PLANT NUTRITION WITHOUT BORDERS

IPNI
International
Plant Nutrition
Institute

Program Report 2013

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- Fertiliser Association of India (FAI)
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- International Potash Institute (IPI)
- The Fertilizer Institute (TFI)

The mission of IPNI is to develop and promote scientific information about the responsible management of plant nutrition for the benefit of the human family.

Plant Nutrition Without Borders

IPNI has 30 scientists working in 12 agronomic programs worldwide and we support research and educational activities in more than 50 countries. Each of our regional programs has a geographic border, but the issues related to plant nutrition are borderless. Because the science related to plant nutrition is universal, our approach has been to group nutrient issues into global thematic areas that can be addressed at a local scale.

Five years ago we organized our staff into working groups to address six thematic areas—Nutrient Use and Cycling; Fertilizer Best Management Practices (BMPs) and Nutrient Use Efficiency (NUE) – 4R; Nutrients and the Environment; Spatial Nutrient Issues; Nutrient Management Decision Support; and Nutrients and Society—as part of a global tactical approach to help us address specific nutrient-based issues. These themes have evolved somewhat as the issues have been evaluated and studied and as results or deliverables have been produced.

Our working group arrangement positions our scientific staff to manage regionally focused programs that incorporate the global challenges and opportunities we face as we strive to sustainably manage plant nutrients efficiently and effectively in their essential role in food security. This annual report will highlight some of our accomplishments that illustrate how plant nutrition and nutrient management share common regional and global objectives and the cross-cutting nature of our program activities.

4R Nutrient Stewardship is a good example of an initiative that developed within our thematic area of fertilizer BMPs and nutrient use efficiency. 4Rs (right source, right rate, right time, right place) began with a question and proposition in a paper raised by Dr. Paul Fixen, IPNI's Senior Vice President, at an International Fertilizer Industry Association (IFA) workshop in 2007. The question: "Can we define a global framework within which fertilizer BMPs can be adapted to local conditions?" This question and the ensuing discussion led to a worldwide dialogue that resulted in an approach for fertilizer BMPs adopted by the world's fertilizer industry. This approach to nutrient management considers economic, social, and environmental aspects that are essential to the sustainability of agricultural systems.

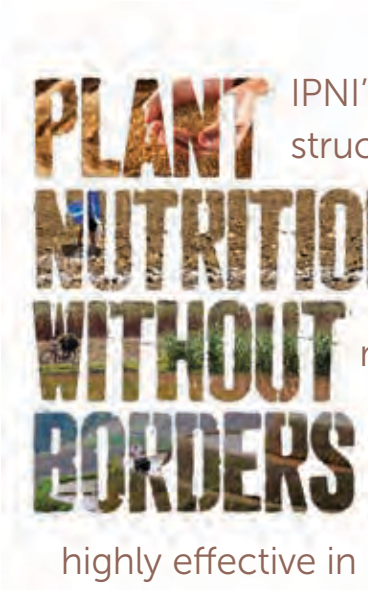
What has been IPNI's role in 4Rs? We have led in the scientific development and support of the concept. We expanded the framework initially put forth by Dr. Fixen. We prepared articles in the farm press and co-authored articles with our academic colleagues promoting the concept within scientific societies and crop advisers. We organized workshops, spoke at conferences, and prepared videos explaining the 4Rs. And we developed a global manual detailing the scientific principles behind each of the four "rights" complete with examples and case studies. We have partnered with our colleagues in IFA, The Fertilizer Institute, and the Canadian Fertilizer Institute to support the adoption and implementation of 4R Nutrient Stewardship within the industry.

The 4R story is not finished. There is still much to do. There are knowledge gaps that will require research and there are awareness gaps that will require more education. IPNI will continue our involvement in scientifically supporting nutrient management through 4Rs.

4Rs are just one example, which will be further expanded later in this report. Other examples such as the multi-country adoption of our Nutrient Expert®, a computer-based decision support tool for making fertilizer recommendations, or adapting our Southeast Asia oil palm management technology to other regions, or our private/public partnerships to study and manage greenhouse gas emissions will also be highlighted.

We encourage you to read and learn about the some of the accomplishments of IPNI and our regional programs from around the world in the following report.

Terry L. Roberts, Ph.D.
President



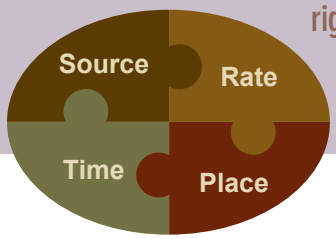
IPNI's tactical approach utilizes the global thematic working group structure outlined by Dr. Roberts combined with geographic regions. Each IPNI staff member has both group and regional responsibilities. Through IPNI's first six years, we have learned that this structure is highly synergistic due mostly to the universality of the scientific foundation of plant nutrition. If a problem exists in one part of the world, it very likely exists or has been encountered in other regions making a globally distributed, but well-connected, group of scientists highly effective in developing a solution to the problem. The refinement of 4R Nutrient Stewardship into a global framework and associated process has greatly facilitated IPNI's ability to connect the universal but dispersed science of crop nutrition to the highly site-specific practice of nutrient stewardship.

Today we see most of the primary themes of IPNI programs pursued through a combination of working group activities and regionally born activities that may be linked to a group but follow a region-specific path. This approach helps assure local relevancy and yet retains the power of a borderless view of the science of plant nutrition. The primary program themes and associated working group activities for IPNI follow.

FERTILIZER BMPS AND NUE – 4R

Fertilizer BMPs (Best Management Practices) are the tools used at the farm level for efficient and effective nutrient management within cropping systems. Based on agronomic science, they are the major means for crop producers to simultaneously meet economic, environmental and social goals. Facilitation of the development and adoption of fertilizer BMPs and advancing the understanding of appropriate parameters for defining BMP impact on nutrient use efficiency (NUE) are the main objectives in this thematic area. IPNI has worked with the fertilizer industry to develop the 4R Nutrient Stewardship approach to fostering BMP adoption at the farm level.

The 4R principles, applying the right source of nutrient, at the right rate, right time and in the right place, are a powerful means of helping farmers and their advisors make economic and environmentally responsible nutrient management decisions, which have a positive impact on society as a whole.



Defining and communicating the science of 4R Nutrient Stewardship

The publication and distribution of *4R Plant Nutrition – A Manual for Improving the Management of Plant Nutrition* was a major long-term accomplishment for IPNI in 2012. The process began in 2007 with the initial definition of a global framework and launched in earnest in 2010 with the development of a formal manual outline. Coordinated by what was at the time the Fertilizer BMPs and NUE Working Group, chaired by Northeast North America Director, **Dr. Tom Bruulsema**, it eventually involved all scientific staff and many of our supporting personnel. The concept of "Plant Nutrition Without Borders" was a core principle of the 4R subject and also essential to the process of manual development. Its development recognized no geographic borders and also broke across academic and private sector borders as it created a global practice-based manual from a concept rooted in a 1988 paper co-authored by J.T. Thorup of Chevron Chemical Company and J.W.B. Stewart of the University of Saskatchewan. Our manual truly assembles in one cohesive document the science, experience, and vision of sustainable nutrient stewardship from numerous sources around the world, from both the public and private sectors, and from the laboratory and the field.

Two print versions of the manual were published in 2012, a North American version with Imperial (U.S.) units, and a Metric version. An eBook version of the manual was also produced specifically for iPad users. The manual is currently being translated into other languages including Spanish, Portuguese, Russian, Mandarin, French, and Arabic. A set of nine accompanying PowerPoint presentations totaling over 250 slides with speaker notes was developed and released to the public early in 2013. Some case studies that show local examples of application of 4R principles were included in the manual, but many more are needed to facilitate use of the manual as a training tool at the field level. This remains a major unfinished aspect of the manual and a task IPNI staff will focus on in 2013 and into the future. We have invited users of the manual to submit their own case studies to be offered through a supporting web portal.

Another crop specific 4R video was developed this year under the leadership of **Dr. Steve Phillips**, Southeast U.S. Director. *"The right way to grow rice"* will be available in mid 2013. The video is expected to be adapted and translated into other languages similar to the process used for the popular 4R wheat video "*The right way to grow wheat*". For example, the Russian version of this video has been released in 2012 with translation and narration by **Dr. Vladimir Nosov**, Director, Southern & Eastern Russia. This has been an important addition to the regional program and website. This 4R video is now widely demonstrated during events with IPNI participation.

IPNI has also been heavily involved in promoting the 4R concept to regulatory, industry and academic leaders as the best way forward to enhance nutrient management. The common thread of the 4Rs throughout the activities of our staff provides opportunity for sharing materials and consistent messaging as we act on the philosophy of Plant Nutrition Without Borders in IPNI programming. As an example, **Dr. Rob Mikkelsen**, Western North

4R Plant Nutrition Manual—one year into its debut, our 4R manual has established itself as the leading resource able to detail the science behind each of the four "rights" and on-farm adoption of 4R practices. Through the use of interactive elements that enhance the content, our 4R Manual eBook delivers a complimentary learning experience to our hardcopy. A set of nine PowerPoint presentations provide an integrated training resource for use with our 4R Manual. Crop-specific videos explaining the "right way to grow" are also available as a 4R training resource.

IPNI's BMP Research Plot in Nursery on the IJM Plantation, in Sandakan, Malaysia.

America Director, received a grant to develop educational materials for growers, which will improve their nitrogen (N) use efficiency for major N-using crops. In addition to written material, he is developing web-based training materials and a smartphone app for implementing the 4R concepts within a N budget. As another example, at a meeting of the USDA Partnership Management Team, Dr. Bruulsema spoke to a group of 35 leaders of USDA agencies including the Natural Resources Conservation Service, the Agricultural Research Service, and the National Institute for Food and Agriculture. He explained how industry's enthusiastic embrace of 4R Nutrient Stewardship was helping agri-service providers to advocate for change to source, rate, timing and placement practices. In follow-up to the meeting, Dr. Bruulsema and the other speakers were thanked for being "very successful at helping identify opportunities for tech transfer and in stimulating discussion of the directions we need to go for increasing N use efficiency."

At the dealer or farmer level, **Dr. Tom Jensen**, Northern Great Plains Director made numerous presentations on improving fertilizer efficiency through source selection and technologies, appropriate use of soil testing within a 4R framework, and how fertilizer dealers can work with farmers for 4R implementation. And, **Dr. Rob Norton**, Australia & New Zealand Director, has been speaking to groups from the dairy, grains and grazing industries on the 4R approach. His most recent dairy industry

Dr. Tom Bruulsema, Director, Northeast North America

training program on fertilizer use has the 4R Nutrient Stewardship concept at its core. The Grains Research and Development Corporation has also adopted a 4R approach in the latest nutrient management research and extension programs for the grains industry in Australia.

Dr. Luís Prochnow, IPNI Brazil Director, informed Rio+20 participants about 4R Nutrient Stewardship and related fertilizer BMPs. Many times, participants of important global discussion forums such as Rio+20 are not aware

Dr. Valter Casarin, Deputy Director, Brazil (North & Northeast)

of fertilizer's importance to human beings. With this in mind, Dr. Prochnow participated at several side events during Rio+20. His main task was to inform the general public about 4R Nutrient Stewardship principles and how this framework can help farmers around the globe to efficiently use fertilizers. The *"right source, right rate, right time, and right place"* concept was very well received and other speakers following Dr. Prochnow quoted the concept in their own presentations.

4R Nutrient Stewardship is also being applied as part of programs focused on specific regional environmental issues. With the signing of a new Canada-U.S. Great Lakes Water Quality Agreement, more attention is going to be paid to the role of the 4Rs in mitigating losses of dissolved P from cropland. There is a recent trend of increased loadings and concentrations of dissolved phosphorus (P) leading to more frequent algal blooms in Lake Erie. Dr. Bruulsema focused on this topic in presentations to agri-service providers in Ohio, Michigan, Ontario, New York, and beyond—and in a regional newsletter. Expanded presentations on this topic, in collaboration with the Nature Conservancy, are planned for 2013. Dr. Bruulsema also partnered with the American Society of Agronomy to deliver a webcast on the 4R approach to soil and water quality, and with the

Dr. Eros Francisco, Deputy Director, Brazil (Midwest)

Livestock and Poultry Environmental Learning Center Educational Webcast Series to deliver a webcast on the 4Rs of Nutrient Stewardship.

Fertilizer BMPs

Fertilizer BMPs are the in-field manifestation of 4R Nutrient Stewardship and there is a constant need to educate farmers and crop consultants on how to efficiently use fertilizers. IPNI Brazil continues its program on fertilizer BMPs, now with regional symposia around the country. In 2012, symposia were organized in Parana and Bahia. The event is adapted to each region to fulfill their needs and address specific local problems of plant nutrition. The 4R Nutrient Stewardship principles were incorporated into the symposium and more and more people around the country are in contact with 4R examples. Besides the Fertilizer BMPs regional symposia, IPNI Brazil is involved in co-coordinating other events with similar goals of educating the public on how to use fertilizers efficiently. **Dr. Valter Casarin**, IPNI Brazil Deputy Director for the North & Northeast region of Brazil, coordinates these events.

In the state of Mato Grosso, IPNI partners with the Research Foundation MT in evaluating fertilizer BMPs and nutrient cycling within various cropping systems. This project has allowed farmers and crop consultants to calculate the amount of nutrients cycled for each cropping system, helping them develop improved approaches with increased nutrient use efficiency and productivity. **Dr. Eros Francisco**, IPNI Brazil Deputy Director for the Midwest region and Research Coordinator, oversees this effort.

In Mexico, defining and promoting fertilizer BMPs is being accomplished through IPNI participation in the MasAgro initiative. MasAgro was launched in 2011 by the Mexican Government, aiming for the sustainable

Dr. Tasistro (left) from his office explains the 4R Nutrient Stewardship approach to agronomy students at the National Agrarian University in Nicaragua (right) through a webinar.

modernization of Mexican agriculture over a 10-year period. IPNI's Mexico and Central America Director, **Dr. Armando Tasistro**, has been involved in MasAgro since its launch by participating in its "Take It to the Farmer" component. The objectives of this component include increasing annual maize production by 5 to 9 million metric tons (t) in rainfed areas and increasing wheat production by 350,000 t. IPNI has provided advice on strategies to improve soil nutrient management, which is a key aspect of this component. These and other educational efforts in Mexico have pivoted around the 4R Nutrient Stewardship concept, which has been increasingly accepted as a valuable tool to attain more sustainable nutrient use. In addition to regular classroom activities, internet-based training has greatly increased IPNI effectiveness in this vast country by allowing us to reach a greater number of trainees over wider distances.

Dr. Armando Tasistro, Director, Mexico and Central America

In Northern Latin America, oil palm has become an exciting crop. Many see it as the crop with the largest expected increase in planted area and yield in the region. Fertilizer BMPs utilized within well managed cropping systems are essential to realize these gains. Our Northern Latin America program cooperated with the Southeast Asia program in translating and adapting a book on the management of oil palm originally written for

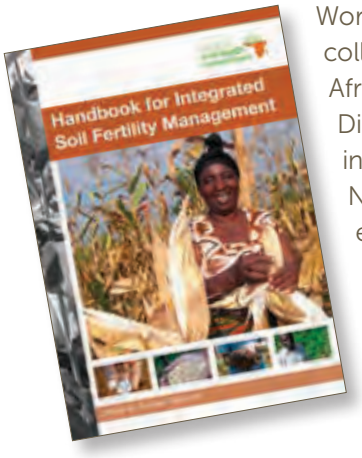
Dr. Raúl Jaramillo, Director, Northern Latin America

Southeast Asia. A series of five book release events were conducted across Northern Latin America under the leadership of IPNI Regional Director, **Dr. Raúl Jaramillo**, and involving oil palm grower organizations and IPNI members. The book was an immediate hit. This transfer of knowledge is a good example of the "Plant Nutrition Without Borders" concept at work.

In Australia, Dr. Norton completed a fertilizer BMP guide in 4R format for canola and delivered canola nutrition workshops. A vegetable crop guide is under development as well.

In southern India **Dr. T. Satyanarayana**, Deputy Director, is working in collaboration with the Central Research Institute for Dryland Agriculture (CRIDA) on "Improving Nutrient Use Efficiency and Profitability in Rainfed Production Systems." On-station experiments conducted since 2009 have demonstrated that the balanced use of nutrients in conjunction with residue management not only helped in improving the yield of both maize and horse gram, but also improved the economics for rainfed farmers. The project clearly supports improved plant nutrition as part of a conservation tillage program in rainfed regions.

A field technician taking soil samples for water and nutrient analysis in Chikwawa, Africa.



Working with a large group of collaborators in sub-Saharan Africa, **Dr. Shamie Zingore,** Director, has been busy working to develop a series of 4R Nutrient Stewardship knowledge products for both research and extension in the region. One group he works with, the Africa Soil Health Consortium, released the Handbook for Integrated Soil Fertility Management (ISFM) in 2012. Available in both hard copy and memory stick versions, the ISFM manual provides both guidance on nutrient management approaches as well as support for achieving 4R Nutrient Stewardship strategies. Additional work includes "translating science into practice", a project which takes the results of key research papers and develops extension materials, and mobile phone SMS service to disseminate nutrient management, and 4R Nutrient Stewardship information to farmers and agronomists in Western Kenya.

Dr. Shutian Li, Deputy Director, China (Northwest)

In Northwest China, Deputy Director **Dr. Shutian Li** has taken an active step in linking his field research activities to the 4R Nutrient Stewardship activities of IPNI. In a series of projects with potato, cotton, apple, and processing tomato, Shutian has developed his field trials to address the issues of fertilizer rate, source and time of application to better identify management strategies for K. He is working toward the development of 4R Nutrient Stewardship guidebooks for the region. As Shutian notes, "the future of food security in China is going to have to come from the western region and IPNI needs to take a lead role in laying the groundwork for economic and efficient nutrient management."

Dr. Fang Chen, Deputy Director, China (Southeast)

Across China during the past four years, IPNI staff has been working with an IPNI member company to evaluate the potential of controlled release urea (CRU) as an alternative N product. A major challenge facing many farmers in China is the lack of on-farm labor for in-season N application, a significant BMP to improve N use efficiency. The summary from a workshop attended by Drs. Li, **Shihua Tu** (Deputy Director, Southwest), **Fang Chen** (Deputy Director, Southeast), and **Ping He** (Director, China Program) showed that rice, corn and potato yields were significantly increased when CRU was used relative to similar rates of untreated urea. In fact, CRU had a major impact on improving N use efficiency, showing improved N recovery by 13-25% in rice, and a savings of up to 25% in total fertilizer N requirement. While these results from irrigated systems were impressive, the impact was less significant in upland crops grown under rainfed conditions. The responses recorded in this project clearly demonstrate the potential of new fertilizer technology in improving N use efficiency.

Dr. Ping He, Director, China Program

In 2012, the sub-Saharan Africa and South Asia programs of IPNI were successful in securing funding from the International Maize and Wheat Improvement Center (CIMMYT) for a new project entitled "Assessment of agronomic and economic benefits of fertilizer use in maize production systems under variable farm size, climate and soil fertility conditions." This one-year project was awarded to South Asia Program Director, **Dr. Kaushik Majumdar**, in India and Dr. Zingore in Kenya. The project involves gathering farm data to support the development of economic groups (farmer typology) within the farm community, and evaluation of nutrient management options that are potentially acceptable to each of these groups. This grouping is based on both access and use of nutrient inputs by farmers. It is anticipated that IPNI will benefit from this project through the development of recommendations for each of the farmer groups. The project will also provide a better understanding of what types of nutrient management technology are most acceptable, leading to better approaches in targeting our technology transfer activities. In South Asia, Drs. Satyanarayana and **Sudarshan Dutta**, Deputy Director (East Region) have both played a major role in the gathering of this farm-based survey data, while research co-operators have played this role in Africa.

Dr. Sudarshan Dutta, Deputy Director, South Asia (East)

The oil palm research conducted by IPNI in Southeast Asia is all based on quantifying a set of BMPs for the crop. This includes completed work on mature oil palm stands, and on-going work on nursery, immature and mature oil palm, as well as work on a detailed evaluation of oil palm nutrition.

Working with consultant experts in oil palm, **Dr. Thomas Oberthür**, Director, has summarized past oil palm projects showing that implementing a series of agronomic and nutrient management practices at the plantation level can significantly increase oil yield and profitability. These BMPs include increased harvesting frequency, frond management around the palms, weed control and fertilizer management. The research shows that initial (first 1-2 year) responses are mainly from the agronomic practices, while after 2 years the impact of fertilizer management was fully evident. The research also clearly showed that where management was optimized already, little benefit could be obtained from the application of BMPs. This initial work has resulted in new on-going projects, which look at management starting in the nursery through to the mature oil palm. Given the labor challenges facing oil palm producers there is great interest in also establishing a working database of performance indicators, allowing the plantation manager to understand where productivity is highest and harvesting should be focused in times of labor shortage.

In 2012, oil palm producers in Southeast Asia acquired plantations in West Africa. With their experience in working with IPNI in Southeast Asia, they immediately requested the initiation of a BMP project in Ghana. Their experience with BMPs optimizing plantation production, as well as staff training, led to their request through IPNI member companies. Dr. Oberthür and Dr. Zingore have established a series of plantation BMP projects in Ghana. The unique feature of this project is that it also involves a collaborative agreement with a European NGO who will contribute support to linking our plantation project to their neighboring smallholder 'out growers'. These out growers actually supply oil palm fruits to the plantation mill of our cooperators, supporting higher efficiency in the oil extraction mill as well. ■

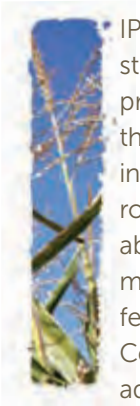
Dr. Thomas Oberthür, Director, Southeast Asia

NUTRIENTS AND THE ENVIRONMENT

Fertilizer has the potential for both positive and negative contributions to climate change, and potentially harmful effects on water and air quality. It is critical that the industry addresses these effects and manages nutrients appropriately to help minimize agriculture's environmental footprint. The major concerns are emissions of nitrous oxide (N_2O), methane (CH_4), and ammonia (NH_3) associated with N fertilizer use, the impact of fertilizers on soil carbon (C) and carbon dioxide (CO_2) balances, and loss of N [principally nitrate (NO_3)] and P (particulate and orthophosphate) to surface waters and loss of NO_3 to groundwater. This working group had the objectives of establishing IPNI as a leading source of practical, objective, scientific information on fertilizer management and environmental quality by developing key publications on fertilizer best management and environmental quality.

The many environmental issues associated with crop nutrient use continue to be a significant component of IPNI programs. Nitrogen and P receive the most attention when problems are being identified, but real-world solutions involve all crop nutrients since balanced nutrition is essential for acceptable nutrient use efficiency. Examples of 2012 activities for the major issues are addressed below.

World food security



IPNI's general approach to environmental issues starts with the role of crop nutrients in food production—that agriculture has no choice other than to continue to increase productivity to meet increasing needs and fertilizer plays a critical role in that process. There are serious questions about how enough food will be produced to meet future need, and what role commercial fertilizer plays going forward. **Dr. Mike Stewart**, Central and Southern Great Plains Director, addressed this question in a paper published in 2012. The paper co-authored by Dr. Terry Roberts, entitled "Food security and the role of fertilizer in supporting it", was published by Elsevier Press in Engineering Procedia. Getting this message into scientific publications is critically important as funding and policy decisions are made concerning environmental problems. Workable solutions that are real solutions cannot come at the cost of productivity.

Dr. Mike Stewart, Central and Southern Great Plains Director

Fertilizer impacts on soil quality

An international misperception exists that fertilizer N degrades soil quality and causes loss of soil organic matter; and that major agriculture regions of the U.S. have excessively positive N balances because U.S. farmers are routinely over-applying fertilizer N. Several publications were developed in response to these concerns.

- An article on the role of N fertilization in sustaining organic matter in cultivated soils authored by a cadre of leading international scientists (Ladha, Reddy, Padre, and van Kessel) was published in IPNI's quarterly magazine *Better Crops with Plant Food*.

Dr. Cliff Snyder, Nitrogen Program Director

- **Dr. Cliff Snyder**, Nitrogen Program Director, authored a *Better Crops with Plant Food* article showing that the vast majority of Midwest U.S. corn farmers apply N at university recommended rates.
- Dr. Snyder also introduced data into a peer-reviewed scientific journal (Frontiers in Ecology and the Environment) that more accurately portrayed North American N balances.
- Evaluation of nutrient balance is also a focus of IPNI's program in Brazil where from 2006 to 2010 an average of 69, 53 and 81% of the N, P and potassium (K) applied was taken up by crops. Our Brazilian staff, Drs. Prochnow, Casarin and Francisco, see these percentages as being reasonable considering the objectives of nutrient use in Brazil and compared to other regions of the world where the ratio of removal to use is sometimes too low or too high, indicating either the potential for high nutrient losses or exhaustion of soil fertility and therefore soil quality. In addition to calculating a general nutrient balance for the whole country, IPNI has estimated balance by crops and states. These estimates were used in the development of the tactical plan for Brazil for the next five years in defining targeted areas and crops for primary focus in the years to come.
- Argentina research by the Institute for Plant Physiology of INTA has shown the beneficial effects of balanced NPS fertilization on soil microbial activity in papers presented at the 2012 Soil Science Congress of Latin America and published in IPNI's *"Informaciones Agrónomicas de Hispanoamérica"*. The field plots

Maturing corn in mid-tasselling stage.

Dr. Fernando García, Director, Latin America–Southern Cone

used in this study were in the Southern Santa Fe Crop Nutrition Network, coordinated by **Dr. Fernando García**, Latin America-Southern Cone Director.

- Dr. Rob Norton collated and presented information on trends in soil C and other nutrients from a long-term fertilizer experiment in the Victorian cropping region. This was published in the Australian Society of Agronomy biennial conference and showed that even very high N use (2-3 times recommended) did not reduce soil C, and that adequate P was critical to building C due to its stimulation of N and C input from legumes crops in the rotation.

Surface and groundwater quality impacts

Many are concerned that surface and ground waters are not being protected adequately from N contamination; that the U.S. Midwest 2012 drought increased nitrate loss risk; and that Mississippi River N loads to the Gulf of Mexico have not decreased since 1980, aggravating hypoxia development. In response, Dr. Snyder enlisted the assistance of a highly respected USDA-ARS N scientist, Dr. J.J. Meisinger, to co-author an IPNI *INSIGHTS* article on capturing residual soil N with winter cereal cover crops. He also worked with other IPNI scientists and PAQ Interactive to develop a paper on N efficiency and flux from the Mississippi River Basin to the Gulf of Mexico for the Soil Science Society of America annual meeting. In the paper he emphasized comprehensive 4R Nutrient Stewardship, balanced fertilization—especially improved P and K management where soil test P and K are below agronomic optimum levels, and the importance of education for voluntary improvements in plant nutrition and improved nutrient use efficiency and effectiveness while meeting global food demands. Additionally Dr. Snyder provided:

- technical guidance on water quality testing, soil testing, and plant N nutrition to California Water Boards and Coalitions; Educational support in 2013 is planned in cooperation with Dr. Mikkelsen;
- technical guidance to Mississippi River Basin federal and state Task Force; communicated with water quality scientists, and distributed IPNI 4R Nutrient Stewardship information;
- technical guidance to Field to Market Sustainability Alliance (which is now collaborating with the Cool Farm Institute) on revision of a Water Quality Index calculator tool, developed by the USDA NRCS National Water Quality Technology Support Center;
- invited advisory assistance to the national USDA NRCS water quality technical advisory committee (Dr. Snyder was the only industry scientist invited).

To expand on the first bullet above, elevated groundwater nitrate in California has led Water Boards there to enact mandatory nutrient management plans and fertilizer N management regulation. Under the Irrigated Lands Program in California, most farmers will be required to develop a N management plan to reduce the potential for nitrate to move into the groundwater. For some commodities, making a nutrient budget will demonstrate a high N removal to N fertilizer ratio. Other crops, especially some of the short-season vegetable crops, will likely need to improve their N balance to meet environmental goals. Dr. Mikkelsen is developing science-based tools to assist growers in dealing with these regulations and in improving their N management.

Nitrous oxide emissions associated with fertilizer and climate change

IPNI is concerned that the risks estimated in the U.S. National Climate Assessment report (for 2013) may not fully consider improved 4R agricultural fertilizer N

Dr. Rob Mikkelsen, Director, Western North America

management and that nitrous oxide emission reduction protocols may focus strictly on N rate reductions and not consider all 4Rs of N management. Dr. Bruulsema co-authored a chapter on climate-N interactions in a peer-reviewed report submitted to the U.S. National Climate Assessment where IPNI's NuGIS model and 4R Nutrient Stewardship were used. Drs. Snyder and **Paul Fixen**, Senior Vice President and Director of Research, published a journal article (J. Soil Water Conserv.) on plant nutrient management and risks of nitrous oxide emission and contributed to another journal article (Frontiers in Ecology and the Environment) on U.S. agricultural nitrous oxide emissions. Dr. Snyder also provided significant input:

- to another paper in the same journal on challenges and opportunities for mitigating nitrous oxide emissions from fertilized cropping systems;
- to a USDA Natural Resources Conservation Service, Conservation Innovation Grant (with The Fertilizer Institute) producing a meta analysis for Midwest corn 4R N management effects on nitrous oxide emissions;
- along with CFI, TFI, and IFA, to GHG protocol and sustainability groups [e.g. Field to Market Sustainability Alliance; Coalition on Agricultural Greenhouse Gases (C-AGG)];
- to the USDA Climate Change Office on nitrous oxide emissions and cropping practices in the U.S.;
- to the U.S. Environmental Protection Agency inventory of greenhouse gas emissions and sinks.

Mr. Steve Couch, Vice President, Administration

Dr. Paul Fixen, Senior Vice President, Americas and Oceania Group, and Director of Research

In California the State Air Resources Board has begun to implement legislation that calls for California to reduce its C equivalent greenhouse gas emissions by 25% within the next 10 years. Dr. Mikkelsen has partnered with key academic researchers to determine how these regulations will impact crop fertilization practices. Nitrogen fertilizers have the potential to emit nitrous oxide after they are applied to soil, and therefore may be subject to regulation. The emerging research, partially funded by IPNI, demonstrates that nitrous oxide emissions following fertilization are extremely variable. The influence of soil properties, irrigation practices, and the time of year is much greater for nitrous oxide than we typically experience for N fertilization practices. The impact of the 4R factors on nitrous oxide emissions is still being quantified. These regulations will also increase the price of fuel and any fertilizer that is manufactured within the state.

In Australia, research supported in part by IPNI under the leadership of Dr. Norton is determining the impact of the elevated CO_2 levels expected in the future on wheat growth. A 15-50% increase in yield is being measured due to the elevated levels. The yield response suggests that CO_2 will help reduce the impact of higher temperatures and lower rainfalls associated with anticipated changes in climate, even in the low rainfall regions of Australia. However, higher yields come with lower grain protein content and the data indicate that adequate P is important in enabling crops to use the added C.

Soil deposited through water erosion in La Fraylesca, Chiapas, México.

Other studies are investigating strategies to improve N use efficiency under elevated CO_2.

Dr. Kaushik Majumdar, Director, South Asia

The IPNI staff in India has entered into an agreement with the Consultative Group on International Agricultural Research (CGIAR) Program on Climate Change, Agriculture and Food Security (CCAFS). Led by Dr. Majumdar, this project seeks to overcome the threats to agriculture and food security in a changing climate, exploring new ways of helping vulnerable rural communities adjust to global changes in climate. There are four CCAFS centers being developed in South Asia, two in India (Karnal and Baishali), one in Bangladesh and one in Nepal. There is some interest to use Nutrient Expert® Decision Support Software as a "climate smart" tool in these CCAFS locations to explore opportunities of reducing GHG emission through optimized nutrient management.

General N losses to the environment and N use efficiency

Global N use continues to receive attention including all the doorways available for N to exit from agricultural systems and the impact of that lost N. Dr. Snyder continued to interact with the leaders of the International Nitrogen Initiative (INI) including communications regarding development of the report entitled, Our Nutrient World, The Challenge to Produce More Food and Energy with Less Pollution, supported by the UNEP Global Program on Nutrient Management and the INI.

Dr. Zingore cooperated with the organizers of the 6th International Nitrogen Conference (N2013) scheduled for Kampala, Uganda, in November of 2013, with input from Dr. Snyder. Additionally, a science workshop was held on the impacts of excess N in the environment on human health at the U.S. National Institute for Health in Bethesda, Maryland. Dr. Snyder was invited to attend this workshop where his goal was to share science-based agronomic N management facts and industry activities relevant to the topic.

In southwest China, Dr. Tu has been working with local agencies to reduce soil erosion on the sloping lands in the Yangtze River basin. Soil loss by water erosion is significant in this region and threatens the Three Gorges Dam with sedimentation. Long-term work in this region has demonstrated the impact of terracing and hedgerow crops to reduce water erosion. More recently, retaining straw mulch from the previous crop was evaluated and found to also reduce surface runoff of water by 74-86%, and soil erosion by 95-98%. This research also found that the actual loss of P was small, at less than 10 kg/ha each year.

Dr. Shihua Tu, Deputy Director, China (Southwest)

Numerous articles were solicited by IPNI staff for publication in *Better Crops with Plant Food* related to N loss reduction and efficient use that included topics covering:

- Ammonia loss from urea under cold temperatures
- Increasing use efficiency of nitrogenous fertilizers in fish ponds
- Evaluation of in-season N management for summer maize
- Development and implementation of a N soil test for rice
- The diversity of N use efficiency for wheat varieties
- Climate change effects on wheat nutrition
- Optical Sensor-based N management for irrigated wheat
- Nitrogen source and placement effects on soil nitrous oxide emissions ■

NUTRIENT DECISION SUPPORT FOR MAIZE, WHEAT AND SOYBEAN CROPPING SYSTEMS

IPNI identified early on that a great global need existed for science-based support of the nutrient management decision making process at the field level. Usually such support, to be meaningful, must focus on specific cropping systems, recognizing the technologies accessible to local farmers, and also recognizing that major agronomic weaknesses in the cropping system will reduce the effectiveness of nutrient management practices (a 4R Stewardship fundamental). Therefore, IPNI has established working groups and inter-regional programs on nutrient decision support for maize, wheat, and recently, soybean systems.

Nutrient Expert®

A major component of IPNI's efforts on nutrient management decision support is devoted to making fertilizer recommendations for smallholder farmers in developing countries. Why would we focus our efforts on this topic? The primary reason is that soil testing services are not easily available to farmers, either for cost, logistical or timeliness reasons. More importantly, most of the smallholder farmers either do not have the money to pay for a soil test, or do not see value in it relative to all the other demands on their minimum cash flow. In August, 2008, IPNI started to work on a tropical maize decision support system (DSS) in Southeast Asia under the direction of Dr. Christian Witt, now with the Bill & Melinda Gates Foundation. This involved both field research trials and computer programming, with the research done in the Philippines, Indonesia and Vietnam. The computer programming was primarily obtained through consulting agreements, under the direction of **Dr. Mirasol Pampolino**, an agronomist who is part of our team in Southeast Asia. This first version of the DSS model, known as Nutrient Expert® (NE) was released on-line in December, 2009, for maize in the tropical region. At the same time, work was started to expand the regions where the maize DSS program could be used to South Asia with Dr. Majumdar and in China with Dr. He. In addition, under the support of the IPNI Global Wheat theme, we initiated work to develop a NE program for wheat in China and South Asia as well. Drs. Pampolino, Witt, **Ms. Julie Mae Pasuquin**, IPNI Agronomist, and **Dr. Adrian Johnston**, Vice President and Asia and Africa Group Coordinator, co-authored a journal article on the development approach and evaluation of NE in cereals (Computers and Electronics in Agriculture). Work is now also going on in sub-Saharan Africa with maize under the direction of Dr. Zingore, in Nepal and Bangladesh under the direction of Drs. Majumdar and Dutta; is planned for introduction into North Africa under the direction of **Dr. Mohamed El Gharous**, Consulting

Dr. Mohamed El Gharous, Consulting Director, North Africa

Dr. Hakim Boulal, Deputy Director, North Africa

Director and **Dr. Hakim Boulal**, Deputy Director; and a version of NE for rice in South and East Asia, and cotton in South Asia, are also being developed.

At the end of 2012, NE maize recommendations have been field tested against existing fertilizer management practices in 534 farmers' fields. In 129 fields in Indonesia and the Philippines, Dr. Pampolino reported increased average maize yield by 1.1 t/ha and profit by US$280/ha/crop with moderate increases in fertilizer P (11 kg P_2O_5/ha) and K (18 kg K_2O/ha) over farmer's fertilizer practice (FFP). In 82 field trials in India, Drs. Majumdar and Satyanarayana reported NE again increased average maize yield by 1.1 t/ha and profit by $259/ha/crop with lower fertilizer applications (37 kg N, 62 kg P_2O_5 and 39 kg K_2O/ha lower than the fertilizer rates applied under FFP). In 323 field experiments in China, Dr. He reported maize yields with NE were comparable with both FFP and local recommendations (OPT), but NE helped reduce fertilizer N application quite significantly (72 kg N/ha and 52 kg N/ha lower than fertilizer rates applied under FFP and OPT, respectively). This also helped in increasing profits over the existing fertilizer management practices by $94/ha over FFP and $145/ha over the OPT in China.

For NE in wheat, field validation trials were conducted at 218 locations in China and at 186 locations in India. In India, Dr. Majumdar reported NE increased wheat yield by 1.2 t/ha and profit by $289/ha with increased fertilizer K application (67 kg K_2O/ha over the FFP), while the corresponding figures over the state recommendation were 0.44 t/ha and $96/ha, respectively. In China, Dr. He reported wheat yields with NE were comparable with yields under FFP, but profit under NE was higher than under FFP by $132 /ha/crop. Compared with the soil test, NE wheat showed comparable yields and profits. However, fertilizer N application rates were significantly lower with NE wheat than with FFP (by 113 kg N/ha) and soil test (by 73 kg/ha). NE wheat also reduced fertilizer P rates by 36 kg P_2O_5/ha and 30 kg P_2O_5/ha over FFP and

Dr. Shamie Zingore, Director, sub-Saharan Africa

Dr. Adrian Johnston, Vice President, Asia and Africa Group

OPT, respectively. Fertilizer K application rate, on the other hand, was higher with NE wheat by 19 kg K_2O/ha over FFP and unchanged relative to OPT. Chinese translations of the beta versions of NE maize and NE wheat are ready and NE maize for India has been updated. NE maize and NE wheat for India have also been field validated. A beta version of NE maize for Africa (Kenya and Zimbabwe) has been completed, while a beta version of NE maize for Bangladesh is ready for field validation.

While the NE DSS tool was primarily developed to make science-based, crop-demand driven fertilizer recommendations, it was quickly realized that we could also use the model to support scenario development in South, East and Southeast Asia. When field data has been collected and evaluated for crop response to N, P and K, it is then possible to use the model to run simulations for a range of crop yield goals. When you combine the yield information with fertilizer selection options and the economic calculator, it is easy to see that location specific scenarios can be generated to help in decision-making. We see great promise in using the NE DSS tool to evaluate not only agronomic and economic impact in target regions, but also help in targeting of crop production inputs into those regions where the greatest potential to increasing yield exists. There also exists potential for the program to be used to help policy makers evaluate where future food could come from in the pursuit of food security targets.

Dr. T. Satyanarayana, Deputy Director, South Asia (South)

In South Asia, field research and demonstration work was initiated to support NE development, with support from IFA and IPNI, for the Cereal Systems Initiative for South Asia (CSISA). With the dedicated assistance of agronomists managed by Drs. Majumdar and Satyanarayana, an extensive database on wheat and maize crop responses to deficiencies of N, P and K was collected and analyzed. This exercise provided IPNI with not only a database to support the NE DSS process, but a set of up-to-date farmer field crop response data.

Wheat field in Santa Cruz, Bolivia.

In early 2012 this came in very handy as the partial removal of P and K subsidy support in India resulted in large decreases in P and K nutrient use. Drs. Majumdar, Satyanarayana and Dutta took this crop response data and used it to generate a series of three economic papers that were published in the Indian Journal of Fertilizers. These papers, along with associated extension information, are being used to demonstrate that there were positive economic benefits to using P and K with N even at the new fertilizer prices.

Global wheat management

Wheat is grown on more than 240 M ha, a larger production area than any other crop. Its production leads all crops, including rice, maize and potato, and world wheat trade is greater than for all other crops combined. Considering the obvious importance of wheat in maintaining world food security, the working group focused its efforts to develop and improve scientific nutrient and crop management principles that are applicable across a wide range of environments encountered in major wheat growing areas of the world. With activities initiated in 2008 and completed is 2012, the working group had several relevant outputs.

A database on nutrient uptake by wheat was collected from major wheat production regions around the world under the leadership of Dr. Jensen. This data showed that a large degree of variability in grain nutrients contribute to considerable uncertainty when trying to develop nutrient budgets. Not only were there differences in nutrient accumulation between different wheat species (*T. durum* vs. *T. aestivum*), but that regional differences were also quite large. It highlighted the need for an increased level of local data collection where detailed nutrient budgets are being calculated.

Dr. Phillips coordinated a special video on wheat production, highlighting the 4R Nutrient Stewardship concept, as part of this working group's activities. This highly successful video has subsequently been translated into several languages, including Hindi and Russian. It also has led to the development of other wheat videos in India by Drs. Majumdar and Satyanarayana, which focus specifically on the regionally adapted management practices of smallholder farmers in South Asia.

The wheat theme was used to support the development of Nutrient Expert® wheat DSS tools for both South Asia by Dr. Majumdar and China by Dr. He. The project not only has resulted in working models of NE-wheat, but also allowed IPNI staff to accumulate recent data from farmers' fields on crop responses to N, P and K. These decision support tools are being used to assist in fertilizer recommendations to smallholder farmers in both of these regions.

Better Crops with Plant Food—Our flagship publication remains dedicated to its mandate of providing agronomic research in a condensed, interpretative style serving a global readership. In 2012, we dedicated an entire issue to Nutrient Management Issues for Wheat.

Under the leadership of Dr. Norton, a special issue of *Better Crops with Plant Food* focused on wheat was published in 2012, highlighting the efforts of the working group (*Better Crops with Plant Food* Vol. 96 No. 3). This publication includes articles which summarized some of the work carried out by the staff and focused attention on the importance of wheat production globally. In addition the group were able to accumulate and share publications, presentations and videos gathered.

Dr. Rob Norton, Director, Australia & New Zealand

A global mission to improve maize systems

Growing demand for maize for food, feed, and biofuel, combined with numerous environmental concerns, has put great pressure on the development of ecologically intensive maize systems where yields approach maximal attainable levels with minimal negative environmental impacts or even positive effects. A globally-linked, but locally-delivered, program like IPNI has much to contribute to the creation of practical, science-based decision support tools. This thematic area focuses on that objective for maize systems.

IPNI's largest and most globally dispersed (borderless) research project is the primary activity of the Nutrient Decision Support Systems for Maize working group. The working group is co-chaired by **Dr. Scott Murrell**, Northcentral U.S. Director and Dr. Prochnow. Called "Global Maize", the project is a globally-distributed experiment examining how current farmer practice compares to a localized, high-yield, environmentally sound management approach, termed "ecological intensification" (EI). This study is the first of its kind for IPNI

Dr. Scott Murrell, Director, Northcentral U.S.

in many respects. A standard experimental design has been implemented along with protocols for plant and soil measurements. Additionally, long-term impacts of the two management systems are being examined over a 10-year period at each location. The 19 study locations encompass maize-growing areas in nine countries: Argentina, Brazil, China, Colombia, India, Kenya, Mexico, Russia, and the U.S.

Though this research effort is on-going, in 2012 a new site was established in the Yaqui Valley of Mexico in cooperation with CIMMYT. This creates a bridge between IPNI and CIMMYT's much larger program on maize productivity and sustainability. Also, at the end of 2012 a site was added in the state of Minnesota in the U.S. that will be fully funded by a state fertilizer check-off program (Minnesota Agricultural Fertilizer Research and Education Council).

Preliminary results using a subset of the sites were presented at the combined 19th Latin American and 22nd Argentine Soil Science Congresses in Mar del Plata, Argentina, in April 2012. These results showed that EI approaches increased corn grain yields by an average 914 kg/ha across responsive and non-responsive sites. EI also improved agronomic N use efficiency by 4.9 kg N/kg grain. IPNI is currently preparing a full, mid-term project report that will be available by the end of 2013.

In sub-Saharan Africa, Dr. Zingore reports that the two Global Maize sites were established in both high and low yield potential regions of Kenya. Two crops of maize can be grown each year in Kenya, giving these locations an opportunity to collect more data than most. Initial results indicate that yields are increased significantly when K and zinc (Zn) are added, in addition to the farmers' practice of applying N and P alone.

In China, the Global Maize sites are located in Jilin province where one crop of spring maize is grown each year; and in Hebei province where summer maize is grown after winter wheat. Dr. He reports that the use of EI treatments had no statistical effect on grain yields harvested, but these similar yields were achieved with 28 and 42% less total N than the farmers' practice in Jilin and Hebei sites, respectively. This resulted in a significant increase in crop N use efficiency and supported the recommendations of EI for their economic advantage. The over use of N in most grain growing regions of China requires immediate attention to both improve production economics and minimize environmental impact.

The Global Maize project in Russia, managed by Dr. Nosov, is continuing in Rostov Oblast, Southern Russia, in cooperation with the Southern Federal University (Rostov-on-Don) and the State Variety Testing Unit "Tselinskiy" (N. Tselina). Limited rainfall patterns prevailed in the experimental area during summer, which had a negative effect on crop production in 2012. There was a 17 and 30% yield reduction, respectively, in maize and soybean compared to the previous season. Grain yield increase due to EI management was 8 and 18%, respectively, for maize and soybean compared to growers' fertilizer practice. Moreover, EI for soybean resulted in higher grain protein content. Research experiments were conducted in Southern Russia under the typical North American Corn Belt crop rotation (i.e., maize-soybean). Balanced fertilization including K and seed treatment

Dr. Vladimir Nosov, Director, Southern & Eastern Russia

Soybeans double-cropped after winter wheat in Ridgetown, Ontario, Canada.

with Zn and molybdenum (Mo) resulted in higher productivity in both crops compared to common grower's practice that relies on low rates of N and P. The global EI approach allows the gap between current and attainable yields to be narrowed while improving crop quality.

Expanding global efforts with soybean systems

In 2012, IPNI established a new Soybean Systems working group that will launch in earnest in 2013 and will be co-chaired by Drs. García and Francisco. This is another example of IPNI's "Without Borders" approach where nutrition challenges of soybean systems across the world will be addressed to provide better insight into closing the yield gap between current and attainable yields. Two general situations are recognized among the different IPNI programs: 1) regions or countries in which soybean yields are high and crop management is advanced, and 2) regions or countries in which grain yields are low and/or soybean is just a new crop. In all cases, soybean grain yields have been stagnant for several years. Worldwide yield gains have dropped by 71% comparing the 1965-2010 period to 2005-2010. For the three leading producers (U.S., Brazil and Argentina), the loss was 52% comparing the same periods. Foreseeable activities include: evaluation of potential yield and yield gaps by region; determination of N supplied through biological N fixation and response to N fertilization in intensive systems; recalibration/calibration of soil tests; use of foliar application; response to micronutrients; and determination of current nutrient requirements and removal coefficients, among others. ■

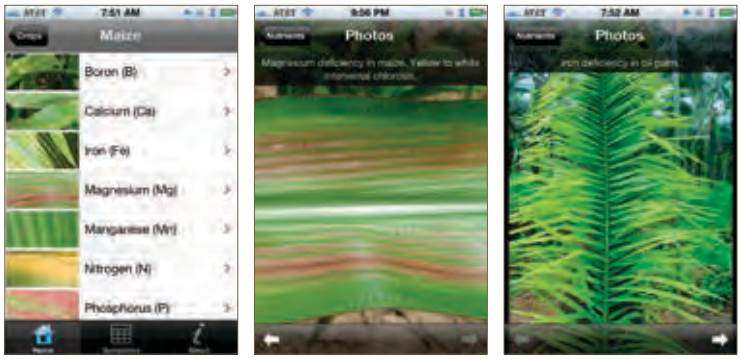
NUTRIENT USE AND CYCLING

The working group on Nutrient Use and Cycling develops the Institute's capability for describing, estimating, documenting, analyzing, and predicting nutrient use, nutrient budgets, and nutrient cycling at scales ranging from individual fields to national and global levels. This involves fertilizer use, application of manure and other nutrient sources, nutrient removal by crops, nutrient losses from production fields to the environment, soil nutrient levels, and impacts of on-going or anticipated changes in land use, crop selection, and cropping intensity. To date, the working group has produced a number of tools outlined below. IPNI activities in this thematic area extend into research and global projects devoted to advancing the science of nutrient cycling.

In 2007, **Mr. Gavin Sulewski**, now IPNI Editor, and Dr. Witt, former Director in Southeast Asia, began work with PAQ Interactive to update an agronomic information collection system known as *AgriStats*. The goal has been to provide a web-based global database designed to collect yield and associated fertilizer use data from regions in which we conduct our Programs (see http://info.ipni.net/agristats). Members and Staff can produce customized reports on fertilizer use by crop, current, attainable and potential yields, related nutrient use data and associated gaps between estimates for current farm practices vs. realistically attainable yields. AgriStats also contains analytical tools to construct medium- to long-term chart projections of agronomic fertilizer market development.

The fundamental importance of providing modern products related to diagnosing crop nutrient deficiency spawned working group activity on producing a *Nutrient Deficiency Image Collection*. Mr. Sulewski, **Mr. Brian Green**, IT Manager, and **Dr. Harman Khurana**, Agronomic & Technical Support Specialist, have built this collection, that has expanded to a larger flash drive format, into a comprehensive assortment of nearly 600 classic cases of crop nutrient deficiency documented from research plots and farm fields located around the world. Images have been sourced from IPNI Staff, its archives, and from a network of agricultural researchers, extension staff, crop scouts, and farmers. The working group also manages IPNI's popular photo contest of nutrient deficiency symptoms (see http://www.ipni.net/photocontest), which generates many of the examples of crop nutrient deficiency. Text and diagrammatic descriptions of nutrient deficiency are also available as supporting information.

The production of new products and tools at IPNI has our staff continually assessing how to best present our information. As part of this process, working group activities have led to the development of a new *Plant Food Uptake and Removal Portal* (see http://info.ipni.net/nutrientremoval) that will act as central location for information and resources related to plant food uptake and removal data, which is of critical importance to analysis of nutrient budgets.



Based on the success of the Flash drive collection (right), the working group also developed a *Crop Nutrient Deficiency Image Collection App* for iPhone and iPad (above). This format provides a subset of images, text and diagrammatic descriptions for 14 prominent field crops along with text and diagrammatic descriptions.

In the field, results of a long-term project in China addressed the issue of straw return versus removal in crop rotations. The work was coordinated by Drs. Tu and Li, within the IPNI cooperative research network in China. In southern China a crop rotation involving rice-winter wheat had been maintained for 20 years where straw was returned or removed, in combination with nutrient application treatments. The results showed that long-term return of both rice and wheat straw could reduce the fertilizer requirements by 60 kg N, 90 kg P_2O_5 and 75 kg K_2O/ha. In addition, soil quality was improved with straw return. In northern China, where soil K was higher, a 20-year spring wheat rotation showed that NP fertilizers combined with 50 or 100% straw return were as productive as an NPK treatment. While this straw return with NP fertilization showed a negative K balance on these trial sites, the indigenous soil K levels were sufficient to support the crop production. Over time, continued removal of K without replacement could negatively impact productive capability.

Phosphorus use sustainability

Fear that our global food production system will run out of P resources in the near future has led to establishment of several groups focusing on the sustainability of P use in food production. IPNI was directly involved in two of them in 2012.

Dr. Harman Khurana, Agronomic & Technical Support Specialist

Global TraPs (Transdisciplinary processes for sustainable phosphorus management). This project is coordinated by IFDC (the International Fertilizer Development Center) and the Fraunhofer Institute in Germany. Dr. Roberts serves on the Steering Committee and Dr. Mikkelsen was the "Use Node" co-leader for 2012. Dr. Prochnow also is active in the project. The major accomplishment of the Use Node was development of a chapter outlining the use of P in agricultural and food

From seed to table—locals with their own rice.

Man and water buffalo working on rice terrace.

production systems in the book: "Sustainable Phosphorus Management: a Transdisciplinary Roadmap". Preparation is underway for the Global TraPS First World Conference in Beijing in 2013. IPNI staff will be involved in program development activities.

Research Coordination Network on Phosphorus Sustainability Issues. The U.S. National Science Foundation provided funding in 2012 to establish a Research Coordination Network on P sustainability issues, coordinated by Arizona State University. Dr. Mikkelsen is serving on the steering committee for this project. They are establishing a network of key experts and plan their first group meeting of stakeholders in Washington, D.C., in 2013. Dr. Mikkelsen was involved in writing a key chapter for a book from this group "Managing phosphorus in urban and agricultural landscapes."

Dr. Luís Prochnow, Director, Brazil

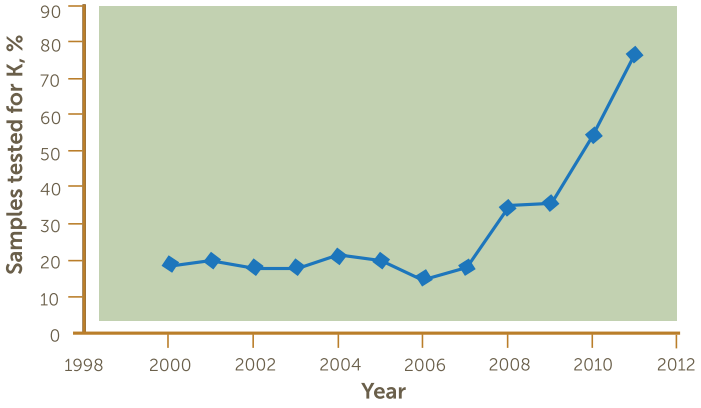
Addressing potassium science and management issues – new regions of K deficiency

Uruguay. In the last few years, some cases of K deficiency symptoms in soils with low soil test K were reported in maize, sorghum and *Lotus corniculatus* L in Uruguay. The increasingly frequent occurrence of visual K deficiency symptoms, confirmed by plant analysis, has led to more specific studies, which showed K response in several crops. Dr. Fernando García has been collaborating with the College of Agronomy of the National University of the Republic (FAGRO-UdelaR, Facultad de Agronomia-Universidad de la Republica) and INIA (National Institute of Agricultural Research) of Uruguay in developing a research project on exploring K deficiencies in field crops (see project URU-02). Canpotex is providing substantial funding for this research project. Good progress has been made in defining a preliminary critical soil test K level for the region of 0.34 $cmol_c$/kg (133 ppm; 0-20 cm depth).

Agronomists and farmers are concerned about soil K levels in the region, as reflected by the increasing demand for soil K analysis. Prior to 2006, only about 20% of the soil samples collected were analyzed for K at the request of the submitters, but by 2011 that value had increased to 80%. Potassium fertilizer consumption in Uruguay has tracked with the increase in soil K analysis

with a 354% increase from 2006-2010. Long-term studies were established in 2012 designed to continue to expand our understanding of K issues in this new region of rapidly growing fertilizer K demand.

Percent of total soil samples collected in Uruguay analyzed for K.



Australia. Central and southeastern Queensland has been shown to suffer multiple nutrient deficiencies through work coordinated by Dr. Norton and undertaken by University of Queensland researcher Dr. Mike Bell, supported by Canpotex. This project has shown subsoil depletion of K, as well as P and S across wide areas, and is developing strategies to place these nutrients at high rates in the subsoil so that high K demanding crops like cotton can be grown. Our work in Western Australia has shown that late K application in wheat and canola requires rates 2 to 3 times the early application rates to achieve similar yields. Lupin is less responsive to K than either wheat or canola, but delaying K application to late in the season reduced lupin yield by half.

California. The California almond industry continues to rapidly expand, with over 800,000 acres of bearing trees and a harvest of over 2 billion pounds (with a $3.8 billion value). Dr. Mikkelsen has been active with the California Almond Board to develop and reinforce research demonstrating the on-going need for K. Though the western U.S. has typically been viewed as an area high in soil K, it is now a university-recommended practice to annually apply up to 500 lb potassium sulfate/acre to support these high almond production levels. The need for monitoring the tree K status through continuing leaf analysis continues to be taught in order to sustain the high yield levels needed for financial profitability.

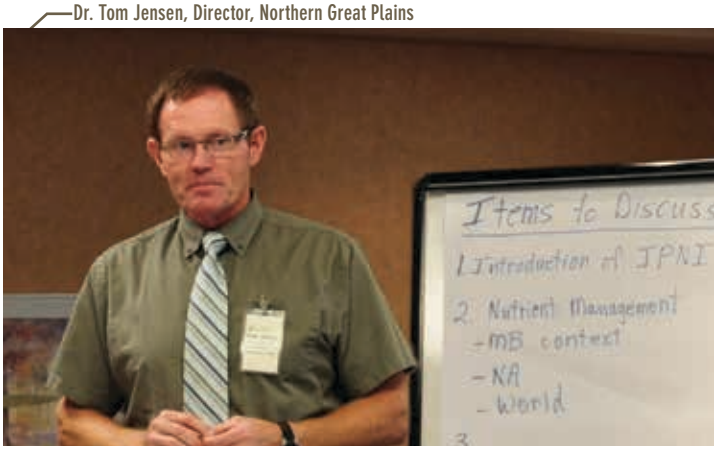
Russia. Starting in 1992, both nutrient rates and ratios changed such that the relative share of P and K fertilizers declined compared to N. The long-term removal of K by harvested crops, together with inadequate K replenishment, has produced observable declines in soil K in various agricultural zones of the country. In the beginning of 2012, several region in Central and South Russia were selected to initiate a new research project with focus on K fertilization. This work was based on analysis of K fertilizer use in both long-term and short-term field experiments, estimated agronomic potential to increase K fertilizer consumption, the share of arable soils with medium amounts of plant-available K, the share of crops with a high K demand, and regional agriculture development. Initiated by **Dr. Svetlana Ivanova**, IPNI Vice President and Director, Central Russia, the project is focusing on optimization of K fertilizer rates in intensive, high K demanding cropping systems (sugar beet, maize, rape/canola, and soybean), and assessing routine soil test methods to adjust current interpretation classes. During the last 15 years such trials have been completely ignored. Thus current recommendations used to calculate required rates of K fertilizers are outdated and cannot meet the requirements of modern high-yield production technologies. IPNI is cooperating with Pryanishnikov Research Institute for Agricultural Chemistry of the Russian Academy of Agricultural Sciences, and State centers and stations for agrochemical service (SCAS) of the Ministry of Agriculture of the Russian Federation.

Dr. Steve Phillips, Southeast U.S. Director

Ukraine. Dr. Ivanova continued to lead a research project on the evaluation of the K status of arable soils on the basis of modern soil diagnostic techniques and development of recommendations for the rational and efficient application of K fertilizers conducted in cooperation with Ukrainian National Scientific Center "Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky". In 2012, the database containing information on crop response to K fertilizer applications in field trials conducted in the Ukraine during the last 40 years was summarized. Data on agronomic efficiency

of K fertilizers applied to winter wheat, grain maize and sugar beet by climatic zone and soil type was assessed. The efficiency of K fertilizers in Ukraine are most affected by growing season precipitation and temperature, as well as soil K content. Due to adverse weather during the whole growing season of 2012 (strong winter frost without snow cover followed by summer drought) the yield of summer wheat was lower than expected at 1.7-2.4 t/ha. However, in summer drought situations, K fertilizers can contribute up to 10% of yield increase on plots with optimized N and P.

Dr. Tom Jensen, Director, Northern Great Plains



Addressing potassium science and management issues – problems with soil K assessment

The challenges with soil tests for plant available K continue to be a frustrating problem for our industry and its clients around the world. However, the combination of science, technological innovation, and effective education may be moving us closer to solutions to these related problems. Soil test methods that do not always accurately reflect K balance or predict crop response to K application are currently in use in many parts of the world. We are hopeful that new scientific trials coordinated by the IPNI Eastern Europe/Central Asia Group will provide a platform for building solutions for that region and that new laboratory technology developed in the U.S. involving testing of soil slurries made from field-moist samples will provide a more reliable decision support tool for K management in many parts of the world.

A seminar on improving the basis for K fertilizer application in Russia took place on October 10. It was jointly organized by the Crop Production Department, Russian Ministry of Agriculture and IPNI. As first speaker, Dr. Ivanova discussed the 4R Nutrient Stewardship concept as well as IPNI's organization, its regional programs, and projects. Dr. Fixen spoke on contemporary approaches for monitoring soil K in North America. About 70 participants took part in the event including the Deputy Director, Crop Production Department Heads and leading specialists from the main State centers for agrochemical services, representatives of the fertilizer industry, and professional unions. For IPNI, it was the first opportunity to introduce itself to this audience and speak about our global and regional programs, and also to promote new IPNI K research being conducted in Russia. This seminar has strengthened relations between IPNI and the government and became a very important step for future development of IPNI in Eastern Europe and Central Asia. ■

Conservation tillage maize in La Fraylesca, Chiapas, México.

SPECIAL PROGRAMS

The working group structure within IPNI was designed to take advantage of the regional expertise of its scientists. Regional expertise not only allows IPNI the capacity to generate comprehensive ideas that can influence the global discussion on plant nutrition, but it also affords the ability to respond directly to regional issues of a time-sensitive nature and lead the discussion on the related science.

Responding to region-specific seasonal challenges

In mid-July, when it was clear that 2012 was bringing one of the most severe and widespread droughts to much of the U.S. that had been experienced for many decades, IPNI launched an information initiative for a series of publications at both national and regional scales addressing the topic of fertilizing after the drought. Though most state extension systems in the impacted area had their own programs on the drought, the structure of IPNI, which largely ignores political borders, allowed us to offer some regionality that individual states could not offer as effectively. The publication series included:

- A series of five IPNI *Plant Nutrition Today* (PNT) articles that were distributed to the major ag media outlets and industry throughout North America. Authors included Drs. Murrell, Snyder, Bruulsema, Stewart, and Jensen.
- A column published on "Drought: Fertilizing for the Next Crop" by Dr. Murrell in *Crop Life*, a trade magazine distributed to much of the fertilizer industry in North America.
- An IPNI *INSIGHTS* series that took the general drought impact factors and placed them in the appropriate regional context of climate, soil types and cropping systems. Most were co-authored with university or regional specialists and utilized the 4R framework in article structure. The IPNI staff involved in this effort were Drs. Bruulsema, Jensen, Murrell, Mikkelsen, Phillips, Snyder, and Stewart.
- Dr. Jensen addressed both drought and flooding issues within the Northern Great Plains of North America with presentations and publications built from information merged across state and national borders. His presentations included the impact of shifts in temperature, precipitation patterns, drought, and excess moisture on crop choices and on flooding effects on nutrient availability and salinity.

In Russia, a monograph on nutrition of small grains on chestnut soils of Stavropol Krai written by Dr. V.N. Bagrintseva from the Maize Research Institute (Pyatigorsk) and reviewed by Dr. Nosov is ready for publication. This publication shows the efficiency of N, P and K fertilizer application to winter wheat and winter barley grown in the cereal-fallow cropping systems under water deficit conditions. The research findings will be helpful in optimizing nutrient management and improving crop productivity in this area.

The Middle East region suffers continuously from a scarcity of water. In addition, for years this land has been cultivated with traditional techniques that foster unbalanced fertilization with respect to P and K as well as micronutrients. This has led to soil nutrient depletion in areas that once had adequate nutrient contents.

The summer of 2012 brought one of the most severe and widespread droughts in recent history to much of the U.S. and regions of Canada, IPNI responded with a series of publications at both national and regional-scales addressing the topic of fertilizing after a drought.

IPNI activities in this region, led by **Dr. Munir Rusan**, Consulting Director, are directed to promoting balanced fertilization and fertilizer BMPs to compensate for the depleted nutrients and enhance crop productivity and ensure its sustainability. This is of particular importance for promoting the use of K fertilizers not only to re-establish nutrient balance, but also to enhance both crop productivity and crop survival and tolerance to the drought, salinity and other abiotic stresses prevailing in this region.

Owing to the scarcity of water resources, fertigation is crucial to maximize both water and fertilizer use efficiencies. With fertigation, farmers can precisely adopt the 4R Nutrient Stewardship concept where farmers can define precisely the right source, rate, time, and place of plant nutrient application. Dr. Rusan is actively involved in training engineers, extension agents and fertilizer dealers (being efficient agents to transfer technology across the borders of all countries of the region) on irrigation and fertigation techniques through annual training workshops. Through these workshops, IPNI is able to bring together specialists from different geopolitical and disciplinary boundaries to get the proper knowledge and technology and exchange their experiences to develop a cross-border and regional framework for BMPs.

Dr. Munir Rusan, Consulting Director, Middle East

IPNI is addressing all these issues through three agronomic projects in Syria (maize, wheat and vegetables), Egypt (wheat), and Turkey (cotton, maize, water melon, and hazelnuts) and annual training workshop on fertigation in Jordan. The IPNI activities included the implementation of on-research station experiments, on-farm demonstration trials and farmers' field days, publication of extension and outreach materials, as well as organizing training workshops for capacity building and for transferring knowledge and innovative technology to farmers, extension agents and decision-makers.

IPNI is significantly contributing to the educational and

Dr. Svetlana Ivanova, Vice President, Eastern Europe/Central Asia and Middle East Group and Director, Central Russia

technology transfer processes in this region. This was achieved through demonstrating the positive impact of balanced fertilization on the crop and soil productivities and increasing farmer's income. Results obtained in research projects for the most important crops at locations in Syria, Egypt and Turkey have responded positively to balanced fertilization through enhancing yield, yield components and nutrient content compared to both unbalanced fertilization and control treatments. This also was reflected favorably in restoring soil fertility and therefore sustainability of soil productivity. IPNI is continuing to significantly contribute to transferring innovative technology in fertilizer use and training local staff on the BMPs for improved farming systems.

Leading conferences and symposia assembling developers and users of Nutrient Stewardship information

IPNI outreach around the world includes leadership in organizing and delivering technical conferences and gatherings that bring together researchers across borders and those that can put research results to use in improving nutrient stewardship.

Our Latin America-Southern Cone Program has promoted 4R Nutrient Stewardship through an impressive set of conferences that over the last two years has drawn nearly 10,000 attendees. A few examples of the 17 major conferences in this program were:

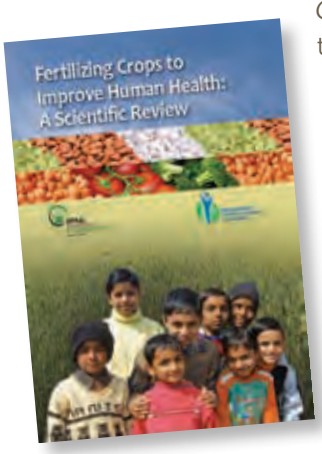
2011 National Symposium on Dryland Agriculture in Paysandú and 19th ISTRO Conference and SUCS Congress in Montevideo, Uruguay. IPNI co-organized the 2011 symposium with the College of Agronomy of the Universidad de la República of Uruguay, and sponsored the 2012 International Soil Tillage Research Organization Conference and the 2012 Soil Science Society of Uruguay (SUCS) Annual Meeting. These events gathered approximately 800 Uruguayan and regional scientists, local dealers, agronomists, and farmers.

2011 and 2012 AAPRESID Congresses (Argentina) in Rosario, Argentina. The XIX and XX National Congresses of AAPRESID (no-till farmer's association of Argentina) gathered more than 5,000 participants. IPNI co-organized the Panel on Crop Nutrition at both events with an audience of approximately 1,000.

Australian Society of Agronomy Biennial Meeting and the Australia and New Zealand Societies of Soil Science Biennial Meeting. IPNI sponsored these meetings, which drew a total of about 1,000 delegates. Dr. Norton chaired sessions, gave presentations and edited papers for both of these meetings. IPNI is also sponsoring the International Soil and Plant Analysis Conference in Queenstown, New Zealand, which will be attended by Drs. Norton and Mikkelsen.

Great Plains Soil Fertility Conference. The 2012 Great Plains Soil Fertility Conference (GPSFC) was held in Denver, CO. This is the premier soil fertility and crop nutrition event in the U.S. Great Plains. This year Dr. Stewart served as chair of the GPSFC, and attended to the duties of program organization, coordination and execution of the conference. IPNI had a strong presence in the conference, assuring that issues of interest and concern to the fertilizer industry were addressed.

Fertilizing for Crop Qualities that Improve Human Health. At the request of leaders of the Soil Science Society of America, Dr. Bruulsema organized and moderated an invitational symposium on this topic, convened in Cincinnati at the Society's Annual Meeting. The IPNI-IFA scientific review publication on *Fertilizing Crops to Improve Human Health* was the basis for the symposium. Symposium speakers were from Australia, Canada and the U.S. and the book also included authors from Turkey, Sweden and Russia.



Fertilizing Crops to Improve Human Heath— **A Scientific Review (an IPNI/IFA joint publication) was released to support the scientific basis for alleviating the burden of nutrition insecurity through new fertilizer recommendations and to stimulate further research in this area.**

International Conference on Precision Agriculture (ICPA). The 11th Conference on Precision Agriculture was held in July in Indianapolis, IN. The conference enjoyed the highest percentage of international attendees in its history with over 45 countries represented. The primary focus of the conference series, for which IPNI is a founding sponsor, is the research community studying precision agriculture but one set of sessions, the A to Z track, focuses on new developments that are ready for field application. Dr. Phillips, chair of the IPNI Precision Nutrient Management working group, organized and moderated the A to Z program track. IPNI has been involved with this successful conference series since its inception, a conference that has done much to break down the communication barriers between public and private sectors and that can be created by geopolitical borders. ■

NUTRIENTS AND SOCIETY

Educating the public about the importance of plant nutrition remains one of the primary goals of IPNI. To better accomplish this objective, the Nutrients and Society working group was recently reorganized to more fully expand the communication efforts of IPNI. Instead of being an independent working group, the task of communication outreach is now distributed among all of the working groups.

Each working group is now assigned the responsibility of regular communication with non-scientists about their products and outcomes. Some of the products from the Nutrients and Society working group follow.

Nutrient Source Specifics are a popular series of 24 fact sheets that summarize the production and use of the most commonly used fertilizers and soil amendments. They provide an important tool in supporting educational efforts for the 4R concept of "Right Source". These publications have been widely distributed and now are translated into Mandarin.

Fertilizer Production and Technology presentations have been developed for use in both academic and general settings. Many people do not understand where fertilizer comes from and there is a frequent apprehension associated with anything considered chemical. Annotated presentations (with lecture notes) have been completed for Nitrogen, Phosphate, Potassium, and Sulfur.

The working group was involved in the redesign of the IPNI website, and the revision of the nutrient deficiency image gallery. Other working group efforts resulted in articles that appeared in *Better Crops with Plant Food* on regional topics identified as high priority. This included technical topics such as "Agronomic use of phosphate rock for direct application"; and highlighting the beneficial social aspects of fertilizer use "Agronomic education and credit for purchasing fertilizer bring environmental and social benefits for coffee growers–An update."■

Our endeavors in digital products have generated some popular items that are expanding our reach. We've rolled out a brand new web presence that has allowed us to present a more complete picture of our activities and achievements. New language and custom content capabilities provide new abilities to customize our message based on regional preferences.

Communications Group

So what image does the phrase "*Without Borders*" conjure up in your mind?

If you are like me, you might find it hard to avoid mental images of emergency medical teams delivering urgent care, or engineers repairing essential infrastructure—all with little regard for the barriers facing them.

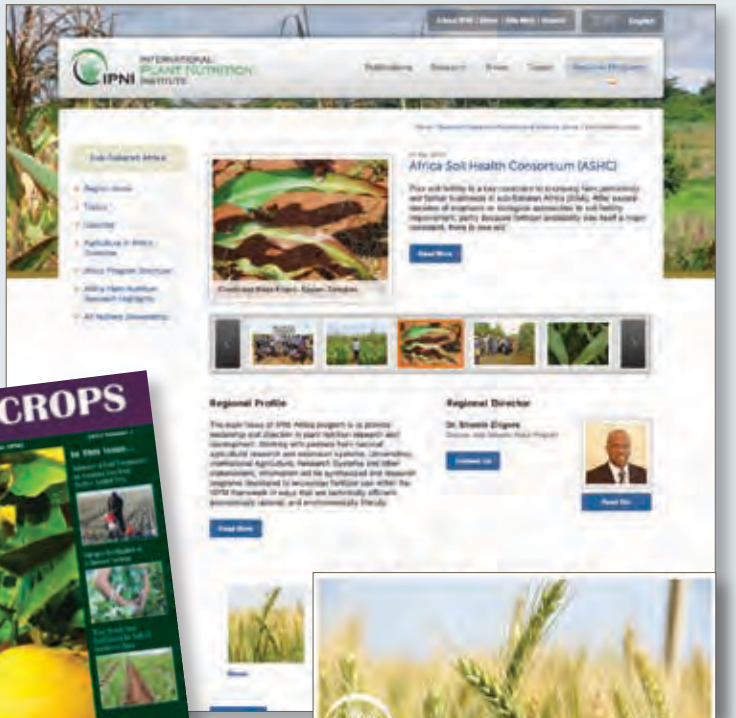
I should make it clear now that the examples of outreach and knowledge-transfer that are highlighted in these pages are clearly less dramatic than these imaginings. However, our inspiration from the *Without Borders* model does come from a similar desire, to affect change on the critical issues related to our specialty—the science of plant nutrition.

Also scattered across the pages of this program report are highlighted examples of publications and communications projects, which are key outputs that we are pleased to have come to fruition over this past year. You'll find targeted responses to issues needing immediate support or increased awareness within our industry and the general public. There are also products of multiple years of legwork and collaboration required to generate a critical mass of ideas.

So drawing from the spirit of other organizations working *Without Borders* I hope you can agree that the parallels we draw with these groups are self evident through this summary of our activities and achievements.

Gavin Sulewski, IPNI Editor

Mr. Brian Green, IT Manager



Gavin Sulewski, IPNI Editor, right, with IPNI Assistant Editor, Danielle Edwards.

IPNI Scholar Award

There were 24 graduate student recipients of the 2012 IPNI Scholar Award. Students from Argentina, Brazil, China, India, Malaysia, Russia, South Africa, Sri Lanka, United States, and Uruguay were selected as outstanding students enrolled in the science programs relevant to plant nutrition and management of crop nutrients.

Students in the discipline of soil and plant sciences including agronomy, horticulture, molecular genetics of plant nutrition, soil fertility, agricultural chemistry, and other areas related to plant nutrition are encouraged to apply: www.ipni.awards. Awards of US $2,000 are presented to students who are candidates for the M.Sc. or Ph.D. degree.

Some of the 2012 IPNI Scholar Award recipients are pictured opposite.

IPNI Science Award

The 2012 IPNI Science Award was presented to Mr. Arthur E. (Johnny) Johnston from Rothamsted Research. Mr. Johnston received a plaque and a monetary award of US $5,000.

The IPNI Science Award is intended to recognize outstanding achievements in research, extension, or education, with focus on efficient management of plant nutrients and their positive interaction in fully integrated crop production that enhances yield potential and quality.

Top: Tom Bruulsema receives the Fellow Award from Malcolm Morrison, president of the Canadian Society of Agronomy at the annual banquet of the Canadian Society of Agronomy held in Saskatoon, SK on 18 July 2012.

Center: Cliff Snyder receives the Soil Science Industry and Professional Leadership Award presented by SSSA Past President Gary Pierzynski, Kansas State University.

Bottom: Dr. Satyanarayana receives the "2012 SAB Young Innovator Award" from the Society for Applied Biotechnology (SAB) for his presentation on "Nutrient Expert: A Novel Decision Support Tool for Optimizing Nutrient Use and Improving Maize Yields in India" 19-20 November 2012.

IPNI Scholar Awards

PUBLICATIONS

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RESEARCH SUPPORT

Special Projects

HarvestPlus Zinc Fertilizer Project

Best Management Practices for Sustainable Crop Nutrition in Bulgaria

Regional Investigation on Interaction of Nitrogen Management, Hybrid Selection and Population on Corn Production

Transferring Oil Palm Plantation Best Management Practices from Southeast Asia to West Africa

Global Maize

Global Maize Project in Brazil: Itiquira, Mato Grosso

Global Maize Project in Brazil: Ponta Grossa, Paraná

Global Maize Project in Argentina: Oro Verde, Entre Ríos

Global Maize Project in the United States: Ames, Iowa

Global Maize Project in Argentina: Balcarce, Buenos Aires

Global Maize Project in China: Liufangzi, Gongzhuling, Jilin Province

Global Maize Project in China: Dahe, Shijiazhuang, Hebei Province

Global Maize Project in the United States: West Lafayette, Indiana

Global Maize Project in Mexico: Celaya, Guanajuato

Global Maize Initiative, Colombia

Global Maize Project in India: Dharwad, Karnataka

Global Maize Project in India: Ranchi, Jharkhand

Global Maize Project Trials in Russia: Rostov Oblast

Americas

Northeast Region: Dr. Tom Bruulsema

Michigan

Evaluating Sources of Sulfur in Michigan Corn Nitrogen Programs

New York

Beta-testing the Adapt-N Tool in On-farm Strip Trials

Ontario

Long-term Optimum Nitrogen Rates for Corn Yield and Soil Organic Matter in Ontario

Investigating Corn Hybrid Interactions with Nitrogen and Foliar Fungicides

Kenneth M. Pretty Graduate Scholarship

Virginia

Evaluation of Ammonium Sulfate Nitrate in Virginia Snap Bean Production

Evaluation of Ammonium Sulfate Nitrate in Virginia Sweet Corn Production

Sulfur Fertility for Barley Production in the Mid-Atlantic

Northern Great Plains Region: Dr. Tom Jensen

Alberta

Large Urea Granules for Broadcast Application for No-till Cropping in Alberta

Farmer applying gypsum to correct soil acidity.

Evaluation of Phosphate and Nitrogen Fertilizers Treated with Polymer Additives to Increase Fertilizer Efficiency

Large Urea Granules for Broadcast Application for No-till Cropping in Alberta Spring Wheat

Large Urea Granules for Broadcast Application in Perennial Forage Grasses

Montana

A Micrometeorological Study to Quantify Ammonia Volatilization Losses from Surface Applied Urea in the Semiarid Northern Great Plains

Nitrogen Fertilization Methods for No-till Cropping of Winter Wheat in Central Montana

North Dakota

Nitrogen Recalibration for Corn in North Dakota

Saskatchewan

Evaluation of Urea Nitrogen Fertilizer Treated with Nutrisphere® Polymer Additive to Increase Fertilizer Efficiency

Western Region: Dr. Robert Mikkelsen

Arizona

Improving Nitrogen Fertilizer Management in Surface-irrigated Cotton

California

Nitrous Oxide Emissions from the Application of Fertilizers: Source Partitioning

Soil Testing Verification in the Fall River Valley, Northeastern California

Mineral Nutrition of Leafy Lettuce and the Impact on Verticillium Severity

Northcentral Region: Dr. Scott Murrell

Iowa

Variability in Soil Test Potassium and Crop Yield in Iowa

Indiana

Corn Sulfur Response on a Sandy Soil in Northern Indiana

Comparative Nutrient Use Efficiency by Candidate Biofuel Crops

Southeast Region: Dr. Steve Philips

Alabama

Evaluation of Fertilizer Application Uniformity and Nutrient Distribution

Arkansas

Biomass and Macronutrient Accumulation and Losses in Switchgrass During and After the Growing Season

Florida

Nitrogen Rate Study for Potato Production in Northeast Florida

Potassium and Phosphorus Fertilization of Grass Pastures

Georgia

Loblolly Pine Stand Fertilization at Mid-Rotation to Increase Small and Large Sawtimber Volume in Georgia

North Carolina

Soil Fertility Management for High Population, Narrow Row Corn Production

Tennessee

Documenting Nutrient Deficiency and Accumulation Rate in Vegetables

Improved Plant Response to Potash Fertilization Through Control of Seedling Diseases

Southern and Central Great Plains Region: Dr. Mike Stewart

Colorado

Contribution of Animal Feeding Operations and Synthetic Fertilizers to Ammonia Deposition in Rocky Mountain National Park

Kansas

Effect of Long-Term Nitrogen, Phosphorus and Potassium Fertilization of Irrigated Corn and Grain Sorghum

Applied Fertility Management for Irrigated Soybean Production

Micronutrient Fertilization for High Yield Wheat Production in Kansas

Nebraska

Soil Test Phosphorus Level and Yield Potential

Texas

Nutrient Removal by Fruit and Vegetable Crops in Texas

Brazil: Dr. Luís Ignácio Prochnow, Eros Francisco, and Valter Casarin

Sustainable Production Systems Under No-Till in the Cerrado of Brazil

Sources and Rates of Phosphorus in a Cultivation System Integrating Crop and Pasture Production in the State of Parana, 2011

Rates and Residual Effect of Potassium Fertilization in a Brazilian Soil

Sustainable Production Systems Under No Till in the Cerrado of Brazil - Piaui

Agronomic Effectiveness of Acidulated Phosphate Fertilizers with Different Water Solubility

Sustainable Production Systems Under No Till in the Cerrado of Brazil - Maranhão

Latin America–Southern Cone: Dr. Fernando García

Argentina

The Crop Nutrition Network in the CREA Region of Southern Santa Fe

Long-term Nutrient Management Network for Southern Buenos Aires Province

Evaluation of Enhanced Efficiency Fertilizers for Wheat and Maize

Response to Zinc in Maize Crop Grown in the Argentinean Pampas

Uruguay

Exploration of Responses to Potassium in Western Uruguay

Northern Latin America: Dr. Raúl Jaramillo

Colombia

Nutrient Demand of Oil Palm Hybrids in Tropical America

Ecuador

Site-specific Nutrient Management for Soft Corn Varieties in the Highlands of Ecuador

Tools for Sustainable Oil Palm Production: In situ Fertilizer Studies for Plantations in Ecuador

Australia/New Zealand

Australia/New Zealand Region: Dr. Robert Norton

Australia

Growth, Yield and Water Use under Elevated Carbon Dioxide

Urea and Gypsum Compared to Ammonium Sulfate for Canola

Nitrogen Dynamics under Elevated Carbon Dioxide

Soil Test Values and Nutrient Balances from a Long-term Fertilizer Experiment

Better Fertilizer Decisions for Crops

Farmers fertilizing oil palm seedlings in nursery in Sandakan, Malaysia.

Longerenong Cropping Challenge - Chickpea Phase

Multiple Nutrient Deficiencies in Central Queensland Cropping Systems

Micronutrient Field Evaluations

Micronutrient Survey

Farm Gate Nutrient Balances of Australian Natural Resource Management Regions

Africa

Sub-Saharan Africa: Dr. Shamie Zingore

Evaluating the Impact of Soil Fertility Heterogeneity on Maize Nutrient Requirement and Productivity in Smallholder Farming Systems

Nutrient Management for Grain Legume Crop Production Intensification in Africa

Asia

China Program, Southwest Region, Dr. Shihua Tu

Effects of Nutrient Management on Potato Yield on Acid Soils in Chongqing

Effects of Potassium Sources, Timing and Placement on Yield and Quality of Lettuce and Chinese Cabbage

Research on Optimal Fertilizer Potassium Oxide to Nitrogen Ratios for Litchi in Guangdong

Nutrient Demands of a Banana Variety

Effect of Balanced Fertilizers on Yield of Red Dragon Fruit in Guangxi

Effect of Different Fertilizer Treatments on Chili Pepper Production in Hainan

Maize Yield and Nutrient Losses from Sloping Lands as Affected by Different Rates of Nitrogen, Phosphorus and Potassium Fertilizers in Sichuan

Response of Maize under Plastic Mulch to Controlled Release Urea (CRU) in Yunnan, China

China Program, Southeast Region: Dr. Fang Chen

Studies and Demonstration of Environmentally Friendly Fertilization Technology in Vegetables and Banana

Study and Demonstration of Soil Nutrient Management and Balanced Fertilizer Technology for Cotton in Anhui

Ecological Effect and Utilization Rate of Potassium for Different Potassium Efficiency Cotton Genotypes

Study on the Fertilization Effect and Nutrient Management for Direct-seeded Rapeseed in China

Study on Nutrient Management Technology for Vegetables in Wuhan

Study on High Efficiency Nutrient Use and Regulation of Soil Nutrient Dynamics for High Yielding Rice

Balanced Fertilization Technology in Sweet Potato

Transformation, Interaction and Bioavailability of Nutrients in the Fertisphere

Improving the Method and Classification System for Evaluating Soil Available Potassium and Plant Potassium Status for Optimal Fertilization of Rice and Winter Wheat

Study on Fertilizer Regulation and Recommendation Technique for Greenhouse Vegetables in Shanghai

Mechanisms of Environmental Factors Affecting Uptake and Utilization of Nitrogen and Phosphorus by Vegetable Crops

Study on High Efficiency Nutrient Management Technology for China's Modern Rice Cultivation

China Program, Northwest Region: Dr. Shutian Li

Nutrient Management and Balanced Fertilization in Inner Mongolia

Nutrient Management and Balanced Fertilization in Main Crops in Ningxia Province

Effect of Long-term Application of Potash and Straw Return on Wheat Yield and Soil K Balance in Qinghai Province

Nutrient Management and Balanced Fertilization in Apple and Kiwi in Shaanxi

Best Management Practice for Potassium Application in Potato in Northwest China

Potassium Management for Improving Processing Tomato Yield and Quality in Xinjiang

Effect of Potassium Management on Lint Yield and Fiber Quality of Cotton in North China

Potassium Management in Apple Production in North China

China Program, Northcentral Region: Dr. Ping He

Nutrient Expert®-based Fertilizer Recommendations for Winter Wheat and Summer Maize in Hebei

Nutrient Expert®-based Fertilizer Recommendations for Spring Maize in Heilongjiang

Nutrient Expert®-based Fertilizer Recommendations for Winter Wheat and Summer Maize in Henan

Nutrient Expert®-based Fertilizer Recommendations for Spring Maize in Jilin

Nutrient Expert®-based Fertilizer Recommendation for Spring Maize in Liaoning

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Development of a Soil Fertility Map as a Decision Support Tool for Fertilizer Recommendations for Citrus in India

Fertility Mapping and Balanced Fertilization for Sustaining Higher Productivity of Pearl Millet-Wheat Cropping System in Agra District

Site-Specific Nutrient Management for Rice-Wheat in Punjab

Site-Specific Nutrient Management for Rice-Wheat in Haryana

Site-specific Nutrient Management for Rice-Maize Systems in Bihar

Assessment of Agronomic and Economic Benefits of Fertilizer Use in Maize Production Systems under Variable Farm Sizes, Climates, and Soil Fertility Conditions in Eastern India

Assessment of Soil Potassium Supplying Capacity from Soil Nutrient Reserves and Dissemination of Nutrient Management Technologies through Nutrient Manager®

South Asia Program, South Region: Dr. T. Satyanarayana

Improving Nutrient Use Efficiency and Profitability in Rainfed Production Systems

Site-specific Nutrient Management in Maize Growing Districts of Tamil Nadu

Balanced Fertilization for Enhancing the Productivity of Pearl Millet-Wheat-Green Gram Crop Sequence in Agra Region of Uttar Pradesh

South Asia Program, North & East Region: Dr. Sudarshan Dutta

GIS-based Spatial Variability Mapping of Agricultural Holdings for Precision Nutrient Management in Red and Lateritic Soil Zones

Maximizing Yield of Groundnut Through Improved Nutrient Management Practices in Acid Soils of Orissa

Comparative Evaluation of Nutrient Dynamics under Conventional and No-till Systems of Crop Establishment in Rice-Wheat and Rice-Maize Cropping Systems

Southeast Asia Program: Dr. Thomas Oberthür

Southeast Asia

Best Management Practice for Crop Nutrition of Mature Oil Palm

Malaysia

Plantation Intelligence to Upscale Best Management Practice in Oil Palm

Nutrient Expert® Development and Assessment

Best Management Practices for Maximum Economic Yield in Mature Oil Palm Plantations

Best Management Practices for Maximum Economic Yield in All Growth Stages of Oil Palm

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Eastern Europe and Central Russia: Dr. Svetlana Ivanova

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Improvement of Recommendations on Potash Fertilizer use and Adjustment of Currently used Soil Potassium Test Interpretation Classes in Intensive Cropping Systems

Ukraine

Evaluation of the Potassium Status of Arable Soils in Ukraine on the Basis of Modern Soil Diagnostic Techniques and Development of Recommendations for the Rational and Efficient Application of Potassium Fertilizers

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Improvement of Winter Wheat Mineral Nutrition on Calcareous Common Chernozems

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Balanced Fertilization of Major Crops in Egypt

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Headquarters:

3500 Parkway Lane, Suite 550
Norcross, Georgia 30092-2844 USA
Phone: 770-447-0335
Fax: 770-448-0439
E-mail: info@ipni.net
www.ipni.net