient recommendations. There is clearly a need to explore new site-specific concepts to optimize fertilizer nutrient use considering yield gap analysis, benchmark yields in BMP blocks with embedded nutrient omission plots to determine nutrient limited yield, and estimates of agronomic efficiency (yield increase per unit fertilizer nutrient applied).

Oil Palm Platform

The principles of crop and nutrient management along with evolving strategies for their implementation are promoted through the Oil Palm Platform (www.oil-palm.info). The platform builds on efforts of individual oil palm agronomists and technical experts from various companies and organizations interested in the integration of information, tools, and technologies. Members share a common vision that oil palm estates need to be economically feasible as well as socially and environmentally responsible to become part of a sustainable future of the oil palm industry. The ecological intensification of crop and nutrient management offers substantial opportunities to achieve this goal.

The PPI/PPIC-IPI Southeast Asia Program (SEAP) continues its long tradition of supporting planters through research, training, technology development, and publications in partnership with leading institutions and companies. The Oil Palm Platform provides an opportunity to further strengthen our efforts in directly collaborating with estates in the evaluation, adaptation, and improvement of technologies promoted by the Oil Palm Platform.

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A SCIENCE-BASED INDUSTRY

We often state with pride that the fertilizer industry is science-based. At PPI, we strive to contribute to the reality of that statement. But what does it really mean to be "science-based"? Prior to the 17th century, the primary tools of science were logic and what was perceived as rational thinking. Scientific progress was made through academic debate by scientists with truth being defined by the winning debate.

However, in the early 1600s Sir Francis Bacon, an English philosopher, contributed greatly to the development of the scientific method as we know it today. He insisted that new ideas be tested by experimentation due to psychological barriers that interfere with logic and rational thinking. He identified four types of barriers and referred to them as "idols."

In Bacon's system, *idols of the cave* involve biases deeply engrained in each of us due to our unique pasts that distort how we process facts. An agronomic example might be what we call our "fertilizer recommendation philosophy." Some subscribe to a sufficiency philosophy while others to a corrective-maintenance philosophy and still others to something in between. Which philosophy an individual follows can have a huge impact on fertilizer rates recommended, even when basing the recommendation on the same crop response data. The philosophy we follow is largely determined by our personal pasts … the "cave" in which we professionally grew up.

***Idols of the tribe* are not unique to individuals but are common to all of us, the entire tribe.** They are "foibles of human thought" that limit our knowledge. When the phrase "everyone knows that …" is used, a good potential exists for a tribe idol. Several years ago when we were publishing on field crop response to chloride (Cl) fertilization in scientific journals, reviewers would not allow us to refer to Cl deficiency because "everyone knew that Cl deficiency does not occur in the field." The entire "tribe" agreed even though multiple studies of the time were showing that deficiency did occur in the field.

So, whether scientist, crop adviser, or captain of industry, we are all susceptible to Bacon's idols. If we are truly a science-based industry, we will test provocative new ideas with experimentation rather than squelch them with the idol-infested blanket of the status quo.

Paul Fixen

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Senior Vice President and Research Director, PPI

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