BETTER CROPS
WITH PLANT FOOD

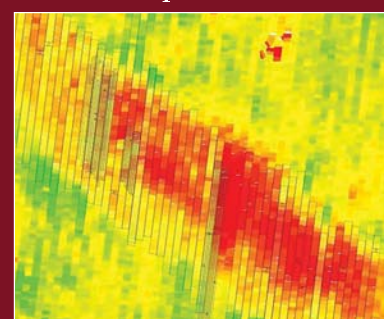
A Publication of the International Plant Nutrition Institute (IPNI)

2013 Number 4

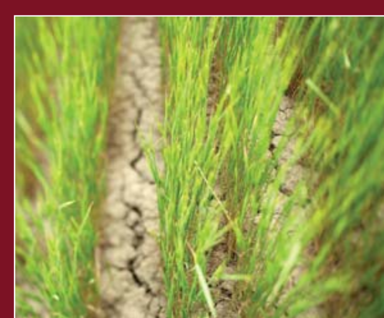
In This Issue...

Using Adapt-N to Improve N Use in Corn

The Case for On-Farm Experimentation



Improving Sensor-Based N Rec's with Local Data



Also:

Silicon: A Beneficial Substance

Our New Crop of IPNI Scholars

...and much more

IPNI

www.ipni.net

BETTER CROPS WITH PLANT FOOD

Vol. XCVII (97) 2013, No. 4

Our cover: Wheat harvest on the Great Plains.
Photo by: Steve McSweeny, iStockphoto.

BETTER CROPS WITH PLANT FOOD (ISSN:0006-0089) is published quarterly by the International Plant Nutrition Institute (IPNI). Periodicals postage paid at Norcross, GA, and at additional mailing offices (USPS 012-713). Subscriptions free on request to qualified individuals; others $8.00 per year or $2.00 per issue. Address changes may be e-mailed to: whollifield@ipni.net

POSTMASTER: Send address changes to *Better Crops with Plant Food*, 3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844. Phone (770) 447-0335; fax (770) 448-0439. Website: www.ipni.net.

Better Crops with Plant Food is registered in Canada Post. Publications mail agreement No. 40035026
Return undeliverable Canadian addresses to:
PO Box 2600
Mississauga ON L4T 0A9 Canada

The Government of Saskatchewan helps make this publication possible through its resource tax funding. We thank them for their support of this important educational project.

C O N T E N T S

Note to Readers: Articles which appear in this issue of *Better Crops with Plant Food* can be found at: >**www.ipni.net/bettercrops**<

2013 IPNI Scholar Award Recipients Announced

The winners of the 2013 Scholar Awards sponsored by the International Plant Nutrition Institute (IPNI) have been selected. The awards of US$2,000 are available to graduate students in sciences relevant to plant nutrition and management of crop nutrients.

"We had a higher number of applicants for the Scholar Awards this year, and from a wider array of universities and fields of study," said Dr. Terry L. Roberts, IPNI President. "And the qualifications of these students are impressive. The academic institutions these young people represent and their advisers and professors can be proud of their accomplishments. The selection committee adheres to rigorous guidelines in considering important aspects of each applicant's academic achievements."

The following 26 graduate students (listed by region) were named to receive the IPNI Scholar Award in 2013.

AUSTRALIA & NEW ZEALAND

Daniela M. Grijalva

Ms. Daniela Montalvo Grijalva is working toward her Ph.D. degree in Soil Science at The University of Adelaide-Waite Campus in Adelaide, Australia. Her dissertation title is "Improving phosphorus fertilizer efficiency in acid strongly phosphorus-sorbing soils." One part of her research focuses on investigating different P fertilizer types (granular versus fluid) in enhancing P availability in strongly P-sorbing soils. The other part of her research aims at investigating the role of colloidal P from soil solutions on plant P uptake. For the future, Ms. Montalvo Grijalva plans to continue her research and education in fertilizer technology and plant nutrition.

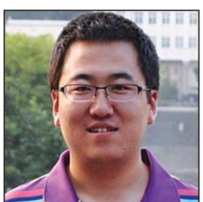
CHINA

Wang Min

Ms. Wang Min is pursing her Ph.D. in Plant Nutrition at Nanjing Agricultural University in Nanjing, China. Her dissertation is titled "Pathogenic mechanisms of soil-borne disease of cucumber fusarium wilt and the relationships with nitrogen nutrition." The research aims to illustrate the pathogenic mechanism of cucumber fusarium wilt and how to effectively control the soil-borne disease by nutrient regulation. For the future, Ms. Wang plans to become an agricultural scientist and help prevent crop disease and improve crop yields.

Xu Xinpeng

Mr. Xu Xinpeng is working toward his Ph.D. degree at Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences in Beijing, China. His dissertation is titled "Methodology of fertilizer recommendation based on yield response and agronomic efficiency for rice," which aims to use Nutrient Expert® for Rice to make field-specific nutrient recommendations. Mr. Xu is quite interested in becoming an agricultural scientist in the future.

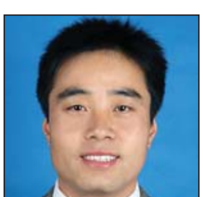


Wang Yin

Mr. Wang Yin is working toward a combined M.S.-Ph.D. degree in Plant Nutrition in the College of Resources and Environment at Huazhong Agricultural University, Wuhan, Hubei, China. His dissertation title is "Different responses of growth, yield and nutrient uptake to nitrogen, phosphorus, potassium fertilizer between direct-sowing and transplanting winter oilseed rape." His objectives are to evaluate the effect of N, P and K fertilizers on crop performance of direct-sowed and transplanted oilseed rape and determine whether the crop nutrient management strategy needs to be changed according to the various establishment methods. Mr. Wang's goal is to become an agricultural researcher and promoter in a university or a research institute to engage in agricultural research work and promote scientific techniques to improve crop yield and quality.

Lu Yuzhen

Mr. Lu Yuzhen has started his M.Sc. degree in Plant Nutrition at Institute of Soil Science, Chinese Academy of Sciences in Nanjing, China. His research work is focused on compositional characterization of rapeseeds by Fourier transform infrared photoacoustic spectroscopy (FTIR-PAS). The research aims to analyze some important quality indicators including N, P, K, Mg, oil content, fatty acid composition, and chlorophyll content in rapeseed, and better understand the compositional variation between seed kernel and seed coat, readily estimate the thickness of seed coat, and further optimize quantitative prediction models. Mr. Lu plans to earn his doctorate in Canada or the USA, and then serve in an agricultural research institute.



Zhao ZuoPing

Mr. Zhao ZuoPing is working toward his doctorate degree in Environmental Sciences at Northwest A&F University in Yangling, China. His dissertation is titled "Coupling effects of water and fertilizer on yield and quality of fuji apple and kiwi fruit." The main objectives of this research are to assess the variation in soil fertility, evaluate fertilizer use efficiency in apple and kiwifruit orchards, establish predictors and classification systems of indigenous soil nutrient supply capacity, develop appropriate fertilizer recommendation methods, and estimate optimum fertilizer application rates for apple and kiwi fruit over large domains. Mr. Zhao intends to continue research and extension efforts to improve crop yields and farmer profits.

Abbreviations and Notes: N = nitrogen; P = phosphorus; K = potassium, Mg = magnesium.

EASTERN EUROPE AND CENTRAL ASIA

Elena Ustimenko

Ms. Elena Ustimenko completed her M.Sc. degree in Agronomy in 2011 at Stavropol State Agrarian University (SSAU) in Stavropol, Russia. She started the Ph.D. program and began to work as an Assistant in the Department of Agricultural Chemistry and Plant Physiology, SSAU, in the same year. The title of her Ph.D. dissertation is "Programming of winter wheat yields in the moderate precipitation zone based on optimization of mineral fertilizer use." Several regional approaches to nutrient rate calculation and their impact on yield and quality of winter wheat are being compared in this research. For the future, Ms. Ustimenko's goal is to continue her plant nutrition-related research and extension activities.

LATIN AMERICA

Facundo Tabbita

Mr. Facundo Tabbita is pursuing his doctorate degree at University of Buenos Aires in Buenos Aires, Argentina. He has also participated in an international exchange program at the University of California-Davis, USA. His doctoral dissertation is titled "Regulation through the gene Gpc-B1 on the nutrient recycling and senescence in wheat," which aims to understand the translocation of nutrient and micronutrients to grain in wheat plants. The main objective of this research is to develop new strategies and tools to apply in wheat breeding quality programs and improve nutrition for the benefit of people. Mr. Tabbita aims to become a wheat breeder in the future.

Javier Coitiño López

Mr. Javier Coitiño López is working toward his master's degree in Agronomy at The University of the Republic in Paysandú, Uruguay. His thesis is titled: "Spatial variability of soybean response to potassium fertilization." The study will investigate how many variables are spatially distributed in the production environment characteristic of Uruguay, and how this spatial distribution can affect responses to K fertilization within a farm. For the future, Mr. Coitiño López wishes to pursue the ultimate goal of becoming an agricultural research scientist.

Esteban Abbona

Mr. Esteban Abbona is pursuing his doctorate degree at The University of La Plata in Buenos Aires province, Argentina. His research is examining the balances and fluxes of nutrients in the province of Buenos Aires from production systems through consumption in urban centers and final disposal. Because the development of sustainable agriculture needs to ensure nutrients for future generations, this research aims to provide guidance for policy decisions by evaluating the current nutrient fluxes and balances. Mr. Abbona's goals are to complete his doctoral studies, continue his teaching and scientific pursuits to help build future professionals on sustainable agriculture, and to work on the regional analysis of soil resource conservation through modeling.

Amanda Silva Parra

Ms. Amanda Silva Parra is completing requirements for her doctorate degree in Agronomy at the University Estadual Paulista-UNESP "Julio de Mezquita Filho" in Jaboticabal, Brazil. Her dissertation title is "Balance of greenhouse gases (GHGs) in the conversion of conventional agricultural and livestock systems for agrosilvopastoral systems in the Andean region of Colombia." Her study will first evaluate current emissions of methane, nitrous oxide, and carbon dioxide as affected by grazing management, fertilizer use, and other agricultural practices in conventional agricultural and livestock production system in the Andean region of Nariño, Southern Colombia. She will then compare the changes in emissions with alternatives such as agroforestry systems. Ms. Parra wishes to continue her research efforts on climate change in the future.

NORTH AMERICA

Charles Barrett

Mr. Charles Barrett is working toward his doctorate degree in horticultural sciences at University of Florida in Gainesville, USA. His research work is focused on the development of a plasticulture cabbage production system for improvement of best management practices (BMPs), environmental stewardship, and sustainability in Florida. The project will focus on designing and validating the plasticulture system to increase cabbage plant density; determining irrigation and N fertilizer requirements and application timing strategies; and adaptation and economic evaluation of the plasticulture system under commercial conditions compared to traditional seepage irrigated cabbage. Mr. Barrett's goals are to work in extension and to apply innovative agricultural production strategies in developing countries where food and fiber needs are not adequately met.

Péter Kovács

Mr. Péter Kovács is pursuing his doctorate degree in Agronomy at Purdue University in West Lafayette, USA. His research focuses on shallow pre-plant anhydrous ammonia application direction effects on grain yield, N uptake, and plant-to-plant uniformity in both no-till and conventional tillage systems. His work also examines the effect of ammonia application timing and the associated horizontal placement on maize yield, N recovery efficiency and N use efficiency. Mr. Kovács received his M.Sc. degrees in Agricultural Engineering and Geographical Information Management at Szent István University (Hungary) and at Cranfield University (United Kingdom), respectively. In the future, he intends to take part in either further improving the technological side of precision farming tools and input delivery systems, or in assisting in the widespread utilization of these tools through collaboration with growers or academic university personnel.

NORTH AMERICA (continued)


Tai McClellan Maaz

Mrs. Tai McClellan Maaz is enrolled in a doctorate degree program in crop and soil sciences at Washington State University in Pullman, USA. Her thesis dissertation is "Residue decomposition and nitrogen cycling in a canola-pea-wheat cropping sequence within two agro-ecological zones of eastern Washington." The research will identify the "right rate" of N required to attain economically optimum canola yields; determine overall N use efficiency for the cropping sequence; calculate N balances and analyze the interactive effects of crop species and N fertility on N balance, N mineralization and N cycling; identify properties driving residue decomposition patterns and net N mineralization/immobilization dynamics; and identify policies and economic tools that encourage the adoption of alternative crops. Mrs. Maaz desires to either work at an independent or academic institute or earn a second masters in economics, information systems, or graphic design.


Curtis Ransom

Mr. Curtis Ransom is working toward his M.S. degree in Environmental Science at Brigham Young University in Provo, Utah, USA. His research is focused on evaluating N use efficiency and environmental impacts of polymer-coated urea fertilizers in Kentucky Bluegrass. The primary goal of this research work is to determine the right time and rate of application of polymer-coated urea fertilizers to maximize plant N use efficiency. Mr. Ransom's future goal is to work internationally helping alleviate human nutritional and hunger problems.


Jay Raymond

Mr. Jay Raymond is pursuing his Ph.D. degree in Natural Resources and Environment majoring in Forestry at Virginia Polytechnic Institute & State University in Blacksburg, USA. His dissertation is titled "The use of stable isotopes to trace the fate of applied nitrogen in forest plantations to evaluate fertilizer efficiency and ecosystem impacts." His research work focuses on gaining a better understanding of the dynamics of applied N fertilizer through loblolly pine plantations to provide forest managers an improved knowledge on nutrient stewardship in these systems. Mr. Raymond's career goals and objectives include research emphasizing the importance of soil nutrition in relation to the productivity of forest agro-ecosystems.

NORTH AFRICA

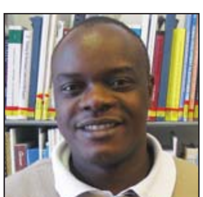

Mouna Labaied Bendaly

Ms. Mouna Labaied Bendaly is working toward her doctorate degree at National Agronomic Institute of Tunisia in Menzeh, Tunisia. Her research work is focused on evaluating the agronomic effectiveness of direct application of Gafsa phosphate rock as compared to commonly available soluble P fertilizers on yield and quality of citrus fruits. Ms. Bendaly wishes to pursue a career in soils and plant sciences.


Saâdia Batali

Ms. Saâdia Batali started her Masters degree in Agronomy at Hassan II Institute of Agronomy and Veterinary Medicine in Rabat, Morocco. Her research work is focused on evaluating the reliability and precision of soil tests and fertilizer recommendations given by different soil testing laboratories in Morocco. Ms. Batali's career goal is to become a specialist in soil and water management.

SUB-SAHARAN AFRICA


Amos Robert Ngwira

Mr. Amos Robert Ngwira is pursing his Ph.D. in Development Studies majoring in Agronomy at the Norwegian University of Life Sciences in Ås, Norway. His dissertation is titled "Agronomic, soil fertility and economic potentials of introducing conservation agriculture among smallholder farmers in Malawi." The research aims to evaluate conservation agriculture practices under smallholder farming conditions in halting soil fertility decline, increasing and/or stabilizing yields, and, thereby, reducing farmers' economic risk. Mr. Ngwira plans to teach graduate level courses and design integrated nutrient management strategies for higher yields, greater farmer profits, and better nutrient use efficiency.


Idowu Atoloye

Mr. Idowu Atoloye is working toward his Master's degree at Obafemi Awolowo University in Ile-Ife, Nigeria. His thesis is titled "Effect of application of compost and inorganic nitrogen on microbial activities, nitrogen and phosphorus mineralization in an alfisol," which aims to provide better understanding on the effects of blending compost with inorganic N on microbial activities and release of N and P for plant uptake. Mr. Atoloye wishes to be a professor of soil science with a focus on increasing food production in Africa without adversely impacting the soil ecosystem.

SUB-SAHARAN AFRICA (continued)

Tariro Gwandu

Ms. Tariro Gwandu is working towards her M.Phil degree at the University of Zimbabwe in Harare, Zimbabwe. Her dissertation title is "Translating integrated soil fertility management knowledge into crop productivity benefits through farmer learning and participatory action in Eastern Zimbabwe." The major objective of this study is to evaluate the effectiveness of participatory information management and smallholder farmer learning alliances in promoting farmer use of integrated soil fertility management technologies to increase crop productivity. In the future, Ms. Gwandu's goal is to become a distinguished extension specialist empowering farmers in using integrated soil fertility management for improved food security.

SOUTH ASIA

Anjani Kumar

Mr. Anjani Kumar is pursuing his Ph.D. in Agricultural System Management at Indian Institute of Technology in Kharagpur, India. The focus of his research is on nutrient and water management in aerobic rice systems, where he is evaluating nutrient management strategies and estimating the critical soil moisture potentials at the rice root zone depth for scheduling irrigation to sustain higher crop and water productivity. In the future, Mr. Kumar wants to pursue his research interests in crop modeling.

Mahesh Rajendran

Mr. Mahesh Rajendran is working toward his Ph.D. Agronomy degree at Tamil Nadu Agricultural University in Coimbatore, India. His research dissertation is titled "Best management practices to improve fertilizer and water use efficiency in sugarcane under subsurface drip fertigation system." The research aims to provide a list of best management practices based on 4R Nutrient Stewardship to enhance sugarcane productivity and achieve higher nutrient- and water-use efficiencies. Mr. Mahesh aims to join a postdoctoral fellowship program to hone his skills in soil fertility and plant nutrition further with the goal of becoming a distinguished agricultural scientist.

Sonalika Sahoo

Ms. Sonalika Sahoo is working toward a doctorate degree in Soil Science and Agricultural Chemistry at Indian Agricultural Research Institute in New Delhi, India. Her dissertation is titled "Effect of nanoclay polymer composites loaded with urea and nitrification inhibitor on nitrogen use efficiency, nitrogen dynamics and soil properties." The main objective of her study is to identify new slow release fertilizer products that will decrease nutrient losses and increase nutrient use efficiency to support the increasing food demand without deteriorating environment and ecosystem. For the future, Ms. Sahoo hopes to establish a career in agricultural research.

Naveen Gupta

Mr. Naveen Gupta is presently pursuing his doctorate program in Charles Sturt University, Australia on "Tillage and mulch effects on water balance and crop productivity of rice-wheat cropping system in northwest India." He has also worked on nutrient management in rice and wheat grown with resource conservation technologies in Indo-Gangetic plains of India. He aims to become a Research Scientist in an international organization of repute in the near future and work on nutrient and water interactions in cereal crops especially under changing climatic scenarios.

SOUTHEAST ASIA

Alagie Bah

Mr. Alagie Bah is working toward his Ph.D. at Universiti Putra Malaysia in Serdang, Malaysia. His research dissertation is titled "Improved and efficient oil palm fertilization through controlled release fertilizers under tropical conditions." The research aims to provide an improved and efficient K recommendation program for sustainable oil palm production in Malaysia. The study is planned to be conducted in three phases: 1) development of controlled-release K fertilizers (granular and briquette forms) in collaboration with an established fertilizer company, 2) establishment of K release pattern of the controlled-release fertilizer (CRF), and 3) test performance of the CRF on oil palm fresh fruit bunch yield, and their leaching and runoff loss potentials. Mr. Bah aims to contribute to local or regional agricultural communities to boost agricultural production and agribusiness management.

Funding for the scholar award program is provided through support of IPNI member companies, primary producers of N, P, K, and other fertilizers. Regional committees of IPNI scientific staff select the recipients of the IPNI Scholar Award. The awards are presented directly to the students at a preferred location and no specific duties are required of them.

Graduate students attending a degree-granting institution located in any country with an IPNI program region are eligible. Graduate students in the disciplines of soil and plant sciences including agronomy, horticulture, ecology, soil fertility, soil chemistry, crop physiology, and other areas related to plant nutrition are encouraged to apply.

More information is available from IPNI staff, individual universities, or from the IPNI website: www.ipni.net/awards. BC

Adapt-N Uses Models and Weather Data to Improve Nitrogen Management for Corn

By Bianca Moebius-Clune, Harold van Es and Jeff Melkonian

Optimal management of N for corn varies from year to year owing to differences in weather. The Adapt-N tool combines soil and crop models to predict the influence of weather on plant N demand, soil N supply, and soil N losses. On-farm validation of the tool in New York and Iowa has confirmed that its use leads to better choices for rate and time of application, improving profitability of fertilizer N use and reducing its environmental impact.

The need for precise and responsive management of N fertilizer in corn production is compelling for both economic and environmental reasons, but the optimum N rate remains an elusive notion. Economically optimal N rates (EONR) in much of North America may range from zero to 225 lb/A (Scharf et al., 2006; Sawyer et al. 2006), and may vary as the growing season progresses (van Es et al., 2007). Many factors impact soil N dynamics and crop N uptake in corn fields, and therefore should be considered in the process of determining an optimum rate recommendation. These include 1) soil texture, depth, structure, drainage, and organic matter content, 2) amount, form, placement, and timing of application of amendments like fertilizer, manure and compost, 3) crop rotational and cover crop effects, 4) tillage and crop residue management, as well as 5) weather events and 6) risk factors associated with fertilizer and grain prices. Most current recommendation systems are simple and generalized (e.g., based on yield potential or average empirical N response), while a few others incorporate some of the above attributes. Many are also static in that they give the same recommendation regardless of weather.

Seasonal temperature and precipitation, notably, influences N gains from mineralization and losses through leaching and denitrification, and are therefore highly correlated with seasonal variation in optimum fertilizer N rates (van Es et al., 2007). A meta-analysis of 51 corn N response studies in North America showed strong soil and weather effects (Tremblay et al., 2012), and fields that received high precipitation in the time period around sidedressing were found to have much greater N response than those receiving low precipitation. Early-season events appear to be the strongest determinant for optimum N rates (Tremblay et al., 2012), although mid- and late-season weather may still affect corn yields (especially in cases of drought).

Static N fertilizer recommendations based on average crop response lead to excessive fertilization in some years, and inadequate fertilization in years with high N losses. From a farmer's perspective, the uncertainty in optimum N rate poses risks for profit losses, which is exacerbated by the asymmetric profit response of corn to N rates. The associated higher cost of under-fertilization relative to over-fertilization drives farmers to apply higher rates, and use additional "insurance" fertilizer applications. This uncertainty can be addressed by providing more accurate location- and time-specific recommendations that increase accuracy and reduce uncertainty. Currently, two general approaches are pursued by scientists: canopy reflectance spectroscopy and model-database tools. This article is focused on the latter.

Abbreviations and Notes: N = nitrogen; IPNI Project # USA-NY10.

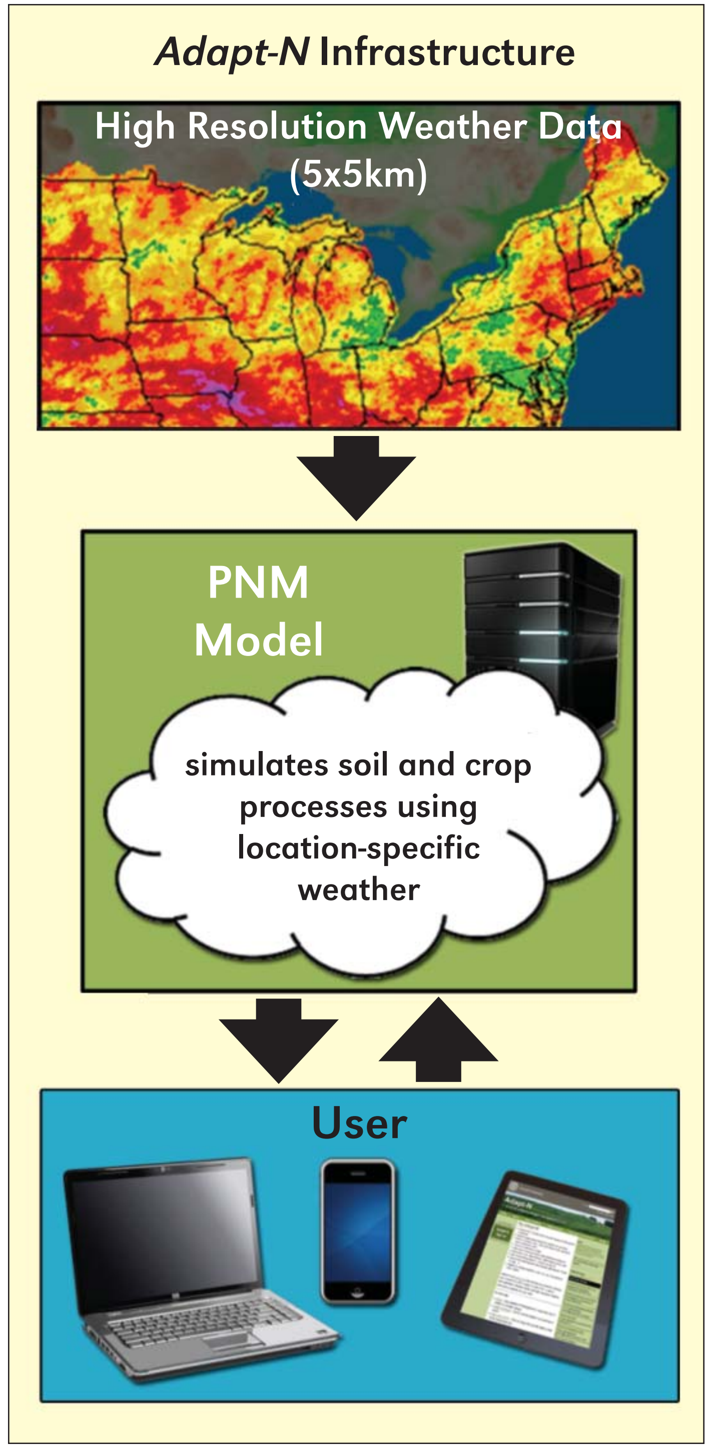


Figure 1. Users access the Adapt-N tool via web-enabled devices, automatically engaging the Precision Nitrogen Management (PNM) simulation model to obtain location-specific, weather-adjusted sidedress recommendations.

The Tool

Adapt-N is a web-based computational tool that uses a simulation model to integrate location-specific soil, crop and weather information to generate in-season N recommendations for corn (**Figure 1**). It incorporates high-resolution weather data and field-specific inputs on soil, crop, and management parameters to estimate in-season optimum N rates. It addresses most concerns with the static and generalized corn N recommendation methodologies (Stanford, 1973; Sawyer et al., 2006), which have limited ability to manage high variability in N response, especially in humid climates, and have inadequate nuance for site-specific crop management.

The Adapt-N tool is accessible (http://adapt-n.cals.cornell.edu) through any internet-connected device that supports a web browser. It is based on the Precision Nitrogen Management (PNM) model (Melkonian et al., 2005), which in turn is a re-coded and integrated combination of a corn N uptake, growth and yield model (Sinclair and Muchow, 1995), and the LEACHN soil water and N transformation model (Hutson, 2003). The crop model uses solar radiation, temperature and rainfall information to estimate the growth, development, and uptake of N and water by the crop, on a daily time step (**Figure 2**). Its version of LEACHN uses a "tipping bucket" approach and information on soil properties and weather to estimate how water from each rain event is stored in soil, lost to drainage, or evaporated over time. It also tracks the transformations and movements of N in the soil profile. Both models have been extensively tested and validated in field trials. An important feature is its dynamic access to gridded high-resolution (5 x 5 km) weather data (daily Tmax, Tmin, Precip), which allows for field-specific and timely adjustments of N recommendations. The weather database is derived from routines using National Oceanic & Atmospheric Administration's (NOAA) Rapid Update Cycle weather model (temperature) and operational Doppler radars (precipitation). For both, observed weather station data are used to correct NOAA estimates and generate spatially interpreted grids (DeGaetano and Wilks, 2009; Wilks, 2008). Soils information is derived from NRCS SSURGO datasets.

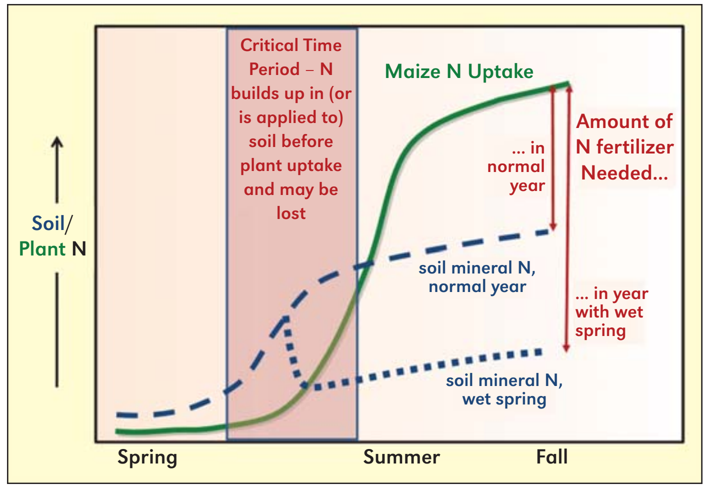


Figure 2. Adapt-N dynamically models the impact of weather on the soil N supply, soil N losses, and crop N demand.

Adapt-N uses dynamic simulations of soil and crop processes to feed into a mass balance equation that derives optimum N rates based on early season (deterministic, near-real time, currently within 1 day) and post-sidedress (stochastic, based on probability via 30-year climate data) simulation results. It provides uncertainty estimates for N rates, and also incorporates economic considerations (crop-fertilizer price ratio). It offers information on simulation results (N mineralized, N leached and denitrified, soil N levels) and allows for

Case Study: New York Farm Uses Adapt-N to Save Money and Reduce Environmental Impact

Donald and Sons Farm in Moravia, NY grows about 1,300 acres of corn and soybean annually. Until 2011, the farm used N application rates recommended by a commercial soil testing laboratory, which ranged between 195 to 260 lb N/A. The majority of their fertilizer N is applied as anhydrous ammonia at sidedress time, because early season applications run the risk of losses during wet springs. Only 22 lb/A of N is applied at planting as urea ammonium nitrate (UAN). Their large expenditures on N fertilizer were a strong incentive to seek new tools to optimize application rates and to collaborate with the Adapt-N beta-testing efforts. The web-based Adapt-N tool combines soil and crop models to predict the influence of weather on plant N demand, soil N supply and soil N losses.

After the dry 2011 spring, the Adapt-N recommendation for their trial field was only 80 lb/A. Their old recommendation was 220 lb/A, and they found no yield penalty with the substantially reduced N rate. For 2012, the farm decided to fully adopt Adapt-N and host numerous trials. They sidedressed 922 acres of corn using the tool's recommendations, employing their real-time kinetic (RTK)-GPS system to target variable rates on 90 management units distributed across 18 fields. Recommendations from Adapt-N varied from 65

to 190 lb/A, depending on local temperature, precipitation, soil texture and organic matter content (varying from 1% to 6%), as well as the date of sidedressing. In collaboration with the Cornell Adapt-N Team, on 15 fields, they left replicated comparison strips of the conventional "old" rate. Decreasing N applications by 87 lb/A reduced the simulated total N losses to the environment by 70 lb/A (by 15 December 2012), and reduced N leaching losses by 10 lb/A. Adapt-N resulted in profit gains in 83% of trials, and average savings were 42 $/A. For the farm, they saved 67,000 lb of unneeded N in 2012, with total savings of over $30,000.

By applying a science-based model of the soil and crop processes involved in the N cycle, their management of source, rate, timing and placement of N led to higher profit and reduced impact on the environment. The approach is consistent with the principles of 4R Nutrient Stewardship.

For more information, see http://adapt-n.cals.cornell.edu/

alternative management scenario analyses. A feature allows for automatic daily updates of simulation results via email or text message. Graham et al. (2010) applied the model to generate within-field site-specific N recommendations.

On-farm Testing

The main question for users is whether the tool provides recommendations that increase profits and reduce environmental impacts. We are answering this through replicated on-farm strip trials, totaling 84 in 2011 and 2012 (**Figure 3**). They involved grain and silage corn in fields with varying management history (organic amendments, crop rotation, tillage practices, etc.). Sidedress treatments involved at least two rates of N, a conventional producer-chosen "Grower-N" rate and an "Adapt-N" rate. A simulation was run for each field just prior to sidedressing to determine the Adapt-N rate.

Yields were measured by weigh wagon, yield monitor, or in a few cases by representative sampling (two 20 ft. x 2 row sections per strip). For farms harvesting silage, yields were converted to grain equivalents assuming 8.14 bu grain per ton of silage. Partial profit differences between the Adapt-N and Grower-N rates were calculated. For grain, prices of 5.50 and 6.00 $/bu were assumed for 2011 and 2012, respectively. For silage, 50 $/ton was assumed in both 2011 and 2012. A fertilizer N price of 0.60 $/lb was used for all trials.

Economic Results

Profit gains for the use of Adapt-N over the producer chosen rates were considerable, in 80% of New York trials, in 75% of Iowa trials, and 79% overall (**Table 1**). Of the 21% of cases where Adapt-N underperformed and caused lower profits, the majority was associated with either underestimated yield expectations from user inputs, or mid-season droughts following higher Adapt-N recommendations. The former concern can be corrected through better user training on yield goal estimation, and the latter relates to as yet unavoidable uncertainty about future weather events at sidedressing time.

Adapt-N recommended lower N rates for 88% of trials, in part related to generally dry growing season conditions in both years. Marginal profits were on the average 27 $/A higher ($p < 0.0001$) and N inputs 54 lb/A lower ($p < 0.0001$) when Adapt-N was used. Profit gains were also achieved in some instances where Adapt-N recommended higher N rates, and consequent yield increases were achieved. Yields decreased by only 1 bu/A on average for all 84 trials (statistically insignificant), indicating that the reduced N recommendations were generally justified. The yield decrease would have been smaller had the expected yields been estimated correctly.

Table 1. Comparison of Adapt-N and Grower-N rates from replicated on-farm strip trials.

Treatment comparison Adapt-N – Grower-N	Iowa 2011	Iowa 2012	New York 2011	New York 2012	Grand Mean (weighted)
Number of fields	9	19	14	42	84
N fertilizer input, lb/A	-25	-36	-66	-65	-54
Yield, bu/A †	+2	-1	-3	-1	-1
Profit, $/A	+25	+17	+26	+32	+27
Trials with greater profit, %	78%	74%	86%	79%	79%

† Yields ranged from 75 to 245 with a mean of 175 bu/A.

Figure 3. On-farm trial locations. Map courtesy of Google maps and batchgeo.com

Environmental Impacts

Lower Adapt-N recommendations resulted in substantial reductions in N losses to the environment. By the end of the growing season, simulated total N losses decreased by an average of 39 lb/A, and simulated N leaching losses declined by 8 lb/A with the use of Adapt-N. In 2012, simulated total N losses and particularly leaching losses of sidedress-applied excess N remained relatively low due to widespread dry conditions until the winter of 2012-2013. The above simulations did not include further environmental benefits achieved during the following, generally wet, spring of 2013.

Conclusions

Two consecutive growing seasons of on-farm strip trial testing demonstrated that Adapt-N resulted in profit gains in four out of five cases. The strip trial results show that using Adapt-N provides a win-win: economic advantages to growers, as well as environmental benefits. In all, Adapt-N promotes more accurate N management, and the tool's increasing precision as the growing season progresses also provides a strong incentive to shift the timing of N applications to late spring and early summer.

Acknowledgments

Funding from the NY Farm Viability Institute, the USDA-NRCS Conservation Innovation Program, IPNI, and MGT Envirotec is gratefully acknowledged, along with the cooperation of many collaborators, farmers, consultants, and extension staff. BC

Dr. Moebius-Clune, Professor van Es, and Dr. Melkonian are with Cornell University, Ithaca, New York; email: bnm5@cornell.edu.

References

DeGaetano, A.T. and D.S. Wilks. 2009. International Journal of Climatology. Volume 29, Issue 2, 185-196.

Graham, C.J., H.M. van Es, J. Melkonian, and D.A. Laird. 2010. p. 301-325, *In* D.A. Clay and J. Shanahan (eds.) GIS Applications in Agriculture – Nutrient Management for Improved Energy Efficiency. Taylor and Francis, LLC.

Hutson, J.L. 2003. Dept. of Crop and Soil Sciences, Research series No. R03-1. Cornell University, Ithaca, NY, U.S.A.

Melkonian J., H. van Es, L. Joseph, and J. Sogbedji. 2005. PNM Model Version 1.0. Dept. of Crop and Soil Sciences, Research series No. R05-2. Cornell University, Ithaca, NY, U.S.A.

Sawyer, J., et al. 2006. Iowa State Univ. Extension Publ. PM2015, 27 pp.

Scharf, P.C., et al. 2006. Soil Sci. Soc. Am J. 70:2154-2160.

Sinclair, T.R. and R.C. Muchow. 1995. Agronomy J. 87:632-641.

Stanford, G. 1973. J. Environ. Qual. 2:159-166.

Tremblay, N., et al. 2012. Agron. J. 104:1658-1671.

van Es, H.M., B.D. Kay, J.J. Melkonian, and J.M. Sogbedji. 2007. *In* T. Bruulsema (ed.) Managing Crop Nutrition for Weather. IPNI Publ. p. 6-13.

Wilks, D.S. 2008. Agricultural and Forest Meteorology 148:111-120.

Establishing a Scientific Basis for Fertilizer Recommendations for Wheat in China

By Limin Chuan, Ping He, Mirasol F. Pampolino, Adrian M. Johnston, Jiyun Jin, Xinpeng Xu, Shicheng Zhao, Shaojun Qiu and Wei Zhou

Inappropriate application of fertilizers has become a common phenomenon in wheat production systems in China. This has led to nutrient imbalances, inefficient fertilizer use, and large losses to the environment. Using datasets from 2000 to 2011, this paper describes and validates a new fertilizer recommendation method for wheat in China based on yield response and agronomic efficiency (AE).

Wheat (*Triticum aestivum* L.) is one of the important cereal crops in China, and fertilizers have played a critical role in increasing wheat yields. However, in pursuing food security in China, over-application of N fertilizer has become a common practice in wheat production systems, which has led to nutrient imbalances, inefficient fertilizer use, and large losses to the environment (Ju et al., 2009). Having access to a science-based fertilizer recommendation method is critical to improve fertilizer use efficiency in a high yielding wheat crop, especially for smallholder farmers in China.

Nutrient Expert® for Wheat (NE) is a decision support system that has been developed by the International Plant Nutrition Institute (IPNI) with the goal of supporting advisers who make fertilizer recommendations to farmers. The science behind this fertilizer recommendation method is based on yield response and AE. This is an alternative approach developed for use when soil testing is limited or not available. The method uses soil indigenous nutrient supply in an attempt to avoid excessive nutrient accumulation in the soil and has been applied with success in rice, maize and wheat crops in some Asian countries (Witt et al., 2007; Buresh et al., 2010; Pampolino et al., 2011). This is a unique approach as it also considers N, P and K interactions.

The determination of fertilizer N requirements from NE has been modified to use a target AE and an estimation of yield response to applied N (Witt et al., 2007; Pampolino et al., 2011). Similarly, the determination of fertilizer P and K requirements considers internal nutrient efficiency combined with estimates of attainable yield, nutrient balances and yield responses from added nutrient within specific fields.

Datasets for grain yield, fertilizer application, and N, P and K uptake in mature aboveground plant dry matter were compiled using published literature from 2000 to 2011 in China, along with published and unpublished datasets from the IPNI China Program. The datasets contained different nutrient management practices including farmers' practice (FP), optimum treatments (OPT), long-term field experiments, and treatments with different fertilizer rates across wheat-growing regions of China. These regions include the MLYR, North Central and Northwest China (**Figure 1**). The data included a wide range of soil types and climatic conditions.

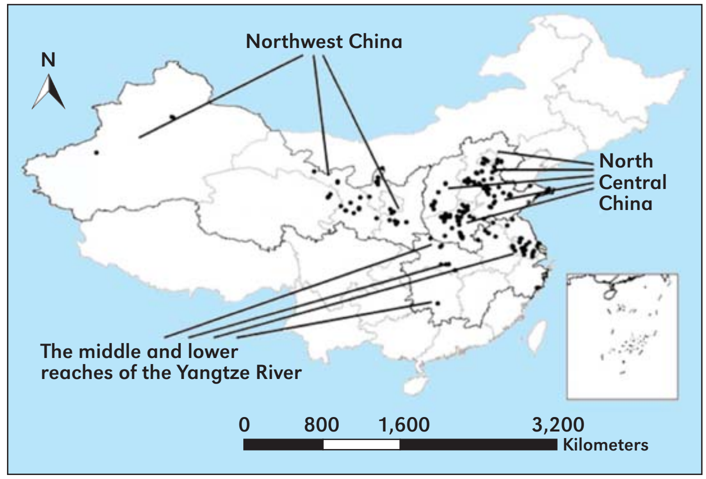
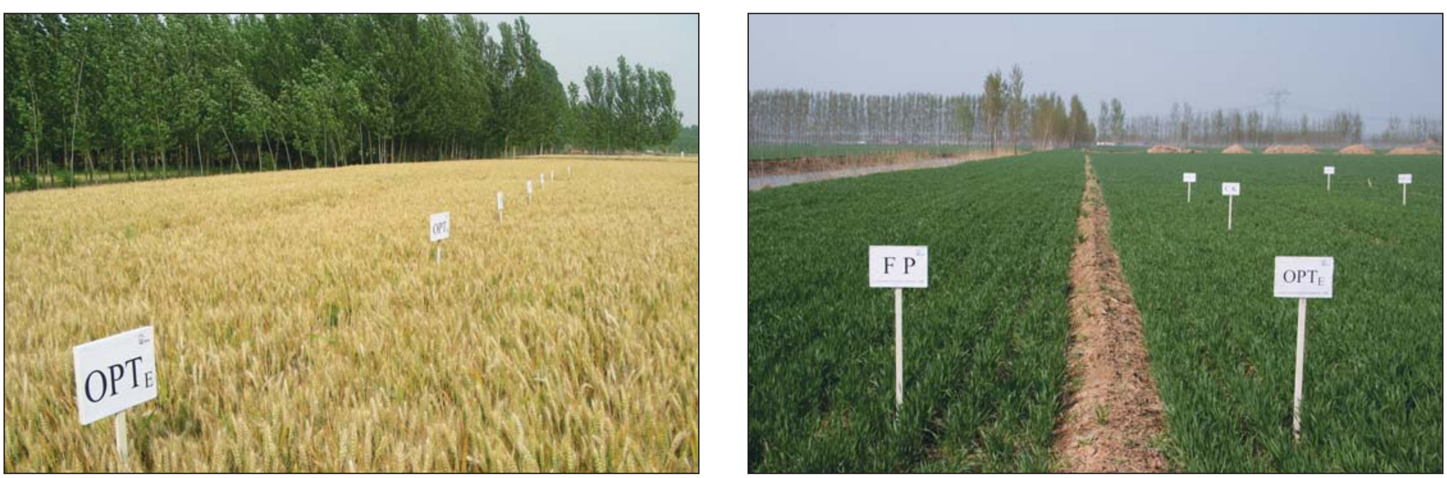


Figure 1. Geographical distribution of studied locations in North Central China, the middle and lower reaches of the Yangtze River, and Northwest China.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Mg = magnesium; Fe = iron; Mn = manganese; Zn = zinc; AE_N = agronomic efficiency of N; RE_N = recovery efficiency of N; PFP_N = partial factor productivity of N; YD = maximum dilution; YA = maximum accumulation; YU = balanced uptake; MLYR = Middle and Lower Reaches of the Yangtze River.



Field validation of Nutrient Expert® for wheat in progress in Hebei (left) and Shanxi (right).

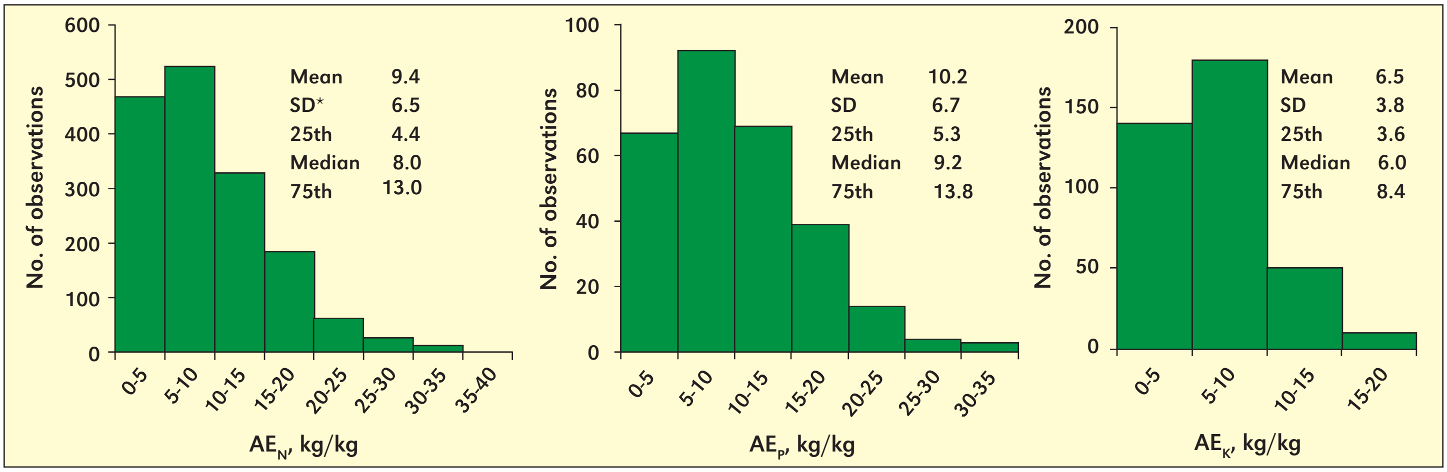


Figure 2. Frequency distribution of agronomic efficiencies of N (AE_N), P (AE_P) and K (AE_K) for wheat in China. * SD = standard deviation.

Experiments were conducted in farmers' fields of North Central China including in Hebei (32 fields), Henan (20 fields), Shandong (30 fields), and Shanxi (10 fields) provinces to validate the fertilizer recommendations provided by NE. All farms had a winter wheat/summer maize rotation and fluvo-aquatic or cinnamon soil.

Treatments included a CK (check, no fertilizer applied), balanced OPT-NE (fertilizer application based on the NE decision support system), balanced OPT-STB (soil test-based), FP, and a series of nutrient omission plots that excluded N, P or K from the OPT-NE treatment. Treatments were arranged using a randomized complete block design, where one-farm represented one-replicate design. In Hebei, the application rates in OPT-STB were the same as OPT-NE, so only OPT-NE was considered at that location. Fertilizer sources used were urea, single superphosphate, and potassium chloride. Urea was split applied two (basal and top-dressed by broadcasting at the jointing stage) or three times (basal, and top-dressed at the jointing stage and filling stage), depending on soil fertility or expected yield response to N. Phosphorus and K fertilizers were both broadcasted and incorporated as basal before seeding. The rates of fertilizer application are listed in **Table 1**.

Table 1. Rates of fertilizer application in different treatments used in the study.

Province	Treatment	Fertilizer application, kg/ha N	P_2O_5	K_2O
Hebei	FP[a]	278 (196~344)[d]	42 (30~68)	24 (0~68)
	OPT-NE[b]	135 (130~150)	52 (50~56)	60 (48~70)
Henan	FP	184 (113~289)	124 (72~225)	127 (27~225)
	OPT-STB[c]	210	90	120
	OPT-NE	144 (140~155)	67	70 (60~80)
Shandong	FP	317 (215~400)	161 (75~276)	13 (0~36)
	OPT-STB	242	150	60
	OPT-NE	140	78	70 (60~80)
Shanxi	FP	262 (179~502)	110 (19~194)	28 (14~72)
	OPT-STB	180	75 (67~90)	76 (60~80)
	OPT-NE	137 (125~140)	67	78 (60~80)

[a]FP= fertilizer application based on farmers' traditional practice; [b]OPT-NE= fertilizer application based on Nutrient Expert for Wheat decision support system; [c]OPT-STB = fertilizer application based on soil testing; [d]Data in parentheses indicates the range of fertilizer application.

Irrigation and other cultural practices were done using the best local management practices.

Results

The frequency distribution of AE for wheat is shown in **Figure 2**. The mean AE for N, P and K were 9.4, 10.2 and 6.5 kg/kg respectively, indicating that 62, 55 and 84% of the observations had AE values less than 10 kg/kg, respectively. Dobermann (2007) reported that AE_N for cereals in developing countries ranged between 10 to 30 kg/kg, and also indicated that AE_N could reach an average value >25 kg/kg in a well-managed system with low levels of N use or with low soil N supply. However, compared with developed countries, the nutrient use efficiency in China was still only at the baseline reported by Dobermann (2007), and only reached about 52% of the world average (18 kg/kg) reported by Ladha et al. (2005). Agronomic efficiency of N remains low in China, thus highlighting the need to improve nutrient management practices in modern production systems.

The indigenous nutrient supply (y) determined from unfertilized plots showed a significant negative exponential relationship with yield response (x) ($p < 0.05$) with 36, 28 and 43% of the variability for N, P and K, respectively (**Figure 3**). For a specific field site, when the indigenous nutrient supply was high, the yield response to the applied nutrient was low. These results support the approach that yield responses could be used as an indicator of soil nutrient supplying capacity.

The yield in an unfertilized plot is mainly supported by the soil indigenous nutrient supply. Yield response between the unfertilized plot and the target yield is supplied by fertilizer application. Yield response varies as the soil indigenous nutrient supply changes. The AE is also determined by the indigenous nutrient supply, fertilizer application, management practices and climatic conditions. The results showed that there was a significant quadratic relationship between yield response (x) and AE (y) ($p < 0.05$) (**Figure 4**).

Initially, the AE for a nutrient increased with increasing yield response, but these increases became smaller as the yield responses became larger. A lower yield response indicates higher soil nutrient indigenous supply or higher soil fertility, resulting in lower AE. In contrast, a larger yield response means lower soil nutrient supply and relatively higher AE. Based on this, the principles of nutrient recommendations were formed and incorporated into the NE decision support system. Nitrogen

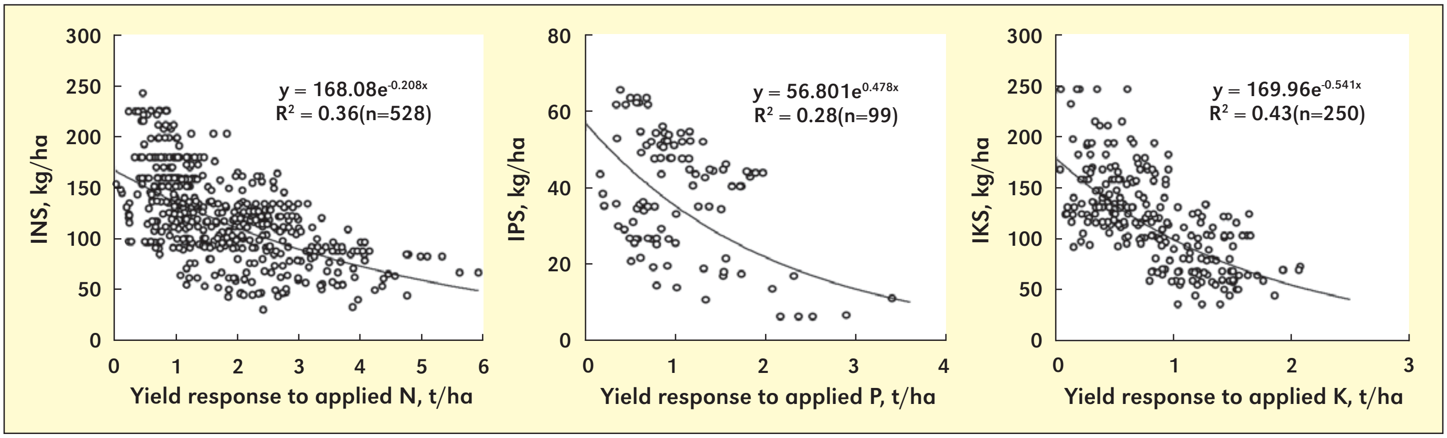


Figure 3. Relationships between yield response to N, P and K, and their indigenous nutrient supplies in different farms across China. INS, IPS and IKS represent indigenous N, P and K supplies, respectively.

fertilizer recommendations were calculated from yield response divided by AE. However, the P and K fertilizer recommendation considered both the nutrient requirement for the yield gain and maintenance of soil fertility. The nutrient requirements for yield gain were calculated from the yield response and AE, and the maintenance of soil fertility was calculated from the nutrient removal estimated by the QUEFTS model (Chuan et al., 2013). Trace elements (Zn, Fe, Mn and Mg) were applied when soil tests showed a deficiency or when their applications were part of established local recommendations.

Field validation trials of the NE decision support system showed that the OPT-NE plots increased grain yields by 3.7 (275.1 kg/ha), 0.1 (5.3 kg/ha) and 1.1% (88.3 kg/ha) compared with that in FP plots in Hebei, Henan and Shandong, respectively. This occurred with a net reduction in fertilizer N application in Hebei by 51%, 22% in Henan, and 56% in Shandong. There was a gross improvement in profits for these three provinces by US\$158, US\$103 and US\$168/ha, respectively (**Figure 5**). However, in Shanxi, with N and P fertilizer application reduced by 48 and 39%, respectively, yields were decreased slightly, but the gross profit was maintained. Overall, compared to the OPT-STB treatment, the yield in OPT-NE treatment was slightly lower, but gross profit remained the same statistically ($p < 0.05$), while AE_N, RE_N, and PFP_N in OPT-NE were significantly increased at most sites ($p < 0.05$) (data not shown).

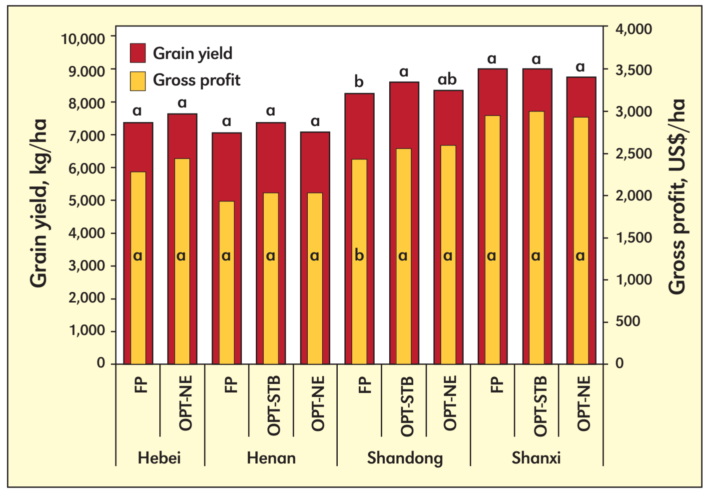


Figure 5. Grain yield and gross profit in Hebei, Henan, Shandong and Shanxi provinces in 2010-2011.Different letters above the columns denote a significant difference ($p < 0.05$).Wheat prices (¥ = Chinese Yuan Renminbi) were 2.2, 2.0, 2.1, and 2.3/kg in Hebei, Henan, Shandong, and Shanxi, respectively. Prices for N, P_2O_5 and K_2O were 5.0, 6.3 and 7.3/kg in Hebei; 4.0, 5.6 and 5.0/kg in Henan; 4.4, 4.8 and 5.3/kg in Shandong; and 5.0, 6.3 and 7.3/kg in Shanxi, respectively. A conversion rate of ¥6.3 was used for US\$1.

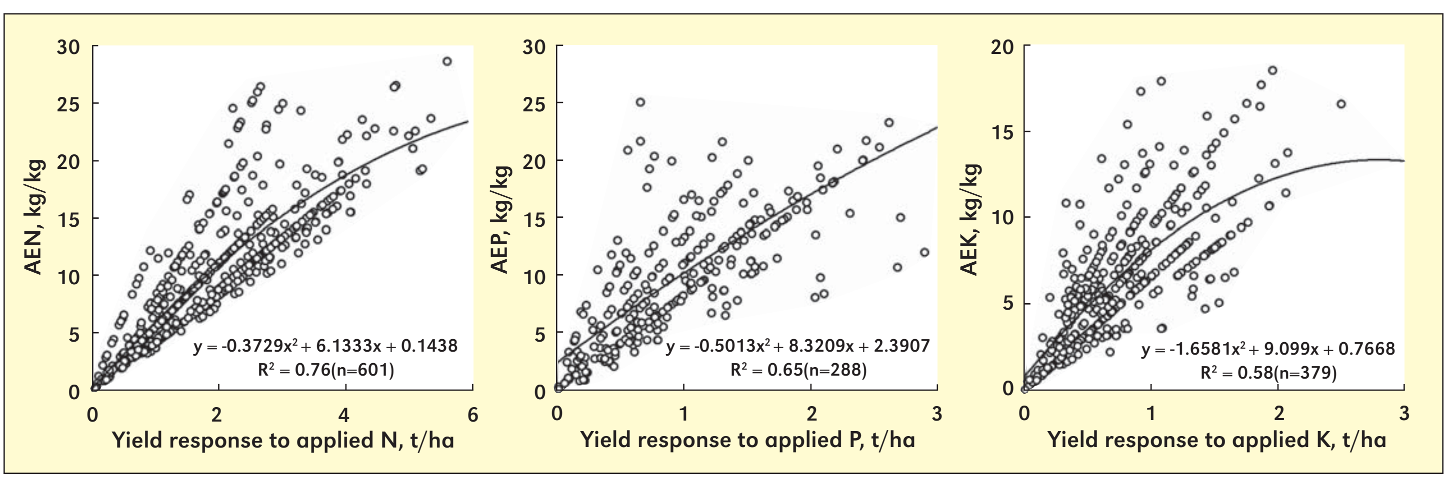


Figure 4. Relationships between yield response and AE for wheat, where AEN, AEP and AEK are mean agronomic efficiencies of N, P and K, respectively.

Summary

There was a significant negative exponential relationship between yield response and soil indigenous nutrient supply, and a significant negative linear correlation between yield response and relative yield. A quadratic equation described the relationship between yield response and AE. Based on the above analysis, the principles of nutrient recommendations were formed and incorporated as part of the NE decision support system. Field validation, based on yield response and AE, showed an increase in both grain yield and gross profits, and AE_N, RE_N and PFP_N were all improved in most sites. It was concluded that NE could be used as an alternative method to soil testing when making fertilizer recommendations for wheat in China.

Acknowledgements

Funding for this research was provided by the National Basic Research Program of China (973 Program, 2013CB127405), National Natural Science Foundation of China (No. 31272243), and IPNI. We also wish to thank all our cooperators for conducting field experiments. Some contents of this paper have been published by Chuan et al. (2013) in Field Crops Research, 140, pp. 1-8.

Dr. Chuan is with the Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences (CAAS), Beijing, 100081, China; e-mail: xiaochuan200506@126.com. Dr. He is Director, IPNI China Program, Beijing, China. Dr. Pampolino is Agronomist, IPNI Southeast Asia Program, Penang, Malaysia. Dr. Johnston is Vice-President, IPNI, Saskatoon, Canada. Dr. Jin is former Director, IPNI China Program. Drs. Xu, Zhao, Qiu, and Zhou are with the Institute of Agricultural Resources and Regional Planning, CAAS, Beijing, China.

References

Buresh, R.J. et al. 2010. Plant Soil 335: 35-64.

Dobermann, A. 2007. *In*, IFA International Workshop on Fertilizer Best Management Practices. 7-9 March 2007, Brussels, Belgium. IFA, Paris.

Chuan, L.M. et al. 2013. Field Crops Research, 146:96-104.

Ju, X.T. et al. 2009. Proc. Natl. Acad. Sci. U.S.A. 106: 3041-3046.

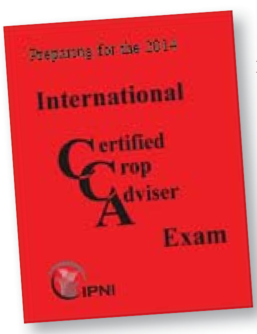
Ladha, J.K. et al. 2005. Adv. Agron. 87:85-156.

Pampolino, M.F. et al. 2011. Nutrient Expert for Hybrid Maize (version 1.11). IPNI, Penang, Malaysia.

Witt, C. et al. 2007. *In*, Fairhurst T.H., Witt, C., Buresh, R.J., Dobermann, A. (eds.), Rice: A Practical Guide to Nutrient Management (2nded.). IRRI/IPNI/IPI, Los Baños (Philippines)/Singapore, pp. 1-45.

New Publications

2014 Study Guide International Certified Crop Adviser Exam



Now available for purchase from IPNI, this publication (Item #50-1000) is a must for all preparing for the 2014 International Certified Crop Adviser exam. The manual's price of US$50 includes shipping and handling.

Contact: IPNI Circulation Department,
3500 Parkway Lane, Suite 550, Norcross, GA 30092-2806.
Phone: 770-825-8084; Fax: 770-448-0439; E-mail: circulation@ipni.net.

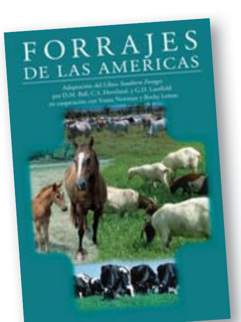
The ICCA exam study guide may also be purchased on-line by visiting this website: www.ipni.net/ccamanual.

Stewardship Specifics

Stewardship Specifics are condensed, one-page bulletins written by IPNI staff. They are intended to provide balanced reviews of current and emerging topics related to nutrient use, crop production, and environmental protection.

Consumers, students, agronomists, farmers, policy-makers, and all who are interested in the role of nutrient stewardship will find this series an informative, easy to read reference on the diverse range of issues facing agriculture.

You may download each of these bulletins from http://www.ipni.net/stewardship.



Forrajes De Las Américas

Forrajes De Las Américas, the newly completed Spanish translation of the Fourth Edition of Southern Forages, has been adapted to extend fully across the Americas. This widely acclaimed, easy to read publication remains a popular resource for all interested in practical forage crop production information.

Please contact IPNI Circulation for details on obtaining copies at circulation@ipni.net.

Silicon: A Beneficial Substance

By Joseph Heckman

Silicon (Si) has been officially designated as a plant "beneficial substance" by the Association of American Plant Food Control Officials (AAPFCO) and plant-available Si may now be listed on fertilizer labels.

Silicon is a major component of sand, silt and clay minerals. Because of this abundance, it typically has not been considered as a limiting factor in soil fertility. However numerous field studies have shown that supplying crops with adequate plant-available Si can suppress plant disease, reduce insect attack, improve environmental stress tolerance, and increase crop productivity.

Chemical Names and Terminology

Silicon refers to the chemical element, while silica, silicon dioxide, or SiO_2, are compounds containing both Si and oxygen. Silicate refers to Si-containing crystalline or amorphous compounds such as calcium silicate ($CaSiO_3$), magnesium silicate ($MgSiO_3$), sodium silicate (Na_2SiO_3), or potassium silicate (K_2SiO_3). Silicic acid or mono silicic acid [$Si(OH)_4$, or H_4SiO_4] refers to the soluble, plant-available forms of Si. These materials should not be confused with silicone, which is a rubber-like synthetic compound used as a sealant or adhesive.

Function of Silicon in Plants

Silicon is classified a "beneficial nutrient" in plant biology. Under controlled hydroponic conditions, Si does not meet the classical definition of an essential nutrient. However in the real world where plants are exposed to multiple stresses, Si plays an important role in plant health.

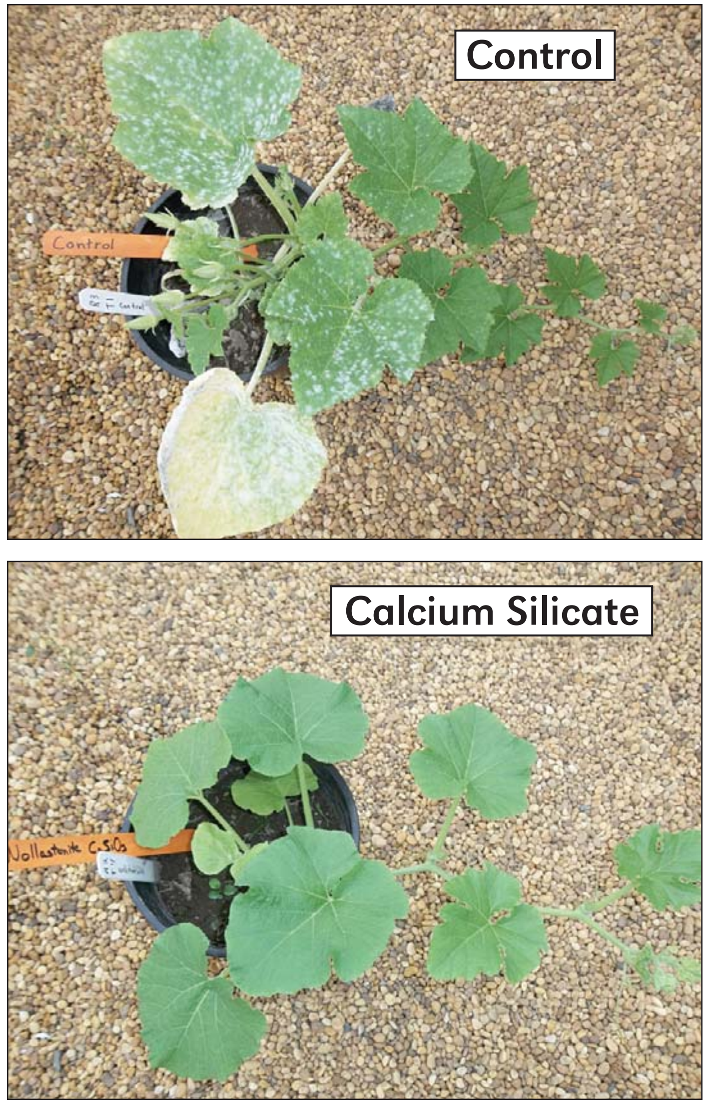
One major contribution of Si is reinforcement of cell walls by deposition of solid silica. It is translocated from the roots as silicic acid [$Si(OH)_4$] through the xylem until it deposits under the cuticle and in intercellular spaces (**Figure 1**). These silica bodies are called phytoliths, or plant opal. These structures are very resistant to decomposition. Many persist in soils as "plant fossils" for very long periods, which is useful in archaeological and paleoecological research.

In addition to naturally occurring soluble Si in soil, many crops respond positively to additions of supplemental Si. Plants, especially grasses, can take up large amounts of Si where it contributes to their mechanical strength. Besides a structural role, Si helps to protect plants from insect attack, disease, and environmental stress. For some crops, Si fertilization of soils increases crop yield even under favorable growing conditions and in the absence of disease.

A second mechanism for the beneficial effects of Si is its role in triggering a range of natural defenses. For example, the presence of Si has been shown to stimulate activity of active compounds such as chitinase, peroxidase, polyphenol oxidases, and flavonoid phytoalexins—all of which can protect against fungal pathogens.

Regardless of the mechanism, some observed benefits due to Si nutrition include:

- Direct stimulation of plant growth and yield through more upright growth and plant rigidity
- Suppression of plant diseases caused by bacteria and fungi (such as powdery mildew on cucumber, pumpkin, wheat, barley; gray leaf spot on perennial ryegrass; leaf spot on Bermuda grass; rice blast)
- Improved insect resistance (such as suppression of stem borers, leaf spider mites, and various hoppers)
- Alleviating various environmental stresses (including lodging, drought, temperature extremes, freezing, UV irradiation) and chemical stresses (including salt, heavy metals, and nutrient imbalances)
- Silicon is an important element for animals where it strengthens bones and connective tissue



Powdery mildew disease suppression on pumpkin plants in response to adding calcium silicate (Wollastonite) to soil.

Symptoms of Low Silicon in Plants

Symptoms of low Si are not generally observed in the field. However, indicators of low Si availability may be manifest as increased disease and pest damage. Grain crops lacking adequate Si are more susceptible to lodging, but this is rarely measured.

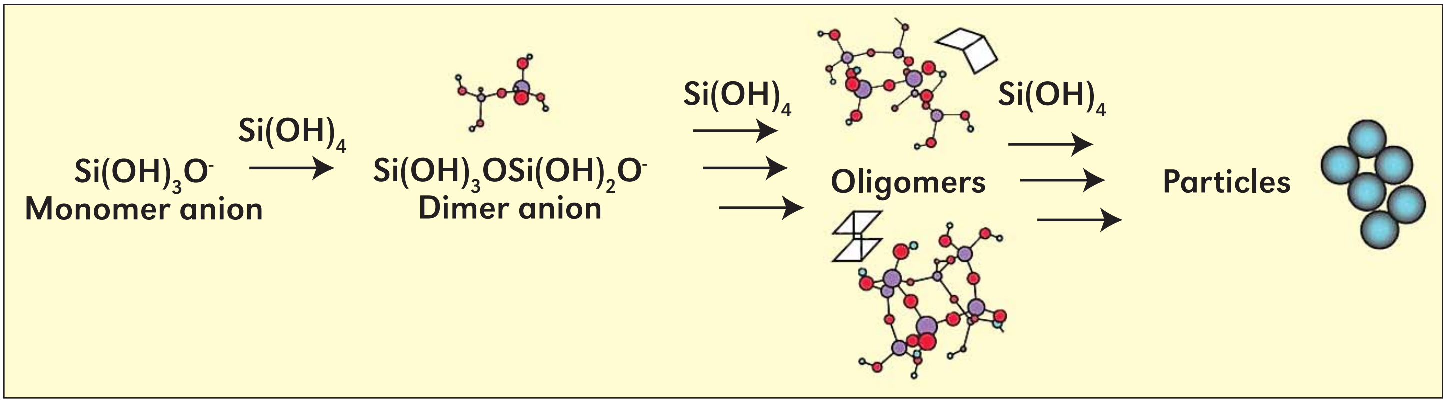


Figure 1. The polymerization of monomeric silicic acid to form larger silica particles proceeds though various condensation reactions with dimers, oligomers and aggregates as intermediates. Adapted from Currie and Perry, 2007.

Plant Tissue Analysis

Plant tissue Si concentrations will vary widely depending on plant species and the soluble Si concentration in the soil. It is not unusual to find Si concentrations in plants at levels comparable to or above those for macronutrients (up to a few percent of dry weight). Grasses and monocots generally accumulate higher concentrations of Si than dicots (approx. 0.1% Si). Concentrations as high as 10% Si are possible in some plant species such as *Equisetum* (Horse tail).

Optimum Si concentrations have not been established for most crops. Research conducted on soils in New Jersey indicates concentration ranges that may occur for some crops. For example, adding supplemental Si increased concentrations in pumpkin leaf tissue from 700 to 3,500 mg Si/kg, in corn stem tissue from 1,300 to 3,300 mg Si/kg, wheat flag leaves from 1,530 to 11,750 mg Si/kg, and Kentucky bluegrass leaves from 4,200 to 7,200 mg Si/kg. Different parts within the same plant can also show large differences in Si accumulation. For example, polished rice contains 0.5 g Si/kg, while the rice hull may contain 230 g Si/kg (Currie and Perry, 2007).

Soil Analysis

Silicon is the second most abundant element in the Earth's crust after oxygen. Soils commonly contain about 30% Si by weight, but most of it is bound in insoluble minerals. With such abundance of Si in nature, the economic value of this element in agronomy and horticulture is sometimes not fully appreciated.

Soils that are highly weathered and have been subject to extensive leaching in a humid environment tend to be depleted of Si. This contrasts with geologically younger soils that generally contain more soluble Si. Soil testing for soluble Si is not a routine part of soil fertility testing, but some laboratories offer an acetic acid extractable Si analysis. At present, the database is very limited in correlating Si soil test levels with plant uptake.

Soil Factors Affecting Silicon Availability

Plants growing in soils with high percentages of sand tend to have low Si concentrations. Although sand is largely composed of Si dioxide, this material provides very little soluble or plant-available Si. Sandy soils also usually have good drainage, which prevents Si accumulation. Thus, it is not unusual for crops grown on sandy soils to benefit from applications of soluble Si.

Silicon is not a major component of soil organic matter. Therefore in soils composed almost entirely of humus and organic matter (muck soils or Histosols), certain crops grown on these soils may benefit from Si application. Similarly, the widespread use of soilless mixes in greenhouse production results in very little Si being supplied from the growth medium. Plants growing in these greenhouse production systems frequently show benefit from Si fertilization.

Silicon availability to plants does not change markedly across the soil pH range where most crops are grown. Many of the commonly used Si fertilizer materials also serve as liming agents and their application results in neutralization of soil acidity.

Crops Likely to Benefit from Silicon

Rice and sugarcane are crops that often exhibit beneficial responses to Si supplementation. Other crops that have shown positive responses to Si include pumpkin, cucumber, corn, wheat, oats, Kentucky bluegrass, and many ornamentals. This is an area that has not yet been extensively studied.

Silicon Sources

Crop residues, animal manures, and composts are all potential sources of Si. Straw from wheat and other small grain crops also return significant amounts of Si to the soil. Wheat straw concentrations range from 0.15 to 1.2% Si depending on the soluble Si concentration of the soil on which it was grown. The Si in crop residues may take many years to dissolve and become available for plant uptake.

To be beneficial for plants, Si amendments should provide a high percentage of Si in a soluble form. Other characteristics to consider are cost, physical properties, ease of application, and perhaps the ability to raise soil pH. Because geologic sources of Si are always combined with other elements, the nutrient value of the other elements present in the product should be considered.

Calcium silicate products are the most commonly applied Si amendments for field application. Steel mill slag by-products are a rich source of calcium silicate. Because this material also neutralizes soil acidity and supplies Ca, it is commonly applied to soil as an alternative liming agent in low pH soils. Wollastonite is a naturally occurring mined $CaSiO_3$ and can be a useful Si source when finely ground. Diatomaceous earth (80 to 90% SiO_2) is also used as a Si source.

Potassium silicate and sodium silicate are commonly used materials for horticultural or greenhouse crop applications. They are soluble Si products that can be added to nutrient solutions or used as foliar sprays. However, plants respond better to Si acquired through the root system than from foliar applications.

Some sources of Si amendments are industrial by-products and should therefore be checked for the presence of undesirable contaminants.

Silicon Fertilization and Rates of Application

The need for Si fertilizer is not easily predicted by currently available soil tests. But soil testing for soil pH and the need for liming may be useful in estimating appropriate application rates of $CaSiO_3$.

A practical approach to managing soil fertility for enhanced Si nutrition of crops is to use $CaSiO_3$ products as a liming material. Application rates can be determined by the need for soil pH adjustment or lime requirement of the soil (often up to several tons per acre).

High-value horticultural crops may benefit for soluble Si fertilizers, such as Na_2SiO_3 or K_2SiO_3, applied through drip irrigation systems or from $CaSiO_3$ additions to soil-less mixes.

An adequate Si supply can benefit plants in a variety of ways, especially when in growing in stressful environments. BC

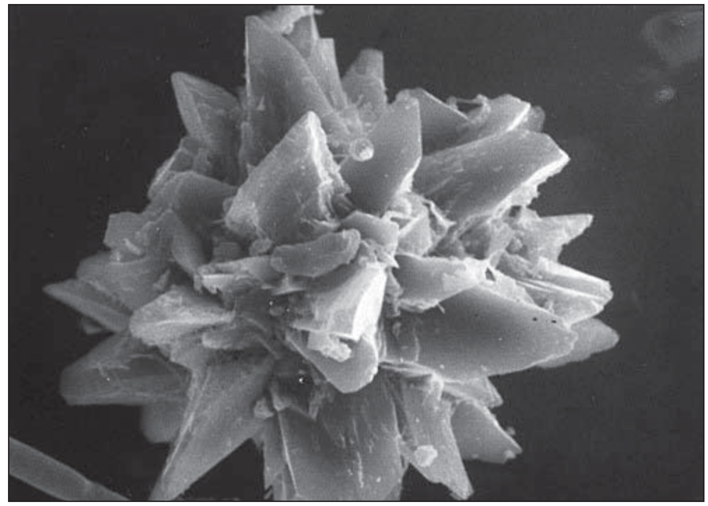
Dr. Heckman is a Professor and Extension Specialist, Rutgers University, New Brunswick, NJ; e-mail: heckman@aesop.rutgers.edu

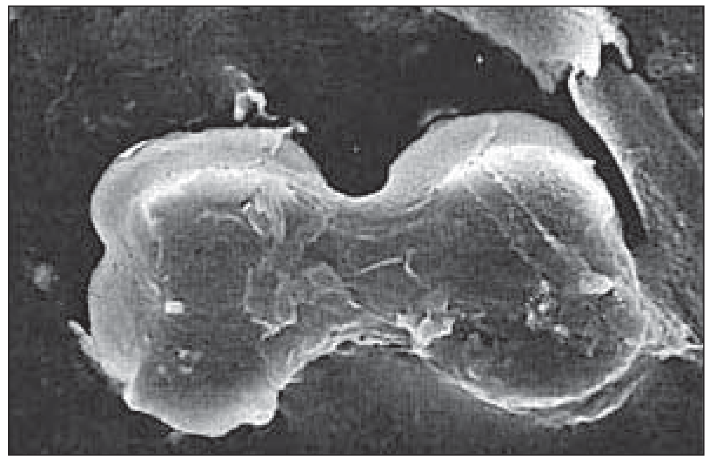
References

Currie, H.A. and C.C. Perry. 2007. Silica in Plants: Biological, Biochemical and Chemical Studies Annals of Botany 100: 1383-1389.

Further Reading

Epstein, E. 2009. Annals of Applied Biology. 155: 155-160.
Heckman, J.R., S. Johnston, and W. Cowgill. 2003. HortSci. 38: 552-554.
Provance-Bowley, M., J.R. Heckman, and E.F. Durner. 2010. Soil Sci. Soc. Am. J. 74: 1652-1661.





Images of Phytoliths or plant microfossils of (top) prickly pear (*Opuntia*) and (bottom) *Panicoid* (*warm season grass*) as viewed through a scanning electron microscope. http://www.texasbeyondhistory.net/varga/images/phytolith.html

Crop Nutrient Deficiency Photo Contest Entries Due December 12

December 12, 2013 (Thursday, 5 pm EDT) is the deadline for entries in the annual IPNI contest for photos showing nutrient deficiencies in crops. An individual can submit an entry for each of the four categories: nitrogen (N), phosphorus (P), potassium (K), and other nutrient deficiencies (i.e., secondary nutrients and micronutrients).

Preference is given to original photos with as much supporting/verification data as possible. Cash prizes are offered to First Place (US $150) and Second Place (US $75) in each of the four categories, plus a Grand Prize of US $200 will be awarded to the photo selected as best over all categories. Winners will be announced in January 2014… also look for details on the 2014 edition of this contest.

Entries can only be submitted electronically to the contest website: www.ipni.net/photocontest BC

On-Farm Experimentation

By Simon Cook, James Cock, Thomas Oberthür and Myles Fisher

The authors examine how farmer experimentation differs from 'conventional' experimentation, and how it might be reintegrated with conventional science and help in improving soil management. The focus is on the competence of farmers in using on-farm experimentation built around their experiences and an approach of "operational research", based on the observation and analysis of farm operations so as to improve them, to manage crops better.

Rich Bennett, who raises corn, soybeans, wheat and cover crop seed in Napoleon, Ohio, relies on research to support his management… but not just research from professional scientists outside the farm. Bennett experiments on-farm, using his own equipment and land (Sare, 2004). The value in on-farm research, he said, is gaining information you can trust. "A farmer will learn more about his soils and stretch to be more efficient," said Bennett.

Experimentation has been a part of farming for millennia, as farmers experimented on their own land with the entire gamut of manageable factors that comprise farming practice. The change supported by this kind of experimentation could be quite rapid, such as in parts of Europe between the 17^{th} and 19^{th} centuries that saw multiplication of crop and livestock productivity through the adoption of institutional and technological change. Industry at this time was also growing rapidly. However, scientific principles could not be applied to farming in the same way as they were applied to industry because of the confounding underlying variability of the natural landscape and the consequent 'disorganized' nature of farming. This uncontrolled variation due to the many site and time-specific effects was a major impediment to the development of agricultural science. In the early 20^{th} century, Fisher and co-workers at Rothamsted developed methods of statistical analysis to clarify experimental treatment effects within the field. This had a huge impact on agricultural research that continues to this day. Yet, as with all scientific methodologies, there is a risk that the method starts to define the problem. Scientists can place more value on the information about the quantifiable effects of factors and discount information about the farming environment in which they occur. Under this scenario, the effects of factors are known, while the interaction with the farmed landscape less so.

This of course, moves agricultural knowledge towards generalizable 'scientific' statements that are true within the bounds of experimentation. But it moves knowledge away from the competence that farmers need to manage particular conditions that exist on-farm. In this way, farmer experiments were left behind and the knowledge they demonstrated was relegated to 'demonstrations' that were considered non-scientific (Maat and Glover, 2012). Where the problem can be defined by a limited set of factors, on-farm research can be astonishingly effective and has underlain the growth of agricultural production. However, the approach leaves a huge proportion of variability unexplained. The highly competent farmer, or those supported by advisers, may be able to bridge the gap between the 'scientific' world of factors and the more complex world of farm management. But many farmers find insights from formal experiments difficult to apply.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; OFE = on-farm experimentation.

Why Farmers Experiment?

Experimentation is defined as a process of discovery, hypothesis testing, or demonstration. We consider this to be the domain of scientists, yet practitioners also experiment. They do so to try out new things or to adapt an idea to their situation. This type of experimentation, which is in essence the collection of information, is not reported in the literature and is generally not considered to be research. In both cases, the purpose of experimentation is to reduce uncertainties. We use the framework of Rowe (1994) to explain how. This framework classifies decision uncertainty generally according to four categories: translational, structural, metric, and temporal.

Both scientists and farmers experiment to reduce uncertainty, but they give different priority to different types of uncertainty (**Figure 1**). For example, translational uncertainty

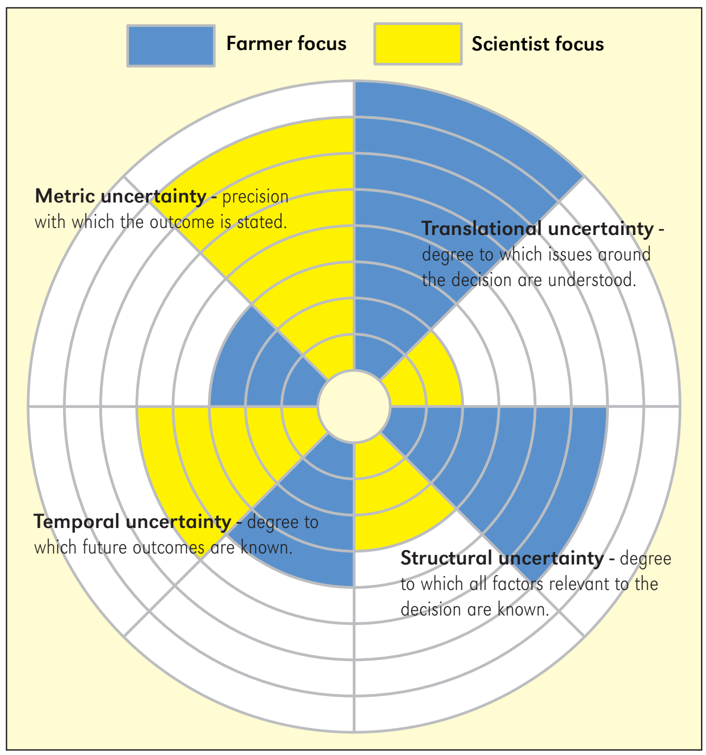


Figure 1. Farmers and scientists focus on different kinds of uncertainty.

(i.e., the contrast between sets of values and meaning of information) is a serious concern to farmers who must consider all factors relevant to a decision, even if they only apply beyond the farm gate. For example, the decision of a farmer to sow a certain variety of crop depends not only on the expected yield but also on factors such as price and availability of seed. By contrast, scientists refer less to external values, in order to focus on clarity of result. Translational uncertainty is reduced by knowledge of the desired outcomes of decisions. Based on experience, good farmers can predict the outcome of decisions with reasonable certainty, despite a wide range of confounding uncertainties. The scientist experimenter will want to reduce these to a limited number of generalizable conditions that can help define the relevance of experimentation.

Scientists often reduce structural uncertainty (i.e., uncertainty caused by variations in the completeness with which people describe systems) by pre-defining part of a system as an object of experimentation, for example, by locating experimental plots in sites selected to avoid complicated terrain. Farmers, conversely, are obliged to manage their farmland as they find it and modify their practices to fit the variation, rather than ignore it. This can be handled during on-farm experimentation by resisting, as far as possible, the temptation to reduce the scope of experimentation to the point at which it ceases to represent 'normal' management.

Conversely metric uncertainty (i.e., uncertainty caused by the difficulty of measuring the state of an attribute) is of greater concern to scientists than structural uncertainty. Agricultural scientists can seek a clear, unambiguous statement of treatment effects far beyond the precision needed by farmers. Virtually all scientists learn statistical analysis to identify improvements that are frequently quite small, and often irrelevant for farmers given the magnitude of uncertainties stemming from non-metric variation.

Similarly, farmers also handle temporal uncertainty (i.e., uncertainty related to past and future events, which influences the relevance of insight gained from long-term observations), but through experience of prior events and conservatism. For example, farmers who live in areas with a strong influence of the El Niño will design a robust strategy that ensures that even if there is a El Niño year they will not face a total disaster, whilst at the same time providing them with an acceptable result in a non-El Niño year. Thus, farmers will use the experience of an El Niño year to design their strategy, but will not base this strategy solely on the results from the El Niño year.

The aim of on-farm experimentation is to enable farmers to improve their competence in terms of metric and temporal uncertainty, whilst at the same time allowing them to take into account their existing strengths of handling translational and structural uncertainty. **Table 1** summarizes these complementary approaches to uncertainty.

There are two underlying principles for the proposed use of on-farm experimentation and operational research. The first principle is heuristic (experience-based): each and every time a farmer prepares a field, plants and manages a crop, he observes and experiments with a unique set of conditions (Cock et al., 2011). Thus, farmers are continuously, although often unconsciously, experimenting as they manage their crops to cope with the changing circumstances, which are a feature of agriculture. The second principle is cognitive (information-based): farmers frequently try to answer specific questions by consciously experimenting on their farms. Farmers do not necessarily attempt to provide propositional knowledge—the why—in either case. In the former case they let their competence guide them in managing their crops according to the particular social, economic and environmental conditions that occur. In the latter case, they wish to increase their competence by obtaining knowledge based on deliberate experimentation that can help them manage variation in the future. The observations of both, conscious experimentation and day-to-day variation in management, are obviously most valid for the farm on which they are produced, but at the same time can be used by others under similar conditions, and may also prompt more conventional experiments. Thus, observations of on-farm experimentation apart from their immediate and direct effect on farm management may encourage scientists to bridge the boundaries between 'formal' science and farming practice. The bridging of this gap and the direct use of the results of on-farm experimentation can reduce management uncertainties and allow farmers to make informed decisions.

Recent On-Farm Experimentation Examples Relevant to Soil and Nutrient Management

Using Precision Agriculture Technology for Fertilizer Application in Australia

Precision agriculture (PA) technology was applied to broad-acre grain farming in Australia in the early 1990s (Cook et al., 1999). Scientists realized that while PA could support the goal of the 4R Nutrient Stewardship philosophy, however the concepts of prescription farming being promoted at that time were less appropriate in a farming landscape over which the average farm-size was greater than 2,000 ha. But farmers were keen for change and used PA to install full-scale experiments, borrowing the concept of on-farm experimentation from operations research (Cook et al., 1999). Where farmers had it, variable rate technology (VRT) was used to install fertilizer experiments over entire fields covering 100's of hectares according to mega-replicated designs. Where VRT was not available, designs were restricted to strips or other easy-to-install designs. In all cases, yield maps were analyzed to determine the effects of treatments

Table 1. Comparison of scientist and farmer approaches to experimentation.

Scientist-based	Farmer-based
Focus on one or two factors for maximum clarity	Multiple-factors included for maximum realism
Assumes insignificant interactions with other factors	Strong interactions observed between other factors
Intended to provide insight for all individuals	Intended to provide insight for specific individuals
Intended to provide insight for specific features	Intended to provide insight for all features present
Deals with abstract / invisible attributes	Deals with tangible / visible attributes
Hypothesis driven	Outcome driven
Focus on accuracy	Focus on relevance
Experimentation to address specific questions	Experimentation as a continuous learning process
Artefact/technology-focussed: deriving optimal parameters for individual technologies	System focussed: optimizing performance for sustainable profits
Analyses of average response	Analyses of processes

(Bramley et al., 1999). The concept is simple: identify controllable and non-controllable sources of variation, vary one or more of the latter as desired by the grower, and determine the effect. The goal is less to understand than to observe. The principle is one of continuous improvement through experimentation.

Recommendations in Variable Colombian Sugarcane Production Systems

The influence of weather at the time of the previous harvest on the yield in the following ratoon crop is of great interest. Growers for years had been aware of the potential loss in yield of ratoon crops, which were damaged during the previous harvest, but no solid experimental data existed to quantify the effects and relate them to harvesting conditions. Reduced production has long been attributed to damage to the stools and soil compaction at harvest under wet conditions, but it has been impossible to quantify these effects using controlled experiments. The Colombian Sugarcane Research Centre (Cenicaña) collected and compiled data on almost all the fields harvested in the large Colombian production region (Cock and Luna, 1996, Isaacs et al., 2007). The basic premise is that farmers or growers are constantly producing crops under a wide range of management practices and varied growing conditions, and that a structured interrogation of their observations can lead to improved management (Cock et al., 2011). The analysis of these commercial data indicated that, with all other things being equal or held constant, for every 100 mm of rainfall in the month before harvest, the production of the succeeding sugarcane crop is reduced by 8 t cane/ha.

Several specific observations can be derived from the two experiences we have related here:

1. Farmers were extremely enthusiastic about designing and carrying out their own experiments, which were generally implemented at low additional costs. In the Australian case, one farmer with whom researchers had agreed to install 12 experiments decided to double the number of experiments, much to the consternation of the data analyst, who initially could make no sense of the data over 'normal' areas that had, in fact, received experiments. Similarly, the experience in the Colombian sugar industry suggests that farmers believe in the results, as there is no gap between experimental plots and commercial fields, and no need for validation trials (Cock et al., 2011), and technology transfer through farmers groups is facilitated due to high credibility of the generated knowledge (Isaacs et al., 2007).
2. Farmers often valued the results of experiments designed to elucidate one problem to understand other aspects of their farm operations. In the Australian case, a P-experiment led the grower to see that he needed to address a micronutrient deficiency. Another farmer deduced from an N experiment that he had K deficiency. A third used the results of an experiment of crop varieties to contrast their performance on good and poor soils. A fourth used a K x N experiment to understand the impact of soil physical variation on actual yield.
3. Farmers were able to place experiments in their local context: Farmers within the highly risky Western Australia environment modified treatments gradually. By contrast, when the results were presented to a group of farmers in an irrigation area elsewhere in the country, they suggested they would more rapidly change in response to on-farm experimental results.
4. Once compiled, farmers interpreted the results of experiments readily in relation to observed features such as micro terrain, wet areas or weed-load. Factors external to the experiment were important guides to interpretation. This indicates that social organization is required so that sufficient information can be compiled and data can be shared between growers to have confidence in the conclusions (Cock et al., 2011). Furthermore, institutionally-guided compiling of data enhances relevance of results beyond the individual farm by enabling more rigorous analysis using the increased data.
5. Consultants and 'formal' experimentalists have frequently been less enthusiastic than farmers about the concept of OFE. Partially, this has been out of an inability to handle technologies. Other reasons include the shift in authority that OFE introduces with the scientist losing control.
6. Finally, scientists regard statistical significance as an essential test of experimental method, since it distinguishes effects that are due to the treatment from those, which might equally occur as a result of chance. Such tests also enhance the efficiency of experimentation, because they enable experiments with relatively small sample populations to generate clear insight of non-random treatment effects. Do the same methods apply to experiments on-farm? It is not at all clear that these methods are appropriate for on-farm experimentation. Several authors suggest that practitioners adopt a pragmatic approach to significance testing (Armstrong, 2007), as conventional tests of statistical significance may help identify non-random effects, but not their relevance for practitioners.

Conclusions

How can OFE support agriculture in general and crop nutrition in particular as it responds to increasing pressure to produce more food and fuel without increasing its use of natural resources?

Projections by the Food and Agriculture Organization of the United Nations (FAO) indicate that agriculture must produce about 70% more food over the next 40 years to meet the demands of a greater and more demanding population. It must do so while maintaining or even reducing its call on natural resources. Few question the importance of knowledge to achieve this, as vast gains of eco-efficiency are yet to be realized by agricultural systems. How can such knowledge be developed for agriculture? Clearly, the linear transfer of the technology model of change—codified knowledge (Mokyr, 2005)—needs to be amalgamated with more collaborative approaches in which researcher and farmer activities complement one another. This is effectively a social process of developing farmer competence through both on-farm and conventional experimentation, and experience with OFE suggests that 'formal' and 'on-farm' research exists as two complementary streams of knowledge generation that address different forms of uncertainty. Furthermore, OFE, whether based on experiments designed to resolve a specific question or on observations on farmers' commercial operations, generates information familiar to farmers which they can easily convert to practical and readily understandable farm practices.

The remaining question is how to practically integrate OFE into the agricultural development process, including that for improved crop nutrition? Most agricultural scientists continue to regard on-farm experimentation as a marginal activity. However, OFE fits well into the concept of adaptive management—an ongoing process of developing improved practices for efficient production and resource conservation by use of participatory learning through continuous systematic assessment (IPNI, 2013). Few farmers receive the support that is critical for its success. We suggest that a review of farmer experimentation should be organized with a principle focus to promote sharing of experiences between farmers themselves, with emphasis on farmers groups or associations, and between farmers and researchers. In order to better share experiences we will need social and organizational change together with standardized means of describing experiences, systems to compile multiple experiences and to accommodate a wide range of data from multiple sources. Adequate statistical analysis and interpretation of the data needs to be developed, to present information to farmers in a format that they can readily understand and incorporate in decisions.

We suggest two immediate areas for consideration that have specific significance for improved nutrient management, and where ideas can be developed and piloted: (1) OFE can reduce dramatically the uncertainties of fertilizer use efficiency and thereby supports the development of intensive yet sustainable farming systems. It can therefore enable responsible nutrient stewardship for targeted increase of fertilizer applications that increase production; (2) OFE can facilitate the development of supply chains for specialty fertilizer products by supporting the extension of diversified production systems into ecological niches. We suggest that if agronomists wish to support adaptive management they should see OFE as a valuable ally rather than a process 'for demonstration purposes only'. OFE provides farmers with the analytical power to adapt broadly-based solutions to their operations with greater certainty. This could convert site variability from an obstacle to agricultural development to one of its greatest assets—where ecological niches are sought for high value product.

Dr. Cook (e-mail: simonernest@gmail.com) is Agricultural Consultant, IPNI, based in Cali, Colombia. Dr. Cock is Agricultural Consultant, IPNI, based in Cali, Colombia. Dr. Oberthür is Director, IPNI Southeast Asia Program, Penang, Malaysia. Dr. Fisher is an Emeritus Scientist, Centro Internacional de Agricultura Tropical, Cali, Colombia.

References

Armstrong, J.S. 2007. Intl. J. Forecasting 23: 321-327.

Bramley, R., S. Cook, M. Adams, and R. Corner. 1999. Grains Res. & Develop. Corp., Canberra, Australia.

Cock, J. et al. 2011. Ag. Systems. 104: 755-769.

Cock, J.H. and C.A. Luna. 1996. *In*, Sugar 2000 Symp. J.R.Wilson (ed.). CSIRO, Brisbane, Australia.

Cook, S. E., M.L. Adams, and R.J. Corner. 1999. *In*, P.C. Robert, R.H. Rust, and W.E. Larson (eds.), Proc. 4th Intl. Conf. Precision Agri., St Paul, Minnesota, USA, 19-22 July 1998. ASA-CSSA-SSSA, Madison, Wisconsin. pp. 611-621.

IPNI. 2013. 4R Plant Nutrition Manual: A Manual for Improving the Management of Plant Nutrition, 1st Rev. Ed., (T.W. Bruulsema, P.E. Fixen, G.D. Sulewski, eds.), International Plant Nutrition Institute, Norcross, GA, USA.

Isaacs, C.H. et al. 2007. *In*, Proc. ISSCT XXVI[th] Congress. Durban, South Africa.

Maat, H. and D. Glover. 2012. *In*, J. Sumberg and J. Thompson (eds.). Contested Agronomy: Agricultural Research in a Changing World. Routledge, Abingdon.

Mokyr, J. 2005. Handbook of Economic Growth, Volume 1B. P. Aghion and S.N. Durlauf (eds.). Elsevier, North Holland.

Rowe, W.D. 1994. Risk Analysis 14: 743-750.

Sare. 2004. Sustainable Agri. Network (SAN). Sustainable Agri. Res. Edu. (SARE). Available online: www.sare.org/Learning-Center/Bulletins/How-to-Conduct-Research-on-Your-Farm-or-Ranch/Text-Version/On-Farm-Research.

Upcoming Conference

Phosphates 2014 International Conference & Exhibition

Policy, supply or demand – what will move the market in 2014?

CRU in participation with the International Fertilizer industry Association (IFA) will host the 7th Annual Phosphates Conference at the Paris Marriott Rive Gauche. Attracting a broad range of organizations from across the fertilizers, industrial and feed phosphates markets, Phosphates 2014 will provide delegates with in-depth market information about phosphates raw materials, intermediates and finished products. Offering supply and demand reviews from the world's production and consumption hubs, discussion of esoteric demand markets, analysis of Europe's recycling initiatives, examination of unconventional mining techniques as well as comprehensive coverage of the agronomic outlook and much more.

Dates/Location: March 23-25, 2013, Paris, France
Program Details: www.phosphatesconference.com
IPNI Speaker: Dr. Terry Roberts, President

Special discount for IPNI members – save 10% on your registration by quoting 'IPNI10' when you book online.

Nutrient Management: A New Option for Olive Orchards in North Africa

By Hakim Boulal, Lhassane Sikaoui and Mohamed El Gharous

North Africa's goal of expanding its olive sector has led to large orchard area expansion under both rainfed and irrigated systems. This summary of best management practices (BMPs) for nutrient application in olive describes the foundation that research must build upon to sustain olive production.

Olive (*Olea europea* L.) is one of the most important crops for North African region. Tunisia, Morocco and Algeria are North Africa's largest olive producers. More than 95% of the world's olive production comes from the Mediterranean basin (IOC, 2012).

Olive trees are adapted to a large variety of soils, however soils with high clay or salt content are not suitable for olive groves. Olive trees grow across a wide range of precipitation regimes, i.e., from less than 200 mm to more than 800 mm. Olive trees cannot tolerate low temperatures and can be severely damaged by winter or early spring frost. Planting densities vary widely, varying from 17 trees/ha (Sfax region, Tunisia) to more than 1,000 trees/ha (irrigated intensive system). In the last few years, the introduction of high-density olive orchards with over 1,800 trees/ha, called the "super-intensive" orchards, has occurred.

Mature olive trees naturally produce a large number of flowers. Depending on the variety, the first production begins in the 3rd or 4th year after plantation establishment. The annual production of olives depends on climatic conditions and the alternate bearing of trees characterized by one year with high and the successive year with low production. Olive yield per hectare can range from less than 1 t/ha to more than 20 t/ha (Vossen, 2009).

Recently in North Africa, there has been a renewed attention to the improvement of the olive sector. In Algeria, a development plan was launched with the objective to reach a total area of 1 million (M) ha by 2014. More than 240,000 ha area was planted with olive trees between 2000 and 2012, making it the most important tree crop in Algeria. In Tunisia, olive trees cover over 33% of the agricultural area with 1,700,000 ha of planted area, making it 2nd in the world in terms of olive cultivated area next to Spain. The plan for olive development in Tunisia is to reach a production of 210,000 t by 2016. In Morocco, the Green Morocco Plan expects the extension of olive groves to more than 1.2 M ha by the year 2020.

Importance of Nutrients for Olive Groves

Most of olive trees are under rainfed conditions. In some regions with a scarcity of water, supplemental irrigation is practiced to improve olive yield. In the last several years, the emergence of intensive systems under irrigation, with very high plant densities, has increased the need for fertigation.

Plant growth, fruit production, oil production and quality are all expected to be influenced by the availability of nutrients.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Ca = calcium; Mg = magnesium; Na = sodium; B = boron; Cl^- = chloride; Cu = copper; Fe = iron; Mn = manganese; Zn = zinc; ppm = parts per million.

Super-intensive irrigated olive orchards in Marrakech region of Morocco.

Most nutrients are removed during fruit harvest, pruning, and natural leaf drop. Studies on olive orchards have shown that fertilizers had an important effect on olive production (Elloumi et al., 2009) and oil quality (Fernandez-Escobar et al., 2006). Each nutrient plays a fundamental role in the productivity of olive trees. After planting, olive groves need fertilizers until the tree begins its productive stage, i.e., for a period of 3 to 4 years. Nitrogen, P, K, and B have been reported to be the essential nutrients for olive orchards (Delgado et al., 1994).

Macronutrients

Nitrogen

Olives respond to N in low fertile soils and the lack of N is the most common nutrient deficiency in olive tree groves (Gregoriou and El-Kholy, 2010). The critical period for N availability is floral induction, and more specifically, before flower bud differentiation. The remainder is applied during the flowering period. In olive-bearing trees, N is applied before this critical period. Excessive N fertilization decreases olive oil quality due a decreased polyphenol content (Fernandez-Escobar et al., 2006). Excess N supply can also negatively affect olive fruit production and delay fruit ripening. The best time for N application depends on the availability of water. In rainfed system, N is applied in the middle to end of winter (February to mid March). Under irrigated system, N can be applied periodically from February to September.

Potassium

Potassium is one of the important nutrients for olive trees. Potassium fertilization is essential for olive growth because a high concentration of K is found in the fruit, which is removed at harvest. Potassium has a significant effect on fruit growth, oil quality (Ben Mimoun et al., 2005) and olive yield (Elloumi et al., 2009). Potassium is required at later stages of crop growth for ripening of fruits. The amount of applied K is normally adjusted to equal N application.

Phosphorus

Phosphorus deficiency is not common in olive trees across North Africa. However, P application at the first stage of the crop has an important role in supporting root growth.

Olive orchards under rainfed system in Essaouira region, Morocco.

Phosphorus is usually applied once every 2 or 3 years. Phosphorus sources should be incorporated into the soil due to immobility after application. Phosphorus fertilizer use has become more common with the increase in intensive olive grove systems. Some recent studies have shown improved flowering and fruit set levels with increased P uptake (Erel et al., 2008). It is generally recommended that P application should not exceed 30% of N application.

Micronutrients

Among the micronutrients that have been shown to have a key role in olive productivity, B requires the most attention. Boron plays an important role in olive fruit set, oil content and oil quality (Desouky et al., 2009). In the case of B deficiency, it is commonly first observed in the growing tips of trees.

Nutrient Management of Olive Trees

Research with olive trees has shown that soil analysis is not enough to diagnose nutrient status (Fernández-Escobar, 2004). Foliar analysis is considered the best tool for detecting the nutritional status of an olive orchard (Fernández-Escobar et al., 2009). Sampling olive leaves for nutrient analysis should be done when the concentration of the nutrient elements is most stable, which in North Africa is the period between the end of June and the end of July. Sampled leaves should be picked from the current year's new growth shoots, which are not bearing fruit. Comparing actual leaf nutrient concentration to reference (critical) values (**Table 1**) allows the diagnosis of nutrient deficiency, sufficiency or excess. Fertilizer application to correct any deficiency can be made directly to the soil, by foliar application or through a drip irrigation system.

Table 1. Critical nutrient levels in olive leaves.

	------ Concentration of elements in plants ------		
Nutrient	Deficiency	Optimum levels	Toxicity
N, %	<1.4	1.50-2.00	>2.55
P, %	<0.05	0.10-0.30	>0.34
K, %	<0.40	0.80-1.00	>1.65
Mg, %	<0.08	0.10-0.16	>0.69
Ca, %	<0.60	1.00-1.43	>3.15
Na, %			>0.20
S, %	<0.02	0.08-0.16	>0.32
Cl-, %			>0.50
Cu, ppm	<1.5	4-9	>78
Zn, ppm	<8	10-24	>84
Mn, ppm	<5	20-36	>164
Fe, ppm	<40	90-124	>460
B, ppm	<14	19-150	>185

Adapted from Freeman et al (1994); Fernández-Escobar (2004) and Connel and Vossen (2007) as cited by Haifa-group (available online at www.haifa-group.com/files/Guides/Olive_Booklet.pdf; verified Aug. 30, 2013.).

Table 2. Uptake of nutrients (kg/ha) based on olive production in Tunisia.

Yield, t/ha	N	P_2O_5	K_2O	References
0.7	7	1.7	11.5	Braham (1999)
2.3	15.6	4.2	30	Braham (1999)
10	120	40	160	Malek and Mustapha (2009)

Since the first year of plantation establishment, nutrient requirement of olive trees should be met using a combination of both organic and inorganic nutrient sources. The rate and type of fertilizers used are based on the type of management used in the olive orchard and the yield potential. Nutrients removed as a result of fruit harvest, annual pruning and natural leaf drop must be replaced and returned to the soil to maintain its fertility and crop productivity. Most of the data from North Africa has shown that N and K are taken up in significantly larger amounts compared to P. The quantities of nutrient removed by olive trees (**Table 2**) should be taken into account in any fertilizer recommendation program.

Summary

Management of fertilization in olive groves is a complex issue, dependent on factors including tree variety, age, planting density and whether the groves are irrigated or rainfed. Future success of olive expansion in North Africa, where governments are encouraging the development of the sector, requires further and more detailed research to identify the best management practices (BMPs) needed for improved fruit and oil production under both rainfed and irrigated systems. BC

Dr. Boulal is Deputy Director IPNI North Africa Program; e-mail: hboulal@ipni.net. Mr. Sikaoui is Olive Specialist, INRA Marrakech, Morocco; e-mail: sikaovilhassane@yahoo.fr. Dr. El Gharous is Consulting Director IPNI North Africa; e-mail: melgharous@ipni.net.

References

Ben Mimoun, M., O. Loumi, M. Gharab, K. Latiri, and R. Hellali. 2005. Revue H.T.E. N° 131 - Mars/Juin pp 61-64.

Braham, M. 1999. Revue ezzaitouna, 5(1&2): 22-29.

Delgado, A., M. Benlloch, and R. Fernández-Escobar. 1994. HortScience 29(6): 616–618.

Desouky, I.M., L.F. Haggag, M.M.M. Abd El-Migeed, Y.F.M. Kishk, and E.S. El Hady. 2009. World J. Agri. Sci. 5(2): 180-185.

Elloumi, O., M. Ghrab, and M. Ben Mimoun. 2009. Proc. Intl. Plant Nutrition Colloquium XVI, Department of Plant Sciences, UC Davis. Aug 26-29, 2009.

Erel, R., R. Dag, A. Ben-Gal, A. Schwartz, and U. Yermiyahu. 2008. J. Amer. Soc. Hort. Sci. 133(5): 639-647.

Fernández-Escobar, R., G. Beltran, M.A. Sanchez-Zamora, G. Garcia-Novelo, M.P. Aguilera, and M. Uceda, 2006. Hort. Sci. 41(1): 215-219.

Fernández-Escobar, R., M.A. Parra, C. Navarro, and O. Arquero. 2009. Spanish J. Agri. Res. 7(1): 212-223.

Fernández-Escobar, R. 2004. *In* D. Barranco, R. Fernández-Escobar, L. Rallo (eds.). El cultivo del olivo. Mundi-Prensa, Madrid, pp. 286–319.

Freeman, M., K. Uriu, and H.T. Hartmann. 1994. *In*, L. Ferguson, G.S. Silbert, G.C. Martin (eds.). Olive Production Manual. Univ. CA. Division of Agri. and Resources. Publ. 3353, pp. 77-86. Oakland, California.

Gregoriou, C. and M. El-Kholy. 2010. *In*, AARINENA & FAO Ed., pp: 182-196, ISBN 978-92-5-106348-4.

IOC, 2012. International Olive Council. www.internationaloliveoil.org

Malek, B., and S. Mustapha. 2009. Olivebioteq S6-C3: 169-176.

Vossen, P. 2009. Olivebioteq S4-C2: 8-37.

Effect of Potassium Chloride Application for Rice, Cotton and Potato in the Irrigated Zone of Kazakhstan

By Abdulla Saparov, Rakhimzhan Eleshev, Beibut Suleimenov, Gennadi Peskovki and Alexey Shcherbakov

Over the past two decades a sharp deficit of all nutrients, especially K, has been observed in Kazakhstan. Field trial results indicated a strong positive response to KCl for potato and rice, and a modest response for cotton.

Trend analysis of mineral fertilizer consumption in Kazakhstan shows that N and P fertilizers are of primary importance both in terms of use and supply. Potassium holds a significantly distant third position. Low domestic supply can be somewhat related to an absence of potash production within the country; but the general low use of KCl can also be associated with results of soil tests conducted by the State Agrochemical service, which historically suggest that arable soils are high in K.

The role of K in improving crop productivity is underestimated in Kazakhstan (Mineev, 1999). Research on the effectiveness of KCl on different crops grown within its soil-climatic zones is of particular interest to growers in Kazakhstan because of the potential to not only increase crop yields, but also to improve quality.

A demonstration of the effect of K rate on the yield of potato tubers.

Cotton is a very important crop in Kazakhstan and cotton lint is one of the top agricultural exports. It is sown on approximately 150,000 ha located in the southern region. The crop is grown under irrigation, which allows farmers to obtain high lint yields. Cotton has a long growing season and high yielding plants demand large amounts of K. With average crop productivity, cotton removes 150 kg K_2O/ha. Cotton is especially sensitive to soil K deficits during the vegetative growth period (Suleimenov, 2008; Umbetaev et al., 2008).

One of the most important irrigated crops in Kazakhstan is rice. Its current sown area is about 90,000 to 100,000 ha. Expansion of rice-swamp soils of the Akdalinski irrigational massif reclamation has, over time, led to an increase in areas with low plant available N, P and K (Otarov et al., 2004). Modern high-yielding rice varieties require high rates of K (Esimbekov et al., 2005).

In Kazakhstan, potato grows on an area of about 170,000 ha. The crop also needs a lot of nutrients for normal growth and development. The nutrient removal from a 10 t tuber harvest plus aboveground growth is commonly 60 to 80 kg N, 15 to 22 kg P_2O_5 and 100 to 140 kg K_2O (Aitbaev et al., 2005; Aitbaev, 2010). Potato has a high demand for K and responds well to K fertilizers at different levels of exchangeable K content in soils (Eleshev et al., 2011).

Abbreviations and Notes: N = nitrogen; P = phosphorus; K = potassium; KCl = potassium chloride.

Studies on the effect of KCl on cotton, rice and potato yield were conducted by the Soil Science and Agrochemistry Science Research Institute in south and southeast Kazakhstan in 2009-2011. Field trials with cotton were carried out on experimental fields of the Kazakh Cotton-growing Research Institute, on light grey soils. Rice was sown in the Almaty region on experimental plots on rice-swamp soils. The experiment with potato was conducted on experimental fields of the Kazakh Research Institute on dark chestnut soils in the Almaty region.

Experimental sites were calcareous, loam-textured, low organic matter (OM) soils with high pH values (8.2 to 8.5). The rice-marsh soils had very low OM in the 0 to 40 cm layer (1.83%), 45 mg/kg hydrolysable N, 11.3 mg/kg available P_2O_5, 315 mg/kg exchangeable K_2O, (medium), and a total base saturation of 15 to 17 mg per 100 g soil. Light grey soils had 0.59% OM with 35.3 mg/kg of hydrolysable N, 32.2 mg/kg available P_2O_5 (medium), 303 mg/kg of exchangeable K_2O, and a total base saturation of 15 to 17 mg per 100 g of soil. The dark chestnut soils has 2.21% OM, 80.7 mg/kg hydrolysable N, 88.5 mg/kg of available P_2O_5 (high), 650 mg/kg of exchangeable K_2O (high), and a base saturation of 21 to 23 mg per 100 g of soil.

Cotton and potato were cultivated under irrigation, and rice under full flooding. Cotton and rice were cultivated in monoculture; potato was planted after tomatoes within a vegetable crop rotation.

Ammonium nitrate (34% N) was the N source for cotton and potato, and ammonium sulfate (21% N) was used in rice. Nitrogen application was done in two splits: 30% at planting and 70% as a top-dressing. Phosphorus and K were applied as triple superphosphate (46% P_2O_5) and KCl (60% K_2O) prior to planting. The content of exchangeable K and plant available P were determined using 1% ammonium carbonate $(NH_4)_2CO_3$ solution (Machigin method for calcareous soils).

Table 1. Fertilizer application rates (kg/ha) for cotton, rice and potato.

Treatment	Cotton	Rice	Potato
Control	-	-	-
T2	K_{60}	K_{40}	K_{70}
T3	$N_{150}P_{90}$	$N_{180}P_{90}$	$N_{90}P_{90}$
T4	$N_{150}P_{90} + K_{30}$	$N_{180}P_{90} + K_{20}$	$N_{90}P_{90} + K_{35}$
T5	$N_{150}P_{90} + K_{60}$	$N_{180}P_{90} + K_{40}$	$N_{90}P_{90} + K_{70}$
T6	$N_{150}P_{90} + K_{90}$	$N_{180}P_{90} + K_{60}$	$N_{90}P_{90} + K_{105}$

Soil samples were collected at both 0 to 20 cm and 20 to 40 cm depths before the initiation of experiments, during flowering, and at crop maturity. Treatments and fertilizer application rates are shown in **Table 1**.

Crop K Response

Cotton lint yields showed a significant response to fertilizer application (**Table 2**). However, sole application of K only increased lint yield by 0.2 t/ha beyond the control plot yield of 2.7 t/ha. Significantly higher lint yields with NPK application, beyond that achieved with N and P alone (3.2 t/ha), was obtained with 90 kg K_2O (3.5 t/ha).

Table 2. The effect of fertilizer application on cotton, rice and potato yields in south and southeastern Kazakhstan.

	------- Yield, t/ha -------		
Treatment	Cotton	Rice	Potato
Control	2.7	2.5	13.9
T2	2.9	2.9	18.0
T3	3.2	3.6	23.0
T4	3.4	3.9	26.6
T5	3.4	4.2	27.0
T6	3.5	4.4	27.6
$LSD_{0.05}$	0.3	0.3	1.7

Cotton-growing soils in the region have relatively high soil test K, which has led to the belief that the use of K fertilizer would be ineffective. However, recent research is showing that application of high rates of N and P fertilizer, providing yields above 3.5 t/ha, increases K efficiency. This positive effect is not only observed on areas with low K availability, but also on soils with medium and even high K content (Umbetaev et al., 2008).

In rice, any K application led to the significantly more grain yield compared to the control plot yield of 2.5 t/ha. The effect of N and P, without K, was greater than K alone. The 40 kg K_2O/ha rate proved most effective in combination with the N and P rates tested as the 60 kg/ha rate did not offer any statistical advantage in terms of yield.

Potato productivity was also impacted by K application as 70 kg K_2O/ha, alone, raised tuber yields by 4.1 t/ha beyond the average control plot yield of 13.9 t/ha. Application of 35 kg K_2O/ha together with N and P proved most beneficial in terms of yield since further increases in K rate up to 105 kg K_2O/ha did not prove to be advantageous.

Agronomic Efficiency

The agronomic efficiency (AE) of K for cotton remained high across treatments producing a range of 4 to 6 kg of lint per kg K_2O (**Table 3**). For rice, the range of AE values were also high across K rates up to 60 kg K_2O/ha and ranged between 13 to 15 kg of grain per kg K_2O. For potato, results varied more broadly across rates and ranged from 41 to 94 kg of tubers per kg of K_2O/ha, but this range is indicative of a high response of potato to K application.

Table 3. Agronomic efficiency of K fertilizers in south and southeastern Kazakhstan.

Treatment	kg cotton lint per kg K_2O applied	kg rice grain per kg K_2O applied	kg potato tuber per kg K_2O applied
T3	-	-	-
T4	6	15	94
T5	4	15	53
T6	4	13	41

Economic Efficiency

The data showed considerable economic efficiency of KCl on potato, followed by rice and cotton (**Table 4**). Net profit over K fertilization of potato grew from US$1,898 to 2,008 per ha with K rates between 35 to 105 kg K_2O/ha. Similarly, 20, 40 and 60 kg K_2O/ha in rice gave net return of $468, $667 and $772 per ha, respectively. Net profit from K applied in cotton amounted to $133, $155 and $210 per ha at rates of 30, 60 and 90 kg K_2O/ha, respectively.

Table 4. Economic efficiency of K fertilizers in south and southeastern Kazakhstan.

Treatment	Net profit over K, US$/ha	Value cost ratio (VCR_K)
	--- Potato ---	
T4	1,898	18.9
T5	1,936	10.6
T6	2,008	8.2
	--- Rice ---	
T4	468	11.6
T5	667	11.8
T6	772	10.5
	--- Cotton ---	
T4	133	4.5
T5	155	3.2
T6	210	3.2

In potato, large value-to-cost ratios (VCR) were obtained, which varied from 8.2 to 18.9. Generally, an economically reasonable VCR should be above 3.0 (Sommer et al., 2013). For rice, VCR was very similar at the three K levels and ranged from 10.5 to 11.8. In cotton, VCR was 4.5 at 30 kg K_2O/ha and was 3.2 at both the 60 and 90 kg K_2O/ha rates.

Summary

Results show high efficiency of KCl application together with NP fertilizers on cotton, potato and rice, which are cultivated under intensive irrigated conditions. As a main outcome from this research, new fertilizer recommendations for K have been developed. Depending on the level of exchangeable K the following rates are recommended:

1. For rice yields of 4.0 to 5.0 t/ha—on soils with low exchangeable K use 30 to 60 kg/ha of K_2O, and 30 kg/ha of K_2O for medium testing soils. Among K fertilizers, KCl is the most efficient source. On saline soils, the rate of K application should be reduced by 10 to 15%.
2. For cotton lint yields of 3.5 to 4.0 t/ha—on low K soils, such as the light grey soils, 60 to 70 kg/ha of K_2O is required; high K soils need 30 to 40 kg K_2O; medium K soils need 40 to 50 kg K_2O.
3. For potato grown on dark chestnut soils with high soil test levels (>400 mg/kg) use 40 to 60 kg/ha of K_2O; low K soils require 110 to 120 kg of K_2O/ha. BC

The author acknowledges help from Dr. S. Ivanova, Vice President, Eastern Europe & Central Asia Group and Director, IPNI Central Russia Region, with the preparation of this article.

Dr. Saparov is Professor, Academician of Agricultural Academy of Sciences of the Republic of Kazakhstan, Research Institute of Soil Science and Agro Chemistry after U.U. Uspanov; e-mail:ab.saparov@mail.ru. Dr. Eleshev is Professor, Academician of National Academy of Sciences of the Republic of Kazakhstan and The Russian Academy of Agricultural Sciences. Dr. Suleimenov is Doctor of Agricultural Sciences, Research Institute of Soil Science and Agro Chemistry after U.U. Uspanov; e-mail: beibuts@mail.ru. Dr. Peskovski and Alexey Shcherbakov are Agrochemists, JSC Belarusian Potash Company; e-mail: g.peskovski@belpc.by.

References

Aitbaev, T., et al. 2005. Fertilizer application system of potato and vegetables in southeastern Kazakhstan. Recommendations. Almaty, pp. 44. (In Russian).

Aitbaev, T. 2010. Synopsis of doctoral dissertation, Almaty, pp. 48. (In Russian).

Eleshev, R., et al. 2011. *In* Reports of the Int. Scientific Conf. on "Status and prospects of scientific researches on potato, vegetables and melon growing." Kainar, pp. 475-478. (In Russian).

Esimbekov, M., et al. 2005. The technology of rice cultivation in the Almaty region. The system of agriculture in Almaty region. Almaty, pp. 292. (In Russian).

Mineev, V.G. 1999. Agrochemistry and environmental role of potassium. Moscow State University Press, p. 332. (In Russian).

Otarov, A., et al. 2004. Collection of scientific papers: Actual problems of soil science. Almaty, pp. 114-124. (In Russian).

Sommer, R., et al. 2013. Profitable and sustainable nutrient management systems for East and Southern African smallholder farming systems – challenges and opportunities. pp.91.

Suleimenov, B. 2008. Synopsis of doctoral dissertation. Almaty, p. 44. (In Russian).

Umbetaev, I., et al. 2008. Soil Sci. and Agrochemistry, 1: 90-94. (In Russian).

Umbetaev, I. 2005. Technology of new domestic cotton varieties cultivation in southern Kazakhstan. Monography. Almaty, pp. 252. (In Russian).

UNITED STATES POSTAL SERVICE®

Statement of Ownership, Management, and Circulation (Requester Publications Only)

1. Publication Title	2. Publication Number	3. Filing Date
Better Crops with Plant Food	0 0 0 6 – 0 0 8 9	10/1/2013
4. Issue Frequency	5. Number of Issues Published Annually	6. Annual Subscription Price *(if any)*
Quarterly	Four	Free to Subcribers

7. Complete Mailing Address of Known Office of Publication *(Not printer) (Street, city, county, state, and ZIP+4®)*
International Plant Nutrition Institute
3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844

Contact Person
Gavin Sulewski

Telephone *(Include area code)*

8. Complete Mailing Address of Headquarters or General Business Office of Publisher *(Not printer)*
International Plant Nutrition Institute
3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844

9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor *(Do not leave blank)*

Publisher *(Name and complete mailing address)*
Gavin D. Sulewski
International Plant Nutrition Institute
3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844

Editor *(Name and complete mailing address)*
Gavin D. Sulewski
International Plant Nutrition Institute
3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844

Managing Editor *(Name and complete mailing address)*

10. Owner *(Do not leave blank. If the publication is owned by a corporation, give the name and address of the corporation immediately followed by the names and addresses of all stockholders owning or holding 1 percent or more of the total amount of stock. If not owned by a corporation, give the names and addresses of the individual owners. If owned by a partnership or other unincorporated firm, give its name and address as well as those of each individual owner. If the publication is published by a nonprofit organization, give its name and address.)*

Full Name	**Complete Mailing Address**
International Plant Nutrition Institute	3500 Parkway Lane, Suite 550, Norcross, GA 30092-2844

11. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages, or Other Securities. If none, check box ▶ ■ None

Full Name	**Complete Mailing Address**

12. Tax Status *(For completion by nonprofit organizations authorized to mail at nonprofit rates) (Check one)*
The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes:
■ Has Not Changed During Preceding 12 Months
☐ Has Changed During Preceding 12 Months *(Publisher must submit explanation of change with this statement)*

PS Form **3526-R,** August 2012 *(Page 1 of 3 (Instructions Page 3))* PSN: 7530-09-000-8855 **PRIVACY NOTICE:** See our privacy policy on *www.usps.com.*

13. Publication Title			14. Issue Date for Circulation Data Below	
Better Crops with Plant Food			November 2013	
15. Extent and Nature of Circulation			**Average No. Copies Each Issue During Preceding 12 Months**	**No. Copies of Single Issue Published Nearest to Filing Date**
a. Total Number of Copies *(Net press run)*			12,430	12,430
b. Legitimate Paid and/or Requested Distribution *(By Mail and Outside the Mail)*	(1)	Outside County Paid/Requested Mail Subscriptions stated on PS Form 3541. *(Include direct written request from recipient, telemarketing, and Internet requests from recipient, paid subscriptions including nominal rate subscriptions, employer requests, advertiser's proof copies, and exchange copies.)*	1,156	1,145
	(2)	In-County Paid/Requested Mail Subscriptions stated on PS Form 3541. *(Include direct written request from recipient, telemarketing, and Internet requests from recipient, paid subscriptions including nominal rate subscriptions, employer requests, advertiser's proof copies, and exchange copies.)*	0	0
	(3)	Sales Through Dealers and Carriers, Street Vendors, Counter Sales, and Other Paid or Requested Distribution Outside USPS®	4,369	4,644
	(4)	Requested Copies Distributed by Other Mail Classes Through the USPS (e.g., First-Class Mail®)	500	500
c. Total Paid and/or Requested Circulation *(Sum of 15b (1), (2), (3), and (4))* ▶			6,025	6,289
d. Nonrequested Distribution *(By Mail and Outside the Mail)*	(1)	Outside County Nonrequested Copies Stated on PS Form 3541 *(include Sample copies, Requests Over 3 years old, Requests induced by a Premium, Bulk Sales and Requests including Association Requests, Names obtained from Business Directories, Lists, and other sources)*	4,263	4,067
	(2)	In-County Nonrequested Copies Stated on PS Form 3541 *(include Sample copies, Requests Over 3 years old, Requests induced by a Premium, Bulk Sales and Requests including Association Requests, Names obtained from Business Directories, Lists, and other sources)*	0	0
	(3)	Nonrequested Copies Distributed Through the USPS by Other Classes of Mail *(e.g., First-Class Mail, Nonrequestor Copies mailed in excess of 10% Limit mailed at Standard Mail® or Package Services Rates)*	0	0
	(4)	Nonrequested Copies Distributed Outside the Mail *(Include Pickup Stands, Trade Shows, Showrooms, and Other Sources)*	200	200
e. Total Nonrequested Distribution *(Sum of 15d (1), (2), (3) and (4))*			4,463	4,267
f. Total Distribution *(Sum of 15c and e)* ▶			10,488	10,556
g. Copies not Distributed *(See Instructions to Publishers #4, (page #3))* ▶			1,942	1,874
h. Total *(Sum of 15f and g)*			12,430	12,430
i. Percent Paid and/or Requested Circulation *(15c divided by f times 100)* ▶			57.4%	59.6%

16. ☐ **Total circulation includes electronic copies. Report circulation on PS Form 3526-X worksheet.**

17. Publication of Statement of Ownership for a Requester Publication is required and will be printed in the No. 4, 2013 issue of this publication.

18. Signature and Title of Editor, Publisher, Business Manager, or Owner
Gavin Sulewski
Date 10/1/2013

I certify that all information furnished on this form is true and complete. I understand that anyone who furnishes false or misleading information on this form or who omits material or information requested on the form may be subject to criminal sanctions (including fines and imprisonment) and/or civil sanctions (including civil penalties).

PS Form **3526-R,** August 2012 *(Page 2 of 3)*

Local Data Improves Sensor-Based Nitrogen Recommendations

By Olga Walsh, Robin Christiaens and Arjun Pandey

Sensor-based technologies facilitate assessment of crop nutrient status and account for spatial and temporal variability. This enables fertilizer rate adjustment according to site-specific conditions. Research in Montana shows that nitrogen (N) fertilization algorithms developed in other regions need adjustment using Montana data, for use in Montana.

Crop sensor-based systems with developed algorithms for making mid-season fertilizer N recommendations are commercially available to producers in some parts of the world. Although there is growing interest in these technologies by grain producers in Montana, use is limited by the lack of local research under Montana's semiarid conditions. A field study was carried out at two locations in 2011 and three locations in 2012 in north west Montana: the two dryland sites at the Western Triangle Agricultural Research Center (WATARC) and the Martin farm (Martin) near Conrad, MT, and one irrigated site at the Western Agricultural Research Center (WARC) near Corvallis, MT. The spring wheat variety Choteau was grown at all sites. The objectives of this research were: 1) to evaluate two optical sensors – GreenSeeker© (model 505) and Pocket Sensor (a prototype GreenSeeker Handheld Crop Sensor), 2) to assess whether the algorithms developed in other regions can be successfully utilized under Montana conditions, and 3) determine whether sensor-based recommendations need to be adjusted depending on what N fertilizer source (liquid UAN), or granular urea is used.

Table 1. Prescribed top-dress N rate (lb N/A) using NDVI sensors, by research site and year.

			Year				
	Pre-plant N	Top-dress	---- 2011 ----		------- 2012 -------		
Treatment	rate, lb N/A	N source	WTARC	WARC	WTARC	WARC	Martin
1	0	-	-	-	-	-	-
2	220	-	-	-	-	-	-
3	20	Urea	18	26	13	99	16
4	40	Urea	18	6	13	99	16
5	60	Urea	18	13	13	99	0
6	80	Urea	9	19	24	99	17
7	20	UAN	27	26	20	99	14
8	40	UAN	18	6	13	87	14
9	60	UAN	9	6	17	99	19
10	80	UAN	9	15	17	87	5

Table 2. Grain yield by preplant N and top-dress N at WTARC and WARC, 2011; and WTARC, WARC, and Martin, 2012.

			Mean spring wheat grain yield, bu/A				
	Preplant N	Top-dress	------ 2011 ------		----------- 2012 ----------		
Treatment	rate, lb N/A	N source	WTARC	WARC	WTARC	WARC	Martin
1	0	-	13.8 f	30.4 e	70.5 d	58.5 f	28.3 c
2	220	Urea	39.6 a	55.6 abc	73.9 d	83.0 e	30.6 bc
3	20	Urea	22.8 e	41.5 d	80.0 c	85.4 de	33.3 ab
4	40	Urea	23.1 e	51.0 bc	86.3 a	88.3 bcde	33.3 ab
5	60	Urea	27.7 cd	57.6 ab	85.7 abc	95.8 abc	34.5 ab
6	80	Urea	32.1 b	59.3 a	87.7 a	87.9 cde	35.3 a
7	20	UAN	21.6 e	48.5 cd	80.4 bc	92.7 abcd	33.3 ab
8	40	UAN	24.4 de	52.3 abc	82.6 abc	94.6 abcd	34.4 ab
9	60	UAN	29.5 bc	50.1 bc	82.5 abc	97.7 ab	33.0 ab
10	80	UAN	32.3 b	53.5 abc	86.0 ab	97.9 a	33.8 ab

Means in the same column followed by the same letter are not significantly different, $p < 0.05$.

The experimental design included ten treatments, an unfertilized check treatment (0 lb N/A), a non-limiting N-rich reference treatment (220 lb N/A), and four pre-plant N application treatment rates of 20, 40, 60, and 80 lb N/A applied as broadcasted granular urea. The pre-plant N application treatments were repeated twice, once for in-crop application of UAN and another for granular urea. Individual plot size was 5' x 25' and each treatment was replicated four times. Wheat crop reflectance measurements – Normalized Difference Vegetative Index (NDVI) from each plot were collected at Feekes 5 growth stage. The Feekes 5, early jointing (beginning of stem elongation, prior to first visible node) has been identified in a course of multiple field studies as the most appropriate sensing time for wheat because it provides reliable prediction of both N uptake and biomass. The two GreenSeeker crop sensors (Trimble Navigation Ltd., Sunnyvale, CA) were used to collect the NDVI measurements. According to treatment structure, top-dress N fertilizer was applied as broadcast urea, or as surface applied UAN (using a backpack sprayer with a fan nozzle). Top-dress N recommendations were generated using algorithms experimentally developed for spring wheat: 1. Spring Wheat (Canada), 2. Spring Wheat (US/Canada/Mexico), and 3. Generalized Algorithm. The algorithms are available at: http://www.soiltesting.okstate.edu/SBNRC/SBNRC.php. The Spring Wheat (Canada) and Generalized algorithms did not prescribe any top-dress N fertilizer to be applied at any of the experimental sites in both growing seasons. The top-dress rates prescribed by the Spring Wheat (US/Canada/Mexico) algorithm ranged from of 0 lb N/A to 99 lb N/A depending on the NDVI values measured. The prescribed N rates were applied to experimental plots (**Table 1**), and harvested grain yields were measured at crop maturity (**Table 2**).

A strong linear relationship was observed between NDVI values obtained with GreenSeeker and with Pocket Sensor

Abbreviations and Notes: UAN = urea ammonium nitrate

Obtaining spring wheat reflectance measurements (Left: Robin Christiaens, Research Associate using GreenSeeker Sensor, and Right: Jeff Jerome, Research Assistant using Pocket Sensor), Western Triangle Agricultural Research Center, Conrad, MT, Spring 2012.

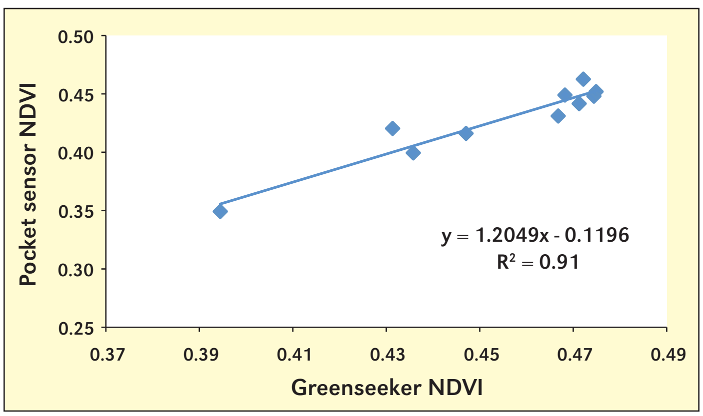


Figure 1. Relationship between GreenSeeker NDVI and Pocket Sensor NDVI, WTARC and WARC, 2011; and WTARC, WARC, and Martin, 2012. NDVI values are averaged by treatment over all five site-years.

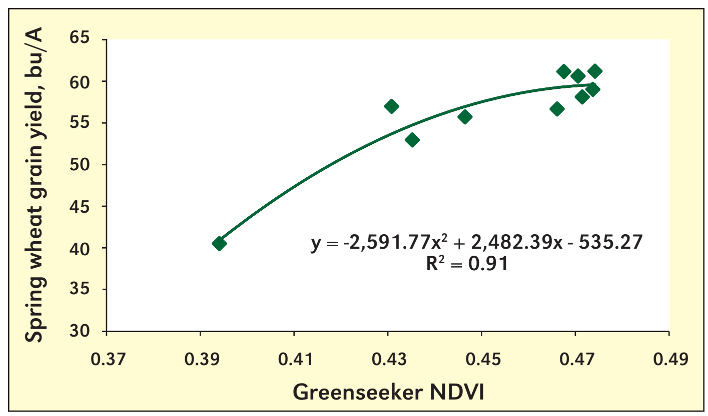


Figure 2. Relationship between mean GreenSeeker NDVI values and mean spring wheat grain yields (averaged over site-years) at WTARC and WARC, 2011; and at WTARC, WARC, and Martin, 2012.

(R^2=0.91) (**Figure 1**). GreenSeeker and Pocket Sensor NDVI readings predicted 91% and 96% of variation in spring wheat grain yields respectively across site-years (R^2 = 0.91 and 0.96) (**Figures 2 and 3**). In both growing season, the rates generated by the USA/Canada/Mexico Algorithm were not appropriate for grain yield optimization. For example, much higher top-dress N rates were prescribed for the irrigated site (WARC) compared to those for the dryland sites WTARC and Martin. This makes sense since the expected yield potential at the irrigated site was much greater. On the other hand, grain yields obtained at WTARC were just as high as at WARC, indicating that the yield potential was either underestimated at WTARC or overestimated at WARC. This puts forward a question of whether there is a need for two separate algorithms, one developed for dryland spring wheat, and another for irrigated spring wheat production systems. At Martin in 2012, a strong relationship between NDVI and grain yield was observed, indicating that

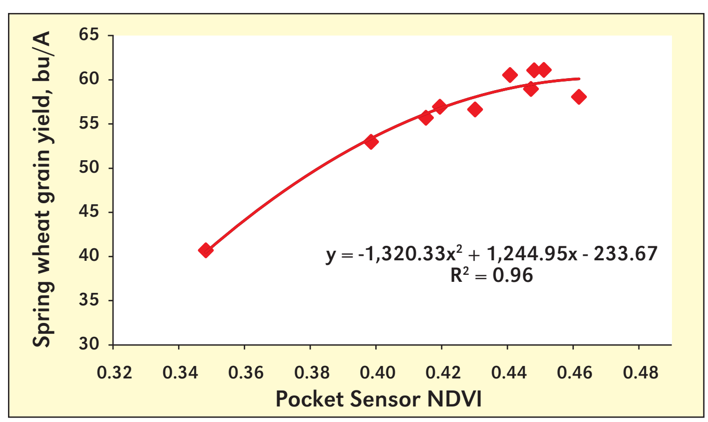


Figure 3. Relationship between mean Pocket Sensor NDVI values and mean spring wheat grain yields (averaged over site-years) at WTARC and WARC, 2011; and at WTARC, WARC, and Martin, 2012.

the sensors performed well in terms of identifying the differences in yield potential among the treatments. The top-dress N rates prescribed at this site-year did not optimize yields. A top-dress rate of 16 lb N/A was generated for Treatment 3, that received 20 lb N/A pre-plant application, compared to a top-dress rate of 17 lb N/A for treatment 6 that received 80 lb N/A pre-plant N application. Treatment 6 was one of the highest yielding treatments (**Table 1**).

Results indicated that both sensors performed well and were useful in predicting mid-season spring wheat grain yield potential. In addition, algorithms developed in other regions did not provide the appropriate top-dress N rates for Montana spring wheat varieties and growing conditions. Lastly, because there were no substantial differences in grain yields associated with top-dress fertilizer N source (urea vs. UAN) at any of 5 site-years, fertilizer rates do not need to be adjusted based on N fertilizer source, urea or UAN.

Currently, additional research is being conducted statewide in Montana to develop improved sensor-based N optimization algorithms for both spring wheat and winter wheat varieties for Montana growing conditions. BC

Acknowledgements

Funding for this research the Montana Fertilizer tax Advisory Committee. Use of the Martin Farm research site, Mr. Linsey Martin, Penroy, MT.

Dr. Walsh (e-mail: olga.walsh@montana.edu) is an Assistant Professor, Soil Nutrient Management, Mr. Christiaens (e-mail: robin.christiaens@montana.edu) and Mr. Pandey (e-mail: arjun.pandey@msu.montana.edu) are Research Associates, Western Triangle Agricultural Research Center, Montana State University.

Fertilizing Crops to Improve Human Health

The importance of fertilizer in boosting agricultural production is well known. It is estimated that at least half of the world's population now depends on fertilizer inputs for growing their food supply. The tremendous increase in agricultural productivity during the last 50 years has contributed to the goal of global food security and raising standards of living.

However, large areas of the world suffer from chronic hunger and still require additional support to overcome persistent shortages. Over 30 million people die each year of malnutrition, making it by far the leading cause of death globally.

In addition to an adequate amount of food (calories), it is also necessary to have adequate nutrition (vitamins and minerals). The Green Revolution focused on boosting the yields of staple cereal crops (such as rice and wheat), but not on the micronutrient-rich crops (such as beans and vegetables). Additionally, plant-breeding efforts tend to focus on traits such as high yields and pest resistance more than the crop nutritional content for human diets.

Trace elements in crops reflect the soil properties the plants are grown on. Crop fertilization with appropriate micronutrients offers a simple and cost effective method of improving the nutritional value of food, especially in regions where pernicious malnutrition has had devastating impacts.

Biofortification of food by using micronutrient-fortified fertilizer can improve the nutritional content of the staple foods that people already eat. This simple technique provides a relatively inexpensive and long-term means of delivering micronutrients to people in need. In some areas, micronutrient fertilizers may also increase crop yields.

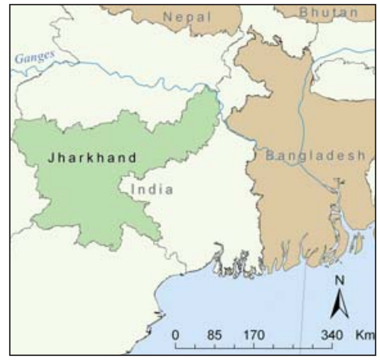
This scientific publication covers other important health aspects related to fertilizer practices such as:

- Proper fertilizer management can increase the health-promoting properties (phytonutrients) of many fruit and vegetables.
- Damage done by plant diseases and pests are reduced through proper plant nutrition. Careful fertilization can improve the quantity, quality, and safety of food crops.
- A scientific review concludes that there is no evidence that organically grown crops are of superior quality. However, supplying appropriate plant nutrients in mineral form enables improvement of crop quality compared with nutrient-deficient crops.
- Calcium (Ca), magnesium (Mg), and potassium (K) are essential for humans. Properly fertilized legumes (beans) and nuts are good sources of Ca. Leafy green vegetables and legumes are rich sources of Mg. Fruits and vegetables are important sources of K. A nutrient-rich soil provides the source of these elements for crops.
- Nutrient management influences the protein, carbohydrate, and oil composition of plants. Fertilizing for optimal yields does not differ greatly from fertilizing for optimum quality for most of the world's major food crops.
- A variety of health-promoting plant substances are enhanced with proper fertilization, such as flavonoids in apples, lycopene in tomatoes, isoflavones in soybeans, sulfur-compounds in plants such as cabbage and broccoli as examples.
- Global food security remains one of the great challenges of the century. Proper plant nutrition (using both inorganic and organic sources) will play a central role in efforts to produce an adequate supply of nutritious food. BC

IPNI and partners have recently published a comprehensive scientific review on this topic with 11 chapters (290 pages) written by global experts. Details on obtaining this publication either in hard copy format or as a free download are available at: http://info.ipni.net/FCIHH

Improving Productivity and Profitability of the Maize-Wheat System in Jharkhand

By Rakesh Kumar, S. Karmakar, Sweety Kumari, A.K. Sarkar, S.K. Dutta and K. Majumdar



Field experiments within the maize-wheat crop sequence grown on the relatively low fertility red and lateritic soils achieved a yield target of 5 t/ha of maize and 4 t/ha of wheat with site-specific nutrient management (SSNM). This research provides a path towards the possibility of doubling current crop production on such soils.

The maize-wheat crop rotation is an important cropping system in the northeastern province of Jharkhand. Yet average maize and wheat productivity in Jharkhand is 1.4 t/ha and 1.6 t/ha, respectively; and are much lower than the national averages of 2.5 t/ha and 3.1 t/ha. Increased productivity of cereal crops can be addressed with proper attention to the introduction of high yielding varieties and suitable nutrient management practices. Red and lateritic soils of eastern India, especially in Jharkhand, have poor fertility because of coarse texture, low organic matter content, soil pH, and availability of N, P and K. Farmers use inadequate amounts of fertilizer and apply them in unbalanced proportions.

Omission plot trial site visit by Dr. Rakesh Kumar (left) and Dr. Sudarshan Dutta (right).

It was hypothesized that maize and wheat yields could be improved by two to three-fold using better quality seed and balanced fertilization. The approach combined an estimation of soil nutrient supply through nutrient omission plots, followed by adequate and balanced application of all yield-limiting nutrients based on attainable yield targets that would also bring about the necessary change in the regional food security scenario.

A field experiment was conducted at the Birsa Agricultural University Farm in Ranchi, Jharkhand to assess the effect of nutrient use and nutrient omission on crop yields, nutrient uptake, soil health, and the economics of the maize-wheat cropping system for two consecutive years (2009-10 and 2010-11). The experiments were carried out with hybrid maize (var. Pioneer 30V 92) grown during the rainy season as a rainfed crop (June to October) and wheat (var. DBW 17) grown in winter as an irrigated crop. The experimental area comes under the Eastern Plateau and Hill region (Agro-Climatic Region 7). The climate is sub-tropical—total rainfalls were 1247 and 1443 mm during 2009-10 and 2010-11, respectively. The soil was sandy loam in texture with pH 5.2, 4.9 g/kg of organic carbon, 272 kg/ha available N, 32 kg P_2O_5/ha, 139 kg K_2O/ha, and 14 kg S/ha. Five treatments comprising ample NPK (250-120-110 kg N-P_2O_5-K_2O/ha for maize and 150-110-100 kg N-P_2O_5-K_2O/ha for wheat), three treatments with successive omission of N, P and K from the ample treatment and a prototype SSNM treatment of 200-90-100 kg N-P_2O_5-K_2O/ha for maize and 120-70-60 kg N-P_2O_5-K_2O/ha for wheat was laid out in a randomized block design with four replications. The nutrient rate in the ample NPK treatment was chosen to avoid any nutrient limitation while the rates in the SSNM treatment was based on published nutrient uptake values for maize and nutrient use efficiencies in the soil (Setiyono et al., 2010; IPNI personal communication).

Abbreviations and Notes: N = nitrogen; P = phosphorus; K = potassium; ₹ = Indian rupee (US$1 = ₹62); CD = critical difference.

For calculation of the system yield, grain yield of wheat was converted to maize equivalent yield (MEY) by multiplying the wheat yield with wheat minimum support price (MSP) and divided by MSP of maize. Composite surface soil samples (0 to 15 cm) were collected after two crop cycles for available N, P and K analysis. Agronomic efficiency (AE) of N, P and K by the cropping system was calculated as described by Cassman et al. (1998).

Crop Yield and Plant Nutrient Uptake by the System

Maize grain yields > 5 t/ha were obtained with the SSNM treatment as well as with the ample NPK treatment (**Table 1**). Wheat yield in the ample NPK treatment was significantly (p

Table 1. Effect of nutrient omission on yield and nutrient use efficiency in maize-wheat sequence.

	Grain yield, t/ha			
Treatments	Maize	Wheat	System (MEY)	kg grain increased/ kg nutrient applied
NPK	5.38	4.63	12.26	17.93
(-N)	1.22	0.86	2.50	8.81
(-P)	3.48	2.98	7.88	13.51
(-K)	4.13	3.63	9.49	18.96
SSNM	5.67	3.78	11.26	22.38
CD (p = 0.05)	0.83	0.52	1.08	

Table 2. Effect of nutrient omission on uptake (kg/ha) of N, P and K by maize-wheat sequence.

	- - - - - N uptake - - - - -			- - - - - P uptake - - - - -			- - - - - K uptake - - - - -		
Treatments	Maize	Wheat	System (MEY)	Maize	Wheat	System (MEY)	Maize	Wheat	System (MEY)
NPK	145.0	99.4	244.4	25.6	18.6	44.2	97.2	117.1	214.3
(-N)	34.6	17.4	52.0	7.4	3.7	11.1	35.5	20.4	55.9
(-P)	92.0	70.0	161.9	16.3	7.1	23.3	67.8	62.9	130.8
(-K)	98.9	92.2	191.1	16.7	13.0	29.7	63.6	85.3	148.9
SSNM	132.0	79.4	211.4	22.9	10.6	33.5	108.2	89.4	197.7
CD (p = 0.05)	20.7	18.1	31.5	3.4	2.8	5.8	20.4	17.4	34.1

Table 3. Agronomic efficiency (%) in maize and wheat in ample NPK and SSNM plots.

Treatments	Maize	Wheat	System
AE of N (%)			
NPK	16.6	25.1	24.4
SSNM	22.2	24.3	27.4
AE of P (%)			
NPK	15.8	15.0	19.0
SSNM	24.3	11.4	21.1
AE of K (%)			
NPK	11.4	10.0	13.2
SSNM	14.0	2.5	10.4

Table 4. Effect of nutrient omission on economics in maize-wheat sequence.

Treatments	Cost of cultivation, ₹/ha	Gross return, ₹/ha	Net return, ₹/ha	Benefit-to-Cost ratio
NPK	60,316	116,470	56,154	1.93
(-N)	53,628	23,750	-29,878	0.44
(-P)	48,241	74,860	26,619	1.55
(-K)	55,057	90,155	35,098	1.64
SSNM	53,535	106,970	53,435	2.00

₹ = Indian rupee (US$1 = ₹62).
Values used for calculating economic data were: Wheat = ₹11.70/kg; Maize = ₹10.50/kg; N = ₹11.40/kg; P_2O_5 = ₹32.20/kg; K_2O = ₹18.33/kg.

≤ 0.05) higher than the SSNM treatment. Maize-wheat system yield, however, did not differ significantly between these two treatments. As expected, significant yield losses were observed in both maize and wheat due to omission of nutrients from fertilization schedules. The highest loss was observed in the case of N omission followed by P and K omissions. Omission of N, P and K in the treatment plots resulted in 77%, 30% and 15.7% lower yields respectively, compared to the ample NPK treatment.

Uptake of N, P and K were highest in the ample NPK treatment (**Table 2**). Omission of nutrients resulted in the reduction of the plant uptake and highlights the importance of balanced fertilization to optimize productivity of crops. Nutrient uptake was lowest in the N omission plots followed by those omitting P and K, and can be associated with biomass production.

Agronomic Efficiency

The AE was calculated by using the example equation for N: AE (for N) = (Yield in NPK plot – Yield in N omission plot) / N applied x 100. The AE of N for the maize-wheat sequence increased by 3% under SSNM compared to NPK treatment (**Table 3**). This was primarily due to higher N utilization efficiency of maize under SSNM management (22.2%) compared to that measured under NPK treatment (16.6%)—caused by excess application of nutrients in the ample NPK treatment following the omission plot experimental protocol. However, this information has considerable importance for farmers of the region as this suggests that optimized SSNM can improve AE of N without compromising crop yield. Similarly, AE of P and K were also increased under SSNM if compared to NPK plots for maize (**Table 3**). Increases in AE were highest for maize compared to wheat or the system as a whole.

Crop response to fertilizer (kg grain/kg NPK applied) was higher in SSNM plots (22.4) than in NPK plots (17.9). Omission of N, P or K from the fertilizer schedule resulted in much lower crop response, which followed the order of N followed by P and then K (**Table 1**).

Soil Available Nutrient Status

Available soil nutrient status after two years of cropping showed major depletion of available N in all treatment plots. Slight depletion of K was also observed across all plots except the N omission plots. A build-up of soil P was observed in all treatments except the P omission plots. Build-up of P and K was highest within the N omission plots, which is most attributed to lower biomass production in this treatment and lower uptake of P and K (**Figure 1**). Considering the widespread deficiency of P in Alfisols of eastern India, the study clearly suggests that P omission can result into extremely low available P status of soil. Soil available K also decreased significantly in the K

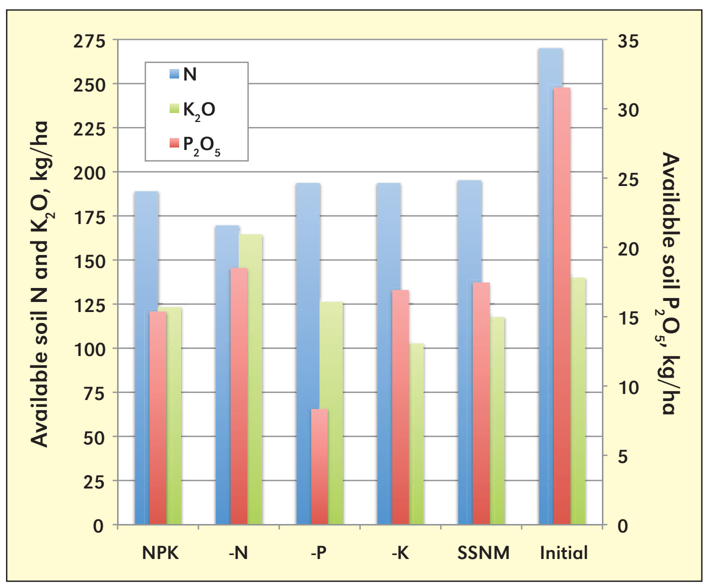


Figure 1. Available nutrient status in fertilized and nutrient omission plots after two crop cycles.

omission plot, but the effect was not as pronounced as the P depletion because of addition of K through irrigation water (data not shown). In P-treated plots, an increase in available P status of soil was observed in both SSNM and NPK plots.

Economics

Economic analysis of the nutrient management practices was determined through a benefit-to-cost (B:C) ratio analysis. The study revealed that the B:C ratio was highest with SSNM (2.00) with a system yield level of 11.3 t/ha followed by the NPK treatment plot (1.93) that yielded 12.3 t/ha (**Table 4**). A lower B:C value associated with the NPK treatment can be attributed to higher input cost associated with additional nutrients prescribed by the omission plot protocol. Omission of N generated a negative net return and lowest B:C ratio (0.44). Omission of P and K produced B:C values of 1.55 and 1.64, respectively. This indicates that production and profitability could be increased in maize-wheat system in Jharkhand with balanced nutrient management practices.

Summary

The study highlights that maize and wheat yields in Jharkhand could be increased two to three-fold to nearly 5 t/ha each with proper nutrient management. The response data obtained from the experiment could provide an alternate approach of estimating nutrient application rates to achieve targeted yields of maize and wheat. One of the advantages of the omission plot approach of estimating soil nutrient supply capacity is that it circumvents the infrastructural issues associated with soil testing and provides an alternate method of estimating site-specific nutrient rates for a crop sequence. This can help in disseminating SSNM strategies for farmers in eastern India for improved productivity, farm profit and environmental sustainability. BC

Dr. Kumar is Professor, Department of Soil Science and Agriculture Chemistry (E-mail: rkssacbau@rediffmail.com); Dr. Karmakar is Chief Scientist, Department of Agronomy; Ms. Kumari is a M.Sc. Ag. Student; Dr. Sarkar is Former Dean, Faculty of Agriculture—all with Birsa Agricultural University, Kanke, Ranchi, India. Dr. Dutta is Deputy Director, IPNI South Asia Program, Kolkata, India. Dr. Majumdar is Director, IPNI South Asia Program, Gurgaon, India.

References

Cassman, K.G., S. Peng, D.C. Olk, J.K. Ladha, W. Reichardt, A. Dobermann, and U. Singh. 1998. Field Crops Res. 56:7-38.

Setiyono, T.D., D.T. Walters, K.G. Cassman, C. Witt, and A. Dobermann. 2010. Field Crops Res., doi:10.1016/j.fcr.2010.05.006

Conversion Factors for U.S. System and Metric

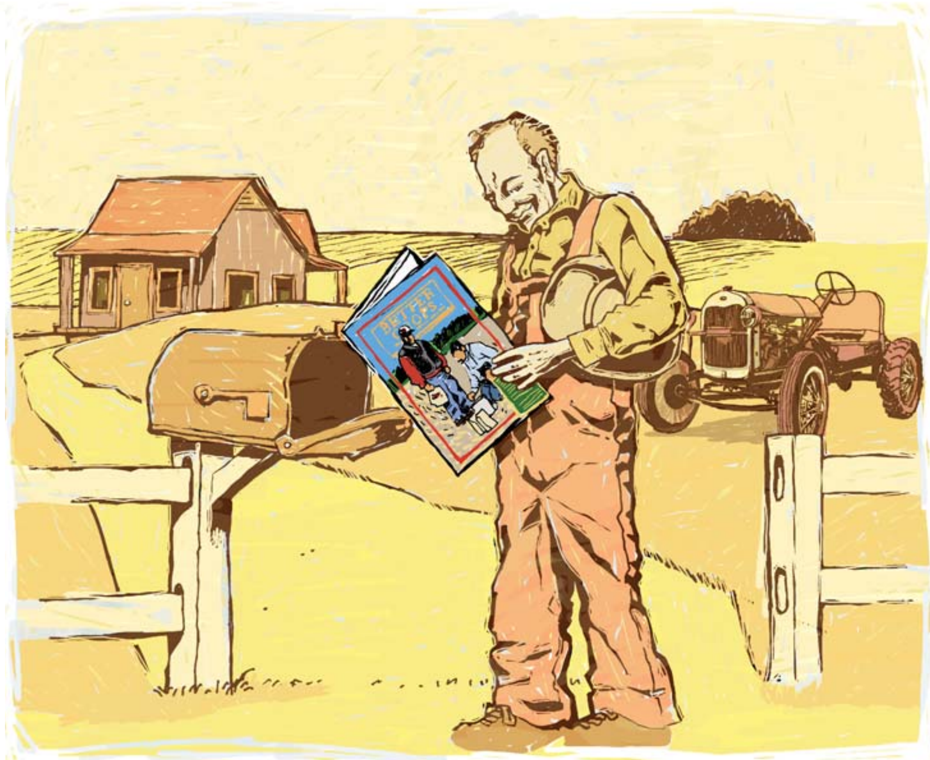
Because of the diverse readership of *Better Crops with Plant Food*, units of measure are given in U.S. system standards in some articles and in metric units in others…depending on the method commonly used in the region where the information originates. For example, an article reporting on corn yields 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.

Better Crops … IPNI's Flagship Publication



A flagship is the first, largest, fastest, most heavily armed, or best-known ship in the fleet. In our fleet of publications—and we have a large fleet—*Better Crops With Plant Food* is our flagship. When I was first introduced to the magazine as a graduate student, it was celebrating its 60th birthday. Today, *Better Crops With Plant Food* is finishing its 90th year and while it has undergone a few face-lifts over the years, it is as popular now as it ever has been.

Better Crops, a.k.a., the pocket book of agriculture, was founded in 1923. *Plant Food*, a contemporary founded in 1926, merged with *Better Crops* and *Better Crops With Plant Food* was born. We acquired the publishing rights in 1935 and have been publishing *Better Crops With Plant Food* ever since.

The new magazines' editorial guidelines stated "The policy of Better Crops With Plant Food is to stimulate interest in all factors pertaining to more efficient crop production and to give accurate information on such subjects. In developing more efficient agriculture … one of the most important factors is sound research and experimental work. We believe such research work is of greatest value when translated into more efficient production." That policy statement has served the magazine well for over 75 years and its just as applicable today as it was in 1935.

Some 3,800 articles written by more than 3,600 authors have been published. Many authors contributed more than once; some up to a dozen or more articles. Topics have included soils, crops, fertilizers, economics, diagnostics, and much more. And the back cover always provides food for thought.

Better Crops is a forum for agriculture and is our flagship publication.

BETTER CROPS
International Plant Nutrition Institute
3500 Parkway Lane, Suite 550
Norcross, Georgia 30092-2844
www.ipni.net

Terry L. Roberts