PLANT NUTRITION WITHOUT BORDERS
One of the strategic goals of the International Plant Nutrition Institute (IPNI) is to facilitate research on the sustainable use of plant nutrients needed for agriculture to meet future global demand for food, feed, fiber, and fuel. We accomplish this objective through partnerships with colleges, universities, government agencies, and other institutions and organizations around the world where IPNI programs are established.

This past year we provided financial and in-kind support to over 141 projects around the world. Our scientists work closely with the researchers and cooperators carrying out the research … often assisting with the initiation, design, and implementation, monitoring of progress, and the interpretation and dissemination of results. The studies are diverse, including fertilizer best management practices, site-specific nutrient management, and other components of 4R Nutrient Stewardship in cropping systems, but increasing crop yields and productivity is a common objective with most of our research.

Projects typically run for 3 to 4 years, although we do support some longer-term studies. IPNI scientists compile short interpretive summaries highlighting key findings and progress of each project annually. This publication has the most recent updates. A complete history of interpretive summaries and other outcomes from our research is available online at our Research Database:

>www.ipni.net/research<.

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IPNI Interpretive Summaries 2013

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NOTES: The following are abbreviations and symbols for nutrients and related terms which appear routinely in the
summaries on the following pages.

N = nitrogen; P = phosphorus; K = potassium; Mg = magnesium; S = sulfur; B = boron; C = carbon; Ca = calcium;
Cl− = chloride; Cu = copper; Fe = iron; Mn = manganese; Mo = molydenum; Ni = nickel; Zn = zinc;
ppm = parts per million; bu = bushels; A = acre; lb = pound; kg = kilogram; t = ton/tonne; hr = hour; yr = year;
in. = inch; USD (orUS$) = United States dollar; INR = Indian rupees; A$ = Australian dollar; RMB=Chinese Yuan

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endorsement or preferential treatment of the product by the authors or IPNI.
**HarvestPlus Zinc Fertilizer Project**

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Zinc deficiency is a global nutritional problem in crops and humans in many countries. Application of Zn-containing fertilizers offers a rapid solution to the problem complementing genetic solutions via plant breeding. This project was initiated in 2008 to evaluate the potential of various Zn-containing fertilizers to increase Zn concentration in cereal grains and improve crop production in various countries.

Results to date have shown large variations among countries and within countries in response to Zn fertilization. Grain Zn concentrations have been significantly increased by foliar application of Zn, often doubling levels, while soil Zn applications have been less effective. The project, now in its second phase, will focus on experiments investigating changes in grain Zn concentration based on timing and rate of a single spray of foliar Zn fertilizer. **IPNI-10**

**Best Management Practices for Sustainable Crop Nutrition in Bulgaria**

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Project Cooperators: Toni Tomov, Damian Mihailev, Liliana Stanislavova, Dobrinka Pavlova, Svetla Kostadinova, Ivan Manolov, Jivko Jivkov, Nidal Shavan, Milena Yordanova, Maria Apostolova, Kiril Popov, Dimitranka Stoycheva, Damyan Michalev, and Sergei Bistrichanov

In 2008, a 5-year project was established in Bulgaria with the general goal of improving cultivation systems in Bulgaria’s agriculture through efficient and sustainable use of plant nutrients. About 50 researchers and discipline specialists are taking part in the project. Project activities include: 1) evaluation of soil nutrient status through summarization of past national soil surveys and more recent localized regional surveys; 2) systematic summarization of past relevant soil fertility research and identification of information gaps; 3) nutrient omission/addition plot trials on target crops; 4) development of tools for site-specific nutrient management that deliver updated recommendations to farmers and farmer advisers; and 5) outreach activities to assure appropriate use of the developed tools.

After conducting a soil test survey of pilot regions and creating a GIS database with soil and field data attributes in 2009 and 2010, layers were created with low, medium, and high content of P and K. The
emphasis in 2011 was in the Northwest and Southwest parts of Bulgaria where additional soil sampling was conducted to better assess the soil fertility tendencies of these regions. In 2009, an Access database was structured for past soil fertility research and to accommodate new project data. In 2010, data obtained from long-term crop field experiments conducted after 1974 were entered into the database. The archive now consists of data from 87 experiments at 26 sites and 8 main soil types.

This (2012) was the fourth year of field omission/addition field plot trials (NPK or NPKMg as complete treatments). Crops tested were wheat, barley, maize, sunflower, potatoes, tomatoes, pepper, apricots, peaches, chokeberry, and wine grapes. Results in 2012 in most cases confirm the tendencies found in previous years but at higher yield levels—most of the tested crops responded to fertilization with the NPK treatment producing the highest yields in many sites. The project now enters its recommendation development phase where data from the new field trials will be integrated with legacy data and soil resource considerations to create new recommended fertilizer BMPs for Bulgaria. *IPNI-14*

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

Project Leader: Richard Ferguson, University of Nebraska - Lincoln Plant Science Department, Lincoln, Nebraska.  
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Project Cooperators: Newell Kitchen and Dave Franzen

Making sound recommendations for N fertilizer rate and timing for optimal corn yield and minimal N loss can be complex and challenging, especially considering seasonal and locational variability. Splitting N applications between pre-plant and in-season allows room for adjustment to specific seasonal conditions. Tools such as crop sensors and the Maize N model have been developed to help fine-tune corn N management. The general objective of this study, initiated in 2012, is to evaluate these two approaches for determining in-season N rates for corn over a three state region (Nebraska, North Dakota, Missouri). Other factors such as plant population, hybrid drought score, and soil productivity were also evaluated. Two experimental sites per state were selected, making a total of six sites. Sites within states were in close proximity, each state having a high and a lower soil productivity site. At each site a high and moderate plant population were evaluated for both a low and a high drought score hybrid. Four basic N treatments were used: unfertilized check, N-rich strip (preplant), sensor-based approach and model-based approach. The two latter treatments involved in-season application. Sensor-based treatments were determined by canopy reflectance using a Handheld Crop Sensor. Pre-plant, at-planting and in-season N application method and source varied by state.

Weather conditions affected study sites in 2012. Water stress masked N treatment effects at some sites that were not fully irrigated. The Nebraska sites experienced a large amount of soil N mineralization, particularly in March, which resulted in all treatments (including control) having high available N. Additionally, leaf curling due to drought stress and low populations due to soil crusting likely impacted the sensor readings in North Dakota. For all sites, the in-season N application rate for the model-recommended treatments exceeded that of sensor-recommended treatments. The sensor treatment appears to have higher N use efficiency as seen by partial factor productivity (yield/total N fertilizer); however, the agronomic efficiency (fertilized-control yield/total N fertilizer) was not correlated to N strategy for many of the sites. This is the first year of a large and complex study that was unfortunately impacted by drought. It is planned to continue in 2013. *IPNI-47*

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

Project Leader: Shamie Zingore, IPNI sub-Saharan Africa Director, Nairobi, Kenya. Email: szingore@ipni.net  
Project Cooperator: Thomas Oberthur

IPNI demonstrated a huge success of BMPs in oil palm growing environments in Southeast Asia. Today, oil palm growers invest in existing plantations elsewhere in the world, including in West Africa. In environmental analyses, IPNI demonstrated similarity of poorer oil palm environments in Kalimantan with other regions in Southeast Asia, in Latin America and also in West Africa. This project will assess the requirements for adaptation of BMPs in West Africa in IPNI partner plantations in Ghana, and if results permit, develop concepts and projects for full BMP adaptation in West Africa.

In 2012, a feasibility assessment was conducted in oil palm plantations in Ghana that belong to plantation partners of IPNI Southeast Asia. We identified and contracted the required expertise to undertake the assessment. Local plantation partners provided the necessary logistical support, data and information. The research team assessed the agronomic, socio-economic and social conditions in the West African plantations against the requirements for successful implementation of BMP. The field feasibility assessment results were encouraging: Three major oil palm producers in Ghana have endorsed the establishment of a BMP project to intensify their oil palm production.
We will work in 2013 in partnership with two or three plantations, smallholder out growers, Ghana Oil Palm Research Institute and Ghana Ministry of Agriculture to establish BMP project sites. The project will be a pioneering effort in West Africa where intensive, high yielding, commercial oil palm production systems are in their infancy. It is estimated that losses in opportunities are indeed significant from the 4 million ha of oil palm grown in West Africa, due to reduced yields. The project provides an opportunity for oil palm growers to intensify production on pre-existing plantations, enhance their profitability and manage the environment sustainably, as shown in previously successful BMP projects in Indonesia. By engaging with the Sustainable West African Palm-Oil Programme, that supports the intensification of oil palm production, IPNI aims to transfer BMPs from its project sites to other plantations and smallholder systems in the region. In 2013, an adaptation process and field trials will be designed and implemented. *IPNI-53*

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**Global Maize**

**Global Maize Project in Brazil: Itiquira, Mato Grosso**

Project Leader: Valter Casarin, IPNI Brazil, Piracicaba, São Paulo. Email: vcasarin@ipni.net

Project Cooperators: Eros A.B. Francisco, Scott Murrell, Aildson P. Duarte, and Adriel F. Fonseca

Cropping system intensification will be necessary to meet the future demand for corn (maize). Ecological Intensification (EI) seeks cereal production systems that satisfy future demands while developing cultivation practices with minimum interference to the surrounding environment. A Global Maize Project (GMP) was established to identify gaps in yield between current technology and improved technology aimed at achieving EI. The experiment was initiated in November 2009 at Itiquira, Mato Grosso in an Oxisol that has been under cultivation for 20 years. The experiment has a split-plot design with main plots involving three types of cultivation systems and the sub plots being three levels of N input plus a control. The types of cultivation being evaluated are: farmer practice (FP) of soybean followed by corn; FP + a forage crop (*Brachiaria decumbens*) in the winter; and EI involving a 3-year complete crop rotation cycle of soybean, corn (second crop), forage, soybean, crotalaria, regular corn, and forage. The EI treatment occurs three times, alternating the initiation point of the crop rotation to permit the production of corn every summer. The levels of N input were 50, 100 and 150 kg N/ha for the first corn crop (summer crop) or 30, 60 and 90 kg N/ha for the second corn crop, plus a control with no N added in both cases.

The results to date indicate that there were good responses to N in both maize crops, which positively influenced maize yields and total N uptake. The addition of N positively impacted the dry matter yield of the forage grass cultivated with corn. Soybean grain yield was similar if cultivated after corn second crop + forage or cultivated only after corn. Soybean crop responded to N previously applied to corn showing that for high soybean yields N biological fixation may not be enough. Latest data have shown a depression in grain yield and biomass of maize second crop when cultivated after maize first crop + forage, likely due to the high N exportation from first maize crop. This is a long-term project intended to influence current opinions on how to best manage cereal production in the region. *IPNI-18*

**Global Maize Project in Brazil: Ponta Grossa, Paraná**

Project Leader: Valter Casarin, IPNI Brazil Program Deputy Director, Piracicaba, São Paulo. Email: vcasarin@ipni.net

Project Cooperators: Adriel F. Fonseca, Gabriel Bartz, Scott Murrell, Aildson P. Duarte, and Eros A.B. Francisco

Cropping system intensification will be necessary to meet the future demands for corn. The proposed system of Ecological Intensification (EI) seeks cereal production systems that satisfy these future demands while developing cultivation practices with minimum interference to the surrounding environment. A Global Maize Project was established to identify gaps in yield between current technology and improved technology aimed at achieving EI. The experiment was first established at Ponta Grossa, Paraná, in May 2011, by seeding winter crops to respective treatment plots. The soil in the area is an Oxisol that has been in a no-till system for six years. The experiment had a split-plot design with the main plots involving three types of management systems and the sub plots being three levels of N input plus a control. Different management systems used were: farmer practice (FP) involving a 2-year complete crop rotation cycle of black oats, corn, wheat, and soybean; FP + silage production; and EI of black oats + forage peas, corn, black oats, and soybean. The EI treatment is planned to occur twice, alternating the crop rotation initiation point to permit the production of corn every summer. The levels of N application for the corn were 70, 140 and 210 kg N/ha, plus a control with no N added.

The results for dry matter yields of winter crops varied from 3.91 t/ha for black oats to 5.72 t/ha for ryegrass. Up to 140 kg/ha of N were applied to the soil for growing winter crops. As mentioned earlier, it was
possible to visualize the effect of winter forage peas, through their addition of N to the system, on summer maize growth. Grain yields were significantly higher when maize was cultivated after forage peas compared to white or black oat. At higher N rates, total grain yield averaged 13.3 t/ha. Soil samples were collected to evaluate soil physical properties and are being analyzed. Also, tissue samples were collected from the summer crop for laboratory analysis. 

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

Project Leader: Kuan Zhang, Agricultural Environment and Resource Research Centre Jilin Academy of Agricultural Sciences, Beijing, Jilin. Email: xiejiagui@163.com

Project Cooperators: Jiagui Xie and Xiufang Wang

This long-term field experiment was initiated in 2009 in Luiufangzi, Gongzhuling City, Jilin province, where mono-cropping of spring maize is common. The aim of the experiment was to compare the performance of ecological intensification (EI) practices with common farmers’ practice (FP) for yield and N use efficiencies. The main plot had two treatments: EI treatment with application of 180 kg N, 75 kg P₂O₅, 90 kg K₂O, 20 kg S, and 5 kg Zn/ha and FP treatment with application of 251 kg N, 145 kg P₂O₅ and 100 kg K₂O/ha. Three sub-plots included: N applied in all years (N all yr); N applied in 2 of every 3 years (N 2/3 yr); and no N applied any year (N 0 yr). In the year 2012, spring maize was planted on April 29 and harvested on September 24.

The EI treatment produced grain yields (12.3 t/ha) similar to the FP treatment (12.4 t/ha), although more N, P and K were applied in FP. However, the agronomic N efficiency (kg grain yield increase per kg N applied) was higher (37 kg/kg) in the EI treatment than in the FP treatment (8.4 kg/kg). Similarly, partial factor productivity of N (kg grain yield per kg N applied) was higher (68.5 kg/kg) in the EI treatment when compared with the FP treatment (49.4 kg/kg). This was possibly due to lower fertilizer N use in the EI treatment compared to the FP treatment. Grain yield under N 2/3 yr treatment was significantly lower than under the N all yr treatment, which demonstrated the value of N application in every spring maize growing season at the experimental site.

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

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Project Cooperator: Liangliang Jia

This long-term experiment was initiated in June 2009 in Hebei province. Summer maize was the first crop grown at this site, where winter wheat-summer maize rotation system is common. The main plot had two treatments: ecological intensification (EI) treatment with application of 170 kg N, 75 kg P₂O₅ and 70 kg K₂O/ha in winter wheat and 182 kg N, 67 kg P₂O₅ and 65 kg K₂O/ha in summer maize; and farmer’s practice (FP) treatment with application of 225 kg N, 120 kg P₂O₅ and 50 kg/ha in winter wheat and 255 kg N, 80 kg P₂O₅ and 20 kg K₂O/ha in summer maize. Three subplots included: N applied in all three years (N all yr), N applied in 2 of every 3 years (N 2/3 yr), and no N applied (N 0 yr). Winter wheat (the sixth successive crop) was planted on October 19, 2011 and harvested on June 18, 2012, while summer maize (the seventh successive crop) was planted in the same plots on August 20, 2012 and harvested on October 12, 2012.

No significant difference in grain yields was found between EI and FP treatments for winter wheat, although more N and P were applied in FP. However, agronomic N efficiency (kg grain yield increase per kg N applied) was higher in the EI treatment (6.6 kg/kg) than in the FP treatment (5.1 kg/kg). Similarly, partial factor productivity of N (kg grain yield per kg N applied) was considerably higher in the EI treatment (41.5 kg/kg) than in the FP treatment (29.5 kg/kg). Similar trends for grain yield and N use efficiencies were found in summer maize. N 2/3 yr treatment produced yields similar to N all yr treatment. This demonstrated that skipping N application in two seasons did not affect the grain yield during the third maize growing season.

Global Maize Project in India: Ranchi, Jharkhand

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Project Cooperators: A. K. Sarkar and S. Karmakar

Three sets of field experiments were conducted at Birsa Agricultural University farm at Ranchi, Jharkhand on system evaluation of ecological intensification (EI), optimization of rate and time of N application, and omission plot studies with maize and wheat. The trials were carried out with hybrid maize grown during kharif (monsoon) and wheat during rabi (winter) seasons. Relevant soil properties were also measured. The first experiment included long-term system evaluation of EI management versus farmers’ fertilization practices (FFP) with four treatments: EI (180 kg N, 90 kg P₂O₅ and 100 kg K₂O), EI–N (0 kg N, 90 kg P₂O₅, and 100 kg K₂O), FFP (0 kg N, 90 kg P₂O₅, and 100 kg K₂O), and FFP–N (180 kg N, 90 kg P₂O₅, and 100 kg K₂O). The trials were conducted for three seasons (2009–2010, 2010–2011, and 2011–2012).
and 100 kg K₂O), FFP and FFP–N for maize and wheat crops. The second experiment involved the effect of rate and time of N application, and comprised of 12 treatments including four levels of N (0, 80, 160, and 240 kg N/ha) in maize and (0, 50, 100, and 150 kg N /ha) in wheat with three different methods of N application. A common dose of 100 kg P₂O₅ and 100 kg K₂O/ha in maize and 90 kg P₂O₅ and 80 kg K₂O/ha in wheat were applied uniformly. The third experiment included analyzing the effect of nutrient management (omission plot) and it consisted of five treatments: 250:120:120 kg/ha N:P:K application in maize and 150:110:100 kg/ha N:P:K application in wheat, SSNM in maize at 200:90:100 kg/ha N:P:K and SSNM for wheat at 120:70:60 kg/ha N:P:K, and omission of N, P and K to assess the soil nutrient supplying capacity on a long-term basis.

Highest grain yields of maize (7.9 t/ha) and wheat (4.1 t/ha) were obtained with the EI treatment in maize and 130 kg N, 70 kg P₂O₅ and 60 kg K₂O in wheat. These yields were two to three times higher than the yields obtained with FFP (3.2 and 2.2 t/ha for maize and wheat, respectively). The study indicated about 120% higher maize equivalent yield in the system over FFP. Highest yield of maize (6.5 t/ha) in experiment 3 was obtained in the SSNM treatment followed by the ample NPK (6.1 t/ha) treatment, while highest yield (4.7 t/ha) of wheat was found in the ample NPK treatment followed by the SSNM treatment (3.7 t/ha). The maximum reduction in yield of the system (80%) was recorded where N was omitted, followed by the omission of P (36%) and K (15%). It can thus be inferred from the data that SSNM can help increase productivity of maize and wheat by two to three times in Jharkhand.  

**Global Maize Project in India: Dharwad, Karnataka**

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Project Cooperators: Y.R. Aladakatti

Evaluation of ecological intensification (EI) and farmer’s practice (FP) in the maize-wheat cropping system during the third year of this trial revealed that EI with application of 180 kg N, 90 kg P₂O₅ and 100 kg K₂O/ha resulted in maize grain and stover yields of 3.9 and 7.2 t/ha, respectively. These yields were 27 and 30% higher, respectively, than the yields obtained in the FP treatment with application of 115 kg N, 52 kg P₂O₅, 45 kg K₂O/ha. However, pooled data for three years indicated 24% higher grain yield in EI than FP. Compared to EI and FP treatments, there was a steep reduction in maize grain yields in the EI-N (64%) and FP-N (53%) treatments over a period of three years. Net returns of INR 25,969/ha were obtained in the EI treatment, which were 26% higher than the net returns obtained with FP (INR 19,099/ha). In wheat, EI resulted in higher grain and straw yields of 3.6 and 6.5 t/ha, respectively, which were 12 and 5% higher than the grain and straw yields obtained with FP. Data averaged over three years also indicated higher wheat grain and straw yields in EI as compared to FP.

Rate and application studies revealed yield responses of 9, 7.6 and 4.3 t/ha in maize-wheat cropping system (MWCS) with applications of 390, 260 and 130 kg N/ha, respectively, over the no-N treatment. Even though the yield increase due to N fertilization was substantial (248% at 390 kg N/ha and 118% at 130 kg N/ha), the AEN (kg grain/kg N) decreased from 32.9 to 23.1 with increasing N rates from 130 to 390 kg N/ha. This indicated lower N use efficiencies at higher N application rates. Also, with increasing N rates, return on investment (ROI) for N fertilizer in the MWCS, decreased from 20.4 to 12.7, with a mean return of 16.6 INR/INR invested. The results indicated that although the net returns increased with increasing N rates, they also came at the cost of increased risk level for the farmer. These studies also gave an indication that, in addition to crop response, AEN and ROI also need consideration while deciding on the N application rate in the MWCS. A relatively better AEN (30.7) and ROI (17.7) were noticed with N application in three splits using a leaf color chart.  

**Global Maize Project in Argentina: Balcarce, Buenos Aires**

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Project Cooperators: Guillermo Studdert, Aníbal Cerrudo, Roberto Rizzalli, Pablo Barbieri, Hernán Echeverria, Liliana Picone, Cecilia Videla, José Luis Costa, Virginia Aparicio, and Pablo Abbatte

A long-term field experiment was established at Balcarce, Buenos Aires, in the 2009/10 growing season. The crop rotation was maize-wheat/double cropped-soybean, with both crop phases occurring each year. Soil samples were collected during site establishment to characterize initial conditions, especially the carbon content in the entire soil profile. Treatments included current farmer practice (FP) and Ecological Intensification (EI) practice. Treatments differed in cultivars, planting dates, pest and weed control, or nutrient management practices. Maize crop in the 2011/12 season grew under dry climatic conditions, which affected the expression of an improved potential yield in the EI treatments. Maize yields were 4.98 t/ha, and 6.57 t/ha for FP and EI treatments, respectively — a significant difference of 32%. Wheat crop was less affected...
by the dry season, and wheat yields were 3.94 t/ha for FP and 5.23 t/ha for EI, which again was a significant
difference of (+33%). Double cropped-soybean was planted immediately after the wheat harvest in early
January, but the crop was lost because of the severe dry conditions during January.

Considering the first three years and the three crops involved in the maize/wheat/double cropped soybean,
the EI treatment significantly improved water use efficiency (determined as kg grain per mm of ET) over FP,
but the two treatments did not differ much in the capture of water (ratio of ET/total precipitation). The EI
treatment also showed higher N use efficiency and N removal and less negative N balances, but lower partial
factor productivity of N as compared to the FP treatment for the maize crop. Preliminary determinations
of N$_2$O-N emissions in the 2011/12 maize crop showed similar emission rates in the FP and EI treatments.
Satellite field experiments evaluating hairy vetch as cover crop for maize showed a significant N supply from
the winter legume to the summer crop without negative effects on yield even in dry years.  IPNI-24

Global Maize Project in Argentina: Oro Verde, Entre Ríos

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Project Cooperators: Ricardo Melchiori, Pedro Barbagelata, Carolina Sasal, Hugo Tassi, and Osvaldo Paparotti

A long-term field experiment was established at Oro Verde (Entre Ríos) in the 2009/10 growing season. The
crop rotation was maize-wheat/double cropped-soybean, with both crop phases occurring each year.
Soil samples were collected during site establishment to characterize initial conditions, especially the
carbon content in the entire soil profile. Treatments included current farmer practice (FP) and ecological
intensification (EI) practice. Treatments differed in cultivars, planting dates, pest and weed control, or nutrient
management practices.

Maize yields showed a low response to the EI treatment because of water stress during the V6-R3 stages,
with 4.15 and 5.15 t/ha yields for the FP and EI treatments, respectively. Practically, this was a non-significant
difference in yields between FP and EI treatments. Wheat yields, on the other hand, showed a significant
difference between FP (2.48 t/ha) and EI (3.36 t/ha) treatments. Like in wheat, double cropped-soybean yields
were also significantly higher in the EI (2.48 t/ha) treatment than in the FP (2.08 t/ha) treatment.

Considering the first three years and the three crops involved in the maize/wheat/double cropped soybean,
the EI treatment significantly improved water use efficiency (determined as kg grain per mm of ET) over FP,
but the treatments didn’t differ much in the capture of water (ratio of ET/total precipitation). The EI treatment
also showed higher N use efficiency and less negative N balances, but lower partial factor productivity of N
when compared with the FP treatment.  IPNI-25

Global Maize Project in the United States: Ames, Iowa

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Project Cooperator: John Sawyer

The objective of this study is to determine whether or not an ecological intensification (EI) approach can
increase yields more quickly over time than current farmer practice. The study design is a split plot. The main
plot is management system: 1) farmer practice (FP), and 2) EI. The split plot is: 1) N application according
to the management system, and 2) no N. The treatments are in a randomized complete block, with four
replications.

Data from 2012 have yet to be analyzed. The site was affected by drought. In 2011, no significant
differences in maize yield resulted from the differences in management practice. Maize in both systems did,
however, respond to N additions, with both systems responding similarly.  IPNI-26

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

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The objective of this study is to determine whether or not an ecological intensification (EI) approach
can increase yields more quickly over time than current farmer practice. The study design is a randomized
compete block design. Two management practices are investigated: 1) farmer practice (FP), and 2) EI. Three
N rates are also being studied: no N, intermediate N, and full N.

The site was affected by drought in 2012 and management practices did not produce significantly different
maize grain yields. Relationships between whole plant nutrient uptake and yield are currently being studied.  IPNI-27
**Global Maize Project in Mexico: Celaya, Guanajuato**

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Project Cooperator: Benjamin Zamudio

The study started in 2009 in Celaya, State of Guanajuato, at 1,830 meters above sea level, in an environment classified as non-equatorial, tropical–subtropical, mid-altitude. In 2012, the design of treatments was modified to include a combination of two plant populations: Farmers’ practice (FP) (89,286 seeds/ha) and a higher population (119,048 seeds/ha), three N fertilization regimes (0 N always, 0 N following 300 kg N/ha applied in 2011, and 300 kg N/ha applied every year), and two levels of P+K+Mg+Zn (0 and 90 kg P₂O₅/ha + 150 kg K₂O/ha + 25 kg MgO/ha + 10 kg Zn/ha). Treatments were arranged in a split-split-plot design, where plant populations, N fertilization regimes, and P+K+Mg+Zn were assigned to large, sub-, and sub-sub-plots, respectively.

Plant populations at harvest differed significantly between FP (67,370 plants/ha) and the higher population (86,311 plants/ha). Average stand reduction between planting and harvest for both populations (24%) was greater than normal. This reduction was probably due to soil crust ing at seedling emergence and losses to wildlife. However, population differences did not result in significant average grain yields differences between FP (5.27 t/ha) and the higher population (5.62 t/ha) treatments. Grain yield with the application of 300 kg N/ha (11 t/ha) was significantly higher than the grain yields obtained with 0 N following 300 kg N/ha applied in 2011 (2.84 t/ha) and 0 N always (2.49 t/ha). The latter two did not differ statistically. Partial Factor Productivity (PFP) and Agronomic Efficiency (AE) of N were 37 and 28 kg grain/kg N, respectively. No significant differences in grain yield could be detected between the two levels of P+K+Mg+Zn used in the experiment (5.48 vs. 5.41 t/ha). These results were consistent with the soil test values for these nutrients.

**Global Maize Initiative, Colombia**

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This experiment was continued at the Villa Escocia experimental farm of FENALCE with two more crop cycles completed. The results obtained in 2012 were similar to the results obtained in the previous four crop cycles. The highest maize grain yields (average 9 t/ha) were obtained with Ecological Intensiﬁcation (EI) and N all cycles treatment, while the lowest maize grain yields (average 2.5 t/ha) were obtained with EI and no N treatment. Statistical analysis did not detect any significant difference in grain yields between EI and traditional technologies (average difference of 1 t/ha), but the differences were highly significant among N strategies used (difference of 6.2 t/ha).

As with the previous crop cycles in the study, N is the main driver of yield at this site (Buga), and the effects of N management erase the advantages of EI strategy (higher planting density and balanced nutrition in this case). Nevertheless, it is worth mentioning that for all the cropping seasons tested in Buga, the best yields were consistently obtained with high N (used across all crop seasons) together with EI strategies.

The Valle del Cauca Department, the region where this study was conducted, can no longer be considered a corn-growing area as most of the crop has been replaced with sugar cane. FENALCE has proposed to move this study to a new area, namely the Llanos Orientales, a large flat expanses in the East of Colombia with a proposed expansion of maize plantings to about 500,000 ha area. The study will be repeated in this region in the following years with a slightly different approach in that we will not use a single crop rotation, but crop rotations instead with emphasis on minimum tillage and lime amendment. 

*IPNI-28*
**Growth, Yield and Water Use under Elevated Carbon Dioxide**

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Project Cooperators: Saman Seneweera, Garry O’Leary, Sabine Posch, and Michael Tausz

In 2007, two free air carbon dioxide (CO\(_2\)) enrichment facilities were established to simulate the future environments under which crops will be grown by raising the CO\(_2\) level under otherwise field conditions. Averaged for six seasons, wheat grown under high CO\(_2\) saw 15 to 50% increases in yield. This increase occurred irrespective of the sowing time or year, but was strongly influenced by temperature and water supply. There were smaller, but significant, yield increases even under hot and dry conditions. The harvest index of these six wheat crops—the proportion of growth that goes to grain—was not reduced with high CO\(_2\) so the plants were actually operating more efficiently with the extra carbon available to them in the atmosphere. The yield response suggests that CO\(_2\) will help reduce the impact of higher temperatures and lower rainfalls, even in the low rainfall regions of Australia. However, higher yields come with lower grain protein content which is part of a physiological adaptation to having more CO\(_2\). Reductions in grain mineral content and changes in other aspects of grain quality were also noticed.

The research also identified interactions between N, P and S supply, and these data indicate that adequate P is important in enabling crops to use the added carbon. Sulfur supply, balanced with N supply is important to ensure wheat baking quality. Our research also found that current varieties vary in their response to elevated CO\(_2\), probably because of changing N allocations, differences in transpiration efficiency, variation in stress response and differences in inherent physiological features. Understanding these differences will allow targeted selection of wheat cultivars better adapted to future warmer, drier and carbon-rich environments. It will also identify regions and management practices where yield response to elevated CO\(_2\) can be maximized. In the future, we will investigate strategies to improve N use efficiency under elevated carbon dioxide using variety differences, agronomic practice and enhanced efficiency fertilizers.

**Urea and Gypsum Compared to Ammonium Sulfate for Canola**

Project Leader: Rob Norton, IPNI Regional Director Australia and New Zealand, Horsham, Victoria.
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Project Cooperators: M.T. Khan, Robert Edis, Deli Chen, and Charlie Walker

The importance of N and S in canola cropping systems is well established. However, in the past, urea and gypsum were the commonly used strategies for N and S nutrition. We hypothesized that the use of ammonium sulphate (AS) along with urea may enhance both N and S efficiencies in a Calcarosol growing canola. We conducted a field experiment to investigate the effects of combining urea and AS on canola growth, yield and nutrient uptake at Walpeup in southeastern Australia.

Irrespective of sources, N significantly increased aboveground biomass at flowering stage and grain maturity stage. Similarly, this was also reflected on a range of nutrient uptake. However, nutrient uptake (N, P, K, S, Ca, Mg, and micronutrients) at flowering stage was also significantly higher in the urea plus AS treatment compared to that observed in the urea plus gypsum treatments. Although a response to S was not seen at flowering stage, a significant S response occurred at grain maturity stage in urea plus AS compared to urea plus gypsum. Urea plus AS significantly increased agronomic N and S efficiencies by 3.6 and 35.6%, respectively, compared to urea plus gypsum. We hypothesize that the higher efficiency may be associated with lower ammonia volatilization and high acidification of the root zone in the alkaline calcareous soil,
which enhanced nutrient uptake. Further results on N and S uptakes at maturity and N isotope studies of plant and soil under field micro-plots will be used to test our hypothesis. ANZ-03

Nitrogen Dynamics under Elevated Carbon Dioxide
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Project Cooperators: Shukee Lam and Roger Armstrong

By 2070, atmospheric carbon dioxide (CO₂) concentration is expected to double that observed in 1950. In this higher CO₂ world, the sustainability of global crop production may be in jeopardy unless current N management strategies are changed. Many studies have tried to quantify the effect of increased CO₂ on plant production and N utilization, but the results have generally been inconclusive and contradictory. To interpret the available information and provide new insight on crop management in the near future, we examined the effects of elevated CO₂ on N dynamics in grain crop and legume pasture systems using meta-analytic techniques (366 observations from 127 studies).

The analysis revealed that elevated CO₂ increases crop production. However, to achieve this increase, an adequate supply of N, derived from soil, fertilizer and/or biological N-fixation is required. Since N demand and removal in many grain cropping systems is predicted to increase under future CO₂-enriched environments, current N management practices need to be revised. These practices may include higher rates of fertilizer N application, greater use of legume intercropping, or legume cover crops, etc. ANZ-04

Soil Test Values and Nutrient Balances from a Long-term Fertilizer Experiment
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Project Cooperators: Rohan Davies and Peter Howie

The Dahlen long-term N and P experiment was established in 1996, and has been sown to a canola, wheat, barley, and pulse rotation each year since then. Treatments included four rates of P (0, 9, 18, 36) applied at sowing and 5 rates of N (0, 20, 40, 80, 160) applied either all at sowing or as a 50:50 split between sowing and the start of reproductive growth. Soil test values, including total P, Colwell P, total N, and mineral N contents were tracked over the course of the experiment to provide information on the long-term effects of fertilizer use in this region, including fertilizer nutrient use efficiency.

Colwell P at the start of the experiment was 24 mg/kg (PBI 115), and after 16 years its values were 17, 40, 72, and 125 mg/kg for the 0, 9, 18, and 36 kg P/ha/yr rates. Soil mineral N values were 24, 36 and 34 kg N/ha at 0 to 60 cm depth and 58, 226 and 529 kg N/ha at 0 to 150 cm depth for 0, 80 and 160 kg N/ha rates, respectively. Soil C values were not affected by N application and averaged 1.09, 1.25, 1.33, and 1.29 (LSD= 0.21 at p=0.05) for the 0, 9, 18, and 36 kg P/ha/yr rates, respectively. Based on these data, it can be inferred that P application rates that are similar to P removal will maintain both soil P and soil C contents. Over application of N resulted in a large accumulation of N in the subsoil but had no effect on soil C. ANZ-08

Better Fertilizer Decisions for Crops
Project Leader: Simon Speirs, Industry and Innovation Wagga Wagga Agricultural Research Institute, Wagga Wagga, New South Wales. Email: simon.speirs@industry.nsw.gov.au

Project Cooperators: Simon Speirs, Ken Peverill, and Doug Reuter

This project concluded in 2012 with the completion and launch of the on-line interrogator tool (http://www.bfde.com.au), which allows trained participants to investigate the response of grain crops to N, P, K, and S from over 5,000 field experiments in Australia. The outputs from the on-line database are soil test critical values that will allow advisers to check and substantiate their recommendations based on these values. The project results will also be published in a special edition of Crop and Pasture Science during 2013.

Using the trial data, soil test critical values can be derived online through the Better Fertiliser Decisions for Cropping Interrogator tool. A trained and registered user is able to filter the data by attributes that include crop type, soil type, soil test, yield, and growing season rainfall. Fertilizer response criteria are obtained by fitting an inverted plot of the natural logarithm for the soil test value and the arcsin of the square root of relative yield. From these curves, critical fertilizer response values and confidence limits are determined for 80, 90 and 95% of relative yield. The fertilizer response curve is presented to the user with the critical values for each of these relative yields. The outcome of the project is to provide easy access to field experiments on soil test and crop response, as well as a repository for future nutrition research. Protocols for experimental design,
data handling, and recording of experimental metadata were also developed, and these will provide guidance for future research. ANZ-09

Longerenong Cropping Challenge - Chickpea Phase

Project Leader: Rob Christie, Nuseed, Horsham, Victoria. Email: robert.christie@au.nuseed.com

Project Cooperators: Mark Slatter, Steve Drum, and Peter Howie

The Longerenong challenge gives local crop advisors the opportunity to put their agronomic skills on show by managing a crop within a three-year cycle within a replicated experiment. Outcomes are assessed in terms of crop yield and gross margins. The plots were in canola in 2010, wheat in 2011, and chickpea in 2012. Despite a very dry season, chickpea crops yielded quite well with many above 2 t/ha, and the IPL team achieved the highest yield of 2.48 t/ha, which was similar to the yields of the crops managed by the Greenmachine (2.27 t/ha), the Raging Reds (2.24 t/ha), and the Longy students.

The highest gross margin—over A $1,000 per hectare—went to the Longy Students, with the Raging Reds not far behind. Overall, these were great gross margins and reflect the careful selection of the variety and good management of the crop. Variety selection was important with the higher yield of Genesis90 in this experiment producing the top three gross margins.

The Colwell-P soil tests at the start of this crop phase were generally 30 to 40 mg/kg, which would be considered sufficient, or at least at maintenance levels, for this soil type, and the low fertilizer input resulted in reasonable yields for one group, but lower yields for another group. One group entered with a soil test Colwell-P value of 26 mg/kg, but this did not seem to adversely affect yields in this case. Chickpea is known to be able to access less available P pools in the soil when compared to cereals.

Multiple Nutrient Deficiencies in Central Queensland Cropping Systems

Project Leader: Mike Bell, University of Queensland, Kingaroy, Queensland. Email: mbell4@uq.edu.au

Central and southeastern Queensland cropping systems are driven by water availability, and in these summer rainfall areas either winter crops (wheat or chickpea) or summer crops (cotton or sorghum) will be selected depending on the amount of stored soil moisture. It has been shown that in these systems, the subsoil nutrient levels are moderately to severely depleted due to the rainfall and root development patterns. Low levels of P, K, S, and micronutrients are routinely seen in the subsoil (>20 cm), but soil testing is usually from surface soils (0 to 10 cm) except on irrigated (bedded) cotton which is sampled 0 to 30 cm. Field experiments on cotton, sorghum, chickpea, and wheat are investigating the placement and type of nutrients to meet the demands of these crops. Because these are grown with minimum tillage, the investigations are considering supplying large amounts of nutrients (e.g. 200 kg KCl/ha) in the subsoil to meet crop demand over several seasons. Nitrogen management is tactical in these systems, as it is in these experiments. Row spacing, placement depth and balancing nutrients are treatments being used.

Results indicated that much of the cropping region faces multiple nutrient deficiencies, particularly with low P, which then constrains the response of K and S. There appears to be little penalty from having wide rows (100 cm) and deep placement (30 cm), and some growers are investigating using specialized deep placement equipment to establish these bands in the field. There are still problems with getting reliable soil K tests, and other work in the region is investigating both sampling depth, clay mineralogy and extractants. ANZ-11

Micronutrient Field Evaluations

Project Leader: Rob Norton, IPNI Australia New Zealand Director, Horsham, Victoria. Email: rnorton@ipni.net

Project Cooperators: Jarrod Brown, Rob Launder, and Brad McLean

During 2011 and 2012, six micronutrient field experiments were undertaken with cooperators from across Victoria. Sites selected on the basis of soil tests and cropping history were likely to respond to either Cu or Zn. The experiment in the Mallee investigated the effect of different presentations of Cu on what would be expected to be a Cu responsive site. There were responses to Cu when compared to an unfertilized control, but the yield of the superphosphate alone treatment was significantly lower than the untreated control, but no explanation is immediately apparent for this result. Three experiments were undertaken on the Vertisols in the Wimmera, at Horsham (2011), Nhill (2011) and Longerenong (2012). No significant responses were seen with added Cu or Zn at these sites. Two experiments were undertaken in the high rainfall zone of the western District, and neither of these showed significant yield responses to Cu or Zn applied as foliar supplements.

Grain analyses of the 2012 experiments will be reported when the results of these analyses are available. These results highlight the difficulty in identifying sites where micronutrients are limiting wheat yields,
although the use of both foliar and at-seeding treatments are quite common across a wide range of cropping systems. It is uncertain if this approach is considered as “insurance” or if responses are seen in paddocks that are not reflected in the experiments reported here.  

_Micronutrient Survey_

Project Leaders: Rob Norton, IPNI Australia and New Zealand Director, Horsham, Victoria. Email: rnorton@ipni.net

Project Cooperators: Alan Bedggood and Jan Edwards

Australia has had a long history of investigation into micronutrient deficiency, including significant advances in nutrition of pastures, crops and animals. In the grain growing regions, there are reports of B, Cu, Mn, Mo, and Zn deficiencies as well as particular cases where Fe deficiency is seen. However, predicting micronutrient deficiency is particularly challenging, with soil test being relatively unreliable, and tissue tests providing guidance but requiring careful monitoring and sampling. Soil type and geology can provide guidance, but there are large areas of the cropping region that have been treated with micronutrients and often finding a potentially responsive site can be difficult. Therefore, a database of 1,500 geo-referenced soil tests is being linked to the Australian Soil Classification (see SoilMapp) to assess the level of variation in soil test values. Around 1,000 grain samples from the 2012 National Variety Testing program for wheat, canola, narrow leaf lupin, and chickpea will be assessed for micronutrient content to assess if levels can be indexed against soil types. This work is in progress at present and will be reported to the Grains Research and Development Corporation by June 30, 2013. The project is part of a wider national crop nutrition project - More Profit from Crop Nutrition, funded by the GRDC in collaboration with state and federal government agencies, private consultants and the fertilizer industry.  

_Farm Gate Nutrient Balances of Australian Natural Resource Management Regions_

Project Leader: Robert Edis, Edis Consulting, North Melbourne, Victoria. Email: roberte@unimelb.edu.au

The amounts of N, P, K, and S applied as fertilizers and removed as agricultural commodities were calculated using the Australian Bureau of Statistics (ABS) data for 2007-08 and 2009-10 for all Australian Natural Resource Management (NRM) regions.

The mass of P in commodities was 43 and 50% of the mass applied as fertilizers in 2007-08 and 2009-10 (with respective national net inputs of 190 and 170 kt P). Regions with (commodity P)/(fertilizer P) < 0.3 and >10 kt P net input in both years were Murray, Murrumbidgee, Lachlan, and Glenelg Hopkins. Nationally, the mass of K in commodities was 2.5 and 3.1 times the mass applied as fertilizers in 2007-08 and 2009-10 (with respective net exports of 196 and 256 kt P). Regions with > 10 kt K net export and (commodity K)/(fertilizer K) >10 in both years were Wimmera, Northern and Yorke. The mass of S removed in commodities was 49 and 62% of the fertilizer mass applied in 2007-08 and 2009-10 (with respective national net exports of 91 and 62 kt P). Strong net additions of S in both survey years occurred in South-East (SA), South-West (WA), and Glenelg Hopkins. Nitrogen balance depends on the method used to calculate biological N fixation. Simply using fertilizer amounts, regions with strong net input of N were Port Phillip and Westernport, West Gippsland, Hawkesbury-Nepean, Wet Tropics, and Condamine.

These balances will be contrasted with land management practices and soil test values, as well as the 1992-1997 Land and Water Audit. Future work will include biological N into the N balance and publishing the data on all nutrients surveyed.  

_ANZ-16_
**Rates and Residual Effect of Potassium Fertilization in a Brazilian Soil**

Project Leaders: Luís I. Prochnow (IPNI Brazil Program Director), Eros Francisco (IPNI Brazil Deputy Director), Valter Casarin (IPNI Brazil Deputy Director).

Potassium is responsible for several vital mechanisms for plant development (enzyme activation, translocation and stock of compounds, osmotic regulation, water maintenance, etc.) and high yields. Potassium fertilizers are a must for balanced plant nutrition in the acid soils of the tropics, including Brazil. In many areas farmers are cutting back on fertilizer expenses, which could compromise good yields, profits, and food security in the future. The main objective of the study is to verify the effects of cutting back K fertilizer rates in some Brazilian soils. The study is also looking at some other important factors that may affect the effectiveness of K fertilizer in tropical soils (P, lime, phosphogypsum, time of application, and locality effects) to evaluate their effects on soil K status with time, plant K status with time, and grain yields.

Results for the first crop season (soybean and corn second crop) indicated: (1) low response to K in soybean and no response in corn second crop, (2) no effect of lime, time of application, and location, and (3) higher K leaf contents with phosphogypsum application in soybean, but with no effect on yield. Results for the second crop season (soybean) indicated: (1) statistically significant response to K rates for soybean yield and soil K availability, (2) locality effect for soil K availability, and (3) no effect of lime rate and time of K application. This report summarizes data only for the first and second cropping years, though the project is planned for six years. Brazil-56

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

Project Leader: Ricardo Luiz Menezes Reis, Engenheiro Agrônomo da In Solo. Email: eufrasrô.brandao@insolo.com.br

Continuous cultivation of lands under the same monocropping systems tends to promote soil degradation and increases the incidence of crop diseases, pests, and weeds, which in turn, reduces crop yield potential. This is a long-term research project looking into various aspects of sustainable agricultural systems. The project gives emphasis to crop rotation and other alternatives to generating long-term profitability. This is believed to be instrumental to many farms located throughout the Brazilian Cerrado. Part of this project is dedicated to the study of soil fertility management under these systems. One experiment containing seven different cropping systems involving soybean and maize was initiated in 2011, and results for the first year are still undergoing statistical analysis. Preliminary evaluation of the results suggests good response of grain yield of maize to applied N rates. IPNI-58.

**Agronomic Effectiveness of Acidulated Phosphate Fertilizers with Different Water Solubility**

Project Leader: Rodrigo Coqui da Silva, University of São Paulo/Luiz de Queiroz College of Agriculture Soil Science, Piracicaba, São Paulo. Email: rodrigo.coqui@gmail.com

Project Cooperators: Takashi Muraoka and Claudinei Kappes

There is a high demand of P fertilizers in Brazilian agriculture, where the most common sources in use are acidulated phosphates. Due to the high P fixation capacity and low P levels of Brazilian soils in general, soluble P fertilizers have always been preferred for their high agronomic effectiveness. Recently, Brazilian legislation allowed the use of P fertilizers with low water solubility, but field trials are still needed to evaluate the effectiveness of such products. This project aims to study the agronomic effectiveness of four P fertilizers (acidulated phosphates) varying in water solubility (85, 70, 60, and 50%) for soybeans in an Oxisol in the Cerrado of Brazil.
Results from the first year of this study suggest the same agronomic effectiveness for P fertilizers with water solubility higher than 60%, but lower effectiveness for the source with 50% water solubility. Therefore, the use of acidulated phosphates with lower water solubility (50%), compared to the currently used source with 85% water solubility, may be an alternative for Brazilian agriculture. This is a three-year project, and valuable and more conclusive results will be possible with time. Brazil-59 ☀
Americas and Australia/New Zealand Group

Brazil Program
Midwest Region:
Dr. Eros Francisco, Deputy Director

Sustainable Production Systems Under No-Till in the Cerrado of Brazil
Project Leader: Eros Artur Bohac Francisco, (IPNI Brazil Program Deputy Director).
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Project Cooperators: Ciro Rosolem and Leandro Zancanaro

Continuous land cultivation with mono-cropping systems tends to promote soil degradation and increases the incidence of crop diseases, pests, and weeds, which in turn, reduces the crop yield potential. A long-term research project was initiated to look into various aspects of sustainable agricultural systems. The project focuses on crop rotation and other alternatives to generating long-term profitability. Part of this project is dedicated to the study of soil fertility management under these systems. Two experiments, one aimed at the production of fiber and the other at grain production, each containing seven different cropping systems, were initiated in 2008.

Results suggested that the production of dry matter of cover crops during the spring season, before sowing cotton, is sufficient for good soil protection and recycling of nutrients. Amounts of N, P, K, Ca, Mg, and S recycled by millet and Brachiaria grass were identical, while the amount of K recycled was higher for systems utilizing Brachiaria in the autumn and millet in the spring. The type of cover crop utilized during the spring did not influence cotton yield. The soil density was higher under no-tillage compared to annual soil tillage, but no fiber yield reduction occurred. For farming systems under no-tillage, soil density may be alleviated using Brachiaria grass for periods longer than 12 months, which may be an advantage for farming systems that include pasture crops. The use of cover crops after soybean harvest is essential to sustain soil biological activity and nutrient cycling, and Crotalaria showed higher levels of N cycled than Brachiaria and millet. Soil P levels were found to be lower in the farming systems with no use of cover crops after soybean, whereas the use of Brachiaria grass increased P level in the soil. Soybean yields were affected when it followed corn intercropped with Brachiaria. This could be related to immobilization of N in corn and Brachiaria residues. The intensification of the farming system with soybean and corn (second crop) in sequence resulted in higher amounts of nutrient export, which should be taken into consideration when planning fertilizer recommendations. If nutrient balance is not properly evaluated in intensive grain production farming systems it may endanger its sustainability. Severe drought at early stages of soybean allowed big differences in crop development due to higher residues covering the soil. More conclusive results from this long-term project will be possible with time. Brazil-53

Sources and Rates of Phosphorus in a Cultivation System Integrating Crop and Pasture Production in the State of Parana
Project Leader: Adriel Ferreira da Fonseca Ponta Grossa State University Department of Soils Av. Carlos Cavalcanti, 4748 Ponta Grossa, Parana. Email: adriel@uepg.br

The integration of crop and pasture production (ICP) within the same area, using no-till cultivation systems, is becoming popular in Brazil due to its agronomic advantages. Phosphorus is a key nutrient in these systems and soils in the state of Parana are generally low to medium in plant available P. The main purpose of this research is to evaluate the effects of P rates and sources (water-soluble and water-insoluble) on soil quality, plant mineral nutrition, forage, grain, and meat yields in an integrated crop-livestock system under no-till. The site has been under no-till for five years. Treatments included three sources of P [triple superphosphate (TSP), magnesium thermophosphate (MTP), and Arad reactive rock phosphate (RP)] and three rates of P (60, 120 and 180 kg total P₂O₅/ha), with all sources applied prior to seeding the winter crop. The trial also included a control, with no P applied, and three treatments supplying each source at 90 kg P₂O₅/ha applied prior to seeding the spring-summer crop.
Results so far indicate that it is possible to obtain high yields of maize and soybean (up to 12 and 5 t/ha, respectively) by applying P prior to the winter forage crop (black oats or ryegrass). Second, besides high grain yields, this timing of the P application leads to animal rate growth of up to 1 kg per day. Third, in the first two years, the TSP performed better as related to other P sources. Fourth, crop response was higher with MTP, while RP has performed as the least effective P source for this system. Fifth, data collected this last year showed that the two water-insoluble sources of P have presented higher residual effect than the water-soluble source of P (TSP) for forage biomass and grains yield. This project is expected to continue providing more insights until 2015. Brazil-55
Sustainable Production Systems Under No Till in the Cerrado of Brazil - Maranhão

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Continuous cultivation of lands under the same monocropping systems tends to promote soil degradation and increases the incidence of crop diseases, pests, and weeds, which in turn, reduces the crop yield potential. This is a long-term research project looking into various aspects of sustainable agricultural systems. The project gives emphasis to crop rotation and other alternatives to generating long-term profitability. This is believed to be instrumental to many farms located throughout the Brazilian Cerrado region. Part of this project is dedicated to the study of soil fertility management under these sustainable agriculture systems. One experiment containing eight different cropping systems was initiated in 2012 and general results for the first year will be available late in 2013. Brazil-60
Americas and Australia/New Zealand Group

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

Argentina

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

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Project Cooperators: Adrian Correndo, Santiago Gallo, Angel Berardo, and Nahuel Reussi Calvo

The Regional Consortium of Agricultural Experimentation (CREA), a farmers’ organization based in Southern Santa Fe, has established a network of field experiments with the objectives of: 1) determining direct and residual responses to N, P, S, and where indicated, to K, Mg, B, Cu, and Zn), 2) evaluating recommendation methods for N, P and S fertilization, 3) identifying the level of deficiency and potential response to nutrients other than N, P and S, and 4) evaluating the evolution of soil quality under contrasting nutrient management practices. In 2011-12, all five remaining sites of the network were planted to wheat/double cropped soybean, with two sites under corn-wheat/soybean (C-W/S) rotation and three sites under corn-soybean-wheat/soybean (C-S-W/S) rotation. Favorable climatic conditions at most of the experimental sites allowed for high yields for wheat. Grain yield responses to N, P and S were significant at all sites (average of 2,730 kg/ha, +113%), but for nutrients other than NPS, responses were significant only at the La Hansa site (407 kg/ha, +9%). Dry conditions affected double cropped soybean yields, which averaged from 1,300 to 3,300 kg/ha in the five experiments. Responses to N, P and S were significant at four sites, with average responses of 404 and 852 kg/ha for C-W/S and C-S-W/S rotations, respectively.

Considering the 12 seasons with 40 sites under corn, 38 sites under wheat, 57 sites under full-season and double cropped soybean, significant relationships were observed between Bray P-1 and P responses, with critical levels ranging between 12 and 20 ppm for the three crops. Below these critical levels, P responses are highly probable. Also, significant relationships were observed between grain yields of corn and wheat and soil N supply as predicted by soil nitrate-N measured at sowing + fertilizer N rate. The analysis of the first 12 years of the nutrition network has shown that adequate NPS management increased grain yields, contributed to improved water use efficiency, tended to increase soil organic matter, decreased soil pH, and allowed for soil P build-up. Return on investment (ROI) estimates were better for the W/S rotation than for the S-W/S rotation. For both rotations, ROI values averaged 2.7 and 0.6 US$/US$ N for corn and wheat, respectively, 2.1, 1.8 and 1.9 kg US$/US$ P for corn, wheat and soybean, respectively, and 4.4, 1.6 and 7.5 US$/US$ S for corn, wheat and soybean, respectively. During the 2012-13 season, sites will be planted to corn crop in both rotations. Argentina-12
**Long-term Nutrient Management Network for Southern Buenos Aires Province**

Project Leaders: Fernando García (IPNI Southern Cone) and Ernesto Caracoche (ASP Southern Division), Acassuso, Buenos Aires. Email: fgarcia@ipni.net

In 2007-08, IPNI and Agroservicios Pampeanos (ASP) established a network of field experiments with the objectives of: 1) determining direct and residual responses to N, P and S, 2) evaluating recommendation methods for N, P and S fertilization, and 3) identifying the level of deficiency and potential responses to other nutrients such as K, Mg, B, Cl, Cu, and Zn. Four sites were planted to full season soybean at Olavarria, Pieres, Tandil, and Tres Arroyos sites during the 2011-12 growing season.

Soybean check yields varied from 1.2 to 3.3 t/ha, and NPS fertilized yields varied from 2.0 to 3.8 t/ha. Phosphorus responses were significant at Olavarria (+373 kg/ha, +13%) and Tres Arroyos (+320 kg/ha, +19%) sites, while P and S responses were significant at Tres Arroyos (+809 kg/ha, +69%) and Tandil (+363 kg/ha, +11%) sites. Grain yield responses related well to low Bray 1P levels and good weather conditions. No responses were observed to nutrients other than N, P and S. These sites will be planted to barley during the sixth season of evaluation in 2012-13.

**Evaluation of Enhanced Efficiency Fertilizers for Wheat and Maize**

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Project Cooperator: Terry Tindall

A field experiment was established for maize in the 2011-12 growing season at Balcarce, Buenos Aires, to evaluate the performance of N and P enhanced efficiency fertilizers. Treatments included N at 120 kg N/ha and P at 18 kg P/ha combinations with urea and 0-46-0 fertilizers with and without the addition of Nutrisphere® (NSN), and Avail®, respectively.

Maize grain yield increased due to N application, but no differences were observed between N sources. On average, Urea and Urea+NSN increased maize yield by 594 kg/ha, an increase of 7.9%. A similar trend was observed for grain N absorption, which increased with N application, but no differences were observed between N sources used. The addition of P did not increase grain yield of maize despite the low Bray 1P value of the experimental soil. Grain P absorption was different between P fertilized and non-fertilized treatments, but no differences were observed between P sources.

**Response to Zinc in Maize Crop Grown in the Argentinean Pampas**

Project Leader: Fernando Garcia, IPNI Southern Cone, Acassuso, Buenos Aires. Email: fgarcia@ipni.net

Project Cooperators: Carlos Michiles, Matias Ruffo, and Laureano Boga

Grain crops grown in the Pampas region of Argentina, especially maize, have shown Zn deficiencies. However, research on Zn responses in maize is scarce. The objectives of this research project were to: 1) quantify maize response to Zn in the Pampas region, 2) determine the optimum Zn rate for maize, and 3) validate local Zn analyses and critical levels. Eighteen field experiments were carried out in the 2009-10, 2010-11 and 2011-12 maize-growing seasons at different locations in the Pampas region including: Alejo Ledesma, Chaján, Adelia Maria, Guatimozin, and Rio Cuarto sites in Cordoba; San Justo, M. Teresa, Rafaela, Wheelwright and Oliveros sites in Santa Fe; and 9 de Julio, Balcarce, Lincoln, Pergamino, and Gral. Villegas sites in Buenos Aires. Treatments included NP, NPS, and NPS with different Zn rates (0, 0.5, 1, 1.5, and 2 kg Zn/ha). Fertilizer sources used were MAP + urea (NP treatment), MES10™ (12-40-0-10S; NPS treatment), and MESZ™ (12-40-0-10S-1Zn; NPS plus Zn treatments). Nitrogen, P and S rates used were 80 kg N, 35 kg P and 20 kg S.

Visual deficiency symptoms of Zn were observed at most locations. Significant grain yield responses to Zn were observed at 12 of the 18 sites. Average maize grain yields for the 18 experiments were 10.3, 10.5, 10.6, 10.8, and 10.7 t/ha for Zn application at 0, 0.5, 1, 1.5, and 2 kg Zn/ha, respectively. Optimum Zn rates varied between 1.0 and 2 kg Zn/ha, depending on the location. The average Zn response, when Zn was applied at 1.5 kg Zn/ha, was 4.7% (+487 kg/ha). No negative responses to Zn application were observed at any of the studied locations.
**Uruguay**

**Exploration of Responses to Potassium in Western Uruguay**

Project Leaders: Monica Barbazan and Oswaldo Ernst, Universidad de la República Producción Vegetal Facultad de Agronomía - EEAMAC Paysandú, Paysandú, Uruguay. Email: mbarbaz@fagro.edu.uy

Project Cooperators: Martin Bordoli, Carlos Bautes, Esteban Hoffman, Andres Quincke, Juan Diego Cano, and Sebastian Mazzilli

This research is based on previous observations of K deficiency and responses in field crops grown within the northwestern Uruguay region. Data from the first three years of field work and other studies, including 50 experiments under wheat, barley, maize, soybean, sunflower, and sorghum crops, indicated a critical K range of 0.30 to 0.40 cmol/kg (117 to 156 ppm), below which there is a high probability of response to K fertilization. Integration of soil survey data with this field work has allowed researchers to estimate that an area of 4 million ha is potentially K deficient in Uruguay.

Field work in the 2011-12 growing season included six trials in western Uruguay - five under full season soybean and one under maize. Grain yield responses to K fertilization averaged 577 kg/ha (+11%) for maize and ranged from 109 to 413 kg/ha (+3 to 14%) for soybean, according to soil exchangeable K levels. A long-term field experiment has been initiated in 2012 to evaluate soil K dynamics under crop rotations of western Uruguay.

As part of the activities of the project, results for the first three years of this project were presented and discussed at a seminar organized at the College of Agronomy of Universidad de la Republica at Montevideo (Uruguay) on 25 April 2012. Also, an article was published in *Better Crops with Plant Food* magazine, and other presentations were made at the 19th ISTRO Conference.
Americas and Australia/New Zealand Group

North America Program

Northern Great Plains Region: Dr. Tom Jensen, Director

Alberta

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

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This experiment with related research at other locations is being done to compare the effectiveness of broadcast urea fertilizer compared to the common standard of side-banded urea at planting. There is a trend in some areas to use broadcast N applications in no-till or direct seeded cropping as a way to save time and speed up planting. To help reduce the chance of losses a few technologies are being evaluated. These technologies include the size of the urea granules and the addition of urease and nitrification inhibitors. Half the experimental treatments use regular-sized urea while half are forestry grade size granules approximately 11 mm (1/2 in.) diameter. The fourth year of the planned five years of research on this project went ahead as planned with the study planted to barley.

Initially, moisture conditions were on the dry side, but ample rains were received by mid May and continued through June and early July. After this little rain was received and warm temperatures were experienced through the rest of the summer and into early September when the site was harvested. Yields were quite high and harvest conditions were dry and completed on schedule. Unfortunately during the summer, the research site was next to a buried oil pipeline and one-quarter of the plots were lost due to pipeline maintenance work. Statistical analysis was done using analysis of variance with allowance made for missing plots. This however did reduce the chance to discriminate between experimental treatments. The ample moisture and warm temperature allowed significant mineralization of N from soil organic matter at the site, thus not giving as great a response to added N as in the previous two years. The only fertilizer treatment that yielded significantly better than the check or zero N treatment was the large urea treated with both a urease inhibitor (Agrotain®) and a nitrification inhibitor (N-Serve®). The yields were respectively 4.19 and 5.52 t/ha (78 and 102 bu/A). All other treatments were neither significantly better than the check treatments and not significantly lower than the highest yielding. Looking at the 2012 results, there does not seem to be any advantage or disadvantage to using the large urea granules. Research at this site will continue for one more year.

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

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Project Cooperators: Claire Langlois, Guy Lafond, and Brian Hellegards

This study is in the fourth and final year of planned research. The growing season was slightly better than average due to greater than normal precipitation in the spring and early summer, followed by warm dry weather the rest of the July, August, and through harvest in September. Research experiments evaluating polymer additives for both P and N fertilizers were conducted at two University of Alberta (AB) research farms. One on a Black high organic matter (8%) clay soil near Edmonton, and the other 120 km south west of Edmonton on a Grey low organic matter (1.5%) clay loam soil near Breton, AB.

There was an excellent response to P for barley at the Breton site with an almost three-fold increase in yield from the zero-P (check) plot to 15 kg P₂O₅/ha (13 lb P₂O₅/A). At the Ellerslie site, the moist spring and early summer conditions followed by warm temperatures appeared to result in sufficient P mineralization from organic matter and no significant response to P fertilizer was found. At all the P research sites, there was no significant difference between P fertilizer with or without addition of polymer additives.
For the N experiments, there was a significant response to added N fertilizer with the highest yields from the highest N rate (120 kg N/ha). The weather conditions did not appear to favor loss of N due to ammonia volatilization or denitrification, and the regular urea yielded similarly to when polymer additives, or urease and denitrification inhibitors were used. The four years of research data will be grouped and analyzed, and a final report will be completed in 2013. AB-26F

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

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Project Cooperators: Dick Puurveen, Ross McKenzie, and Chengci Chen

This summary reports the second of the planned three years of research. The growing season was more moist (234 mm compared to a long-term average of 198 mm) and slightly warmer (1,442 heat units, 30% more than average cool season crop heat units of 1,400). Unfortunately, the more moist and warm season resulted in greater than normal mineralization of N from soil organic matter and there was no yield response to added N fertilizer. Statistical analysis of the experimental factors of timing, size of urea granules, and the addition of urease and nitrification inhibitors was only significant for timing.

The fall applied treatments had an average yield of 2.7 t/ha (40 bu/A) compared to 2.4 t/ha (36 bu/A) for the spring applied treatments, with a least significant difference of 168 kg/ha (2.5 bu/A). The majority of spring wheat crops grown in this region are planted on no-till or chemical fallow. More moist and warmer weather conditions make it challenging to have a yield response to added N. It is planned next year to expand the research of this experiment to also include a winter wheat experiment that will be planted into stubble from the 2012 spring wheat crop. This will be in addition to the regular spring wheat planted into the chemical fallow. AB-29

Large Urea Granules for Broadcast Application in Perennial Forage Grasses

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Project Cooperators: Dick Puurveen, Ross McKenzie, and Chengci Chen

This research was conducted using a cool season perennial grass pasture. The grasses have been established for 10 years, and were part of an original pasture rejuvenation project conducted by the Chinook Applied Research Association in cooperation with the land owner. The 2012 growing season was characterized as being close to average in temperature, but much more moist. There were 355 mm of moisture received during the growing period from when spring growth started until when the forage samples were taken compared to only 157 mm normally received. Late June through to mid July is when the first of a possible two seasonal hay cuttings is normally done in this area. After this initial hay sampling, the weather turned warmer and drier than normal and there was insufficient re-growth for a second hay cut, that is normally taken in early September.

The research site was N deficient and there was considerable response to added N. Hay dry matter yield under the zero-N treatment was 0.34 t/ha, and was significantly lower than all treatments receiving N. The highest yielding N treatment was 1.2 t/ha (equivalent of 1.4 t/A of hay at 15% moisture content). Of the three experimental factors, size of urea granules, timing of application, and use of urease and nitrification inhibitors, there was a significant effect of size of granules and timing, but no difference whether urease or nitrification inhibitors were added. The larger forestry grade size granules, 20 mm (0.5 in) in diameter, resulted in greater hay yields compared to the regular sized 3 mm (0.125 in) urea, respectively 1.05 t/ha compared to 0.98 t/ha. Spring applications yielded higher than fall applications, respectively 1.07 t/ha compared to 0.97 t/ha. The pattern of moisture received resulted in conditions that did not seem susceptible to either ammonia volatilization losses or denitrification losses, thus no measurable benefit from using the urease or nitrification inhibitors was observed in the 2012 growing season. It is planned to repeat this experiment for two more growing seasons. AB-30

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

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In 2012, trials were conducted on a farm near Coffee Creek, Montana. The field site was under no-till management and was seeded to winter wheat. A mass-balance micrometeorological experiment was established to quantify ammonia (NH₃) losses from urea and urea treated with NBPT [N-(n-Butyl)-thiophosphoric triamide]. Three application timings (fall, winter and spring) at 100 kg N/ha, with and without NBPT (1 g/kg), were made to circular plots (20 m radius) at this site. A closely located, replicated small-plot fertilizer experiment was established to measure crop yields. This study consisted of three urea surface-application
Nitrogen Fertilization Methods for No-till Cropping of Winter Wheat in Central Montana

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Project Cooperators: Audrey Bamber, Dick Puurveen, and Ross McKenzie

This experimental study was conducted on a no-till field at the Central Agricultural Research Center, Moccasin, MT, during the 2010-2011 and 2011-2012 crop years using winter wheat. Three N products (urea, Super-U® which contains urease and nitrification inhibitors, and ESN® which is a polymer coated urea) were applied at 80 lb N/A in the fall or spring using three methods (broadcast, sub-surface banded 2 in. deep between rows, and seed placed). Additional broadcast treatments included adding Agrotain® (urease inhibitor) or Agrotain® with N-Serve®(nitrification inhibitor) applied to regular urea. The experiment was a randomized complete block design with four replications.

In 2011, there was greater grain yield (36.5 bu/A) and grain protein (12.9%) from spring broadcasting of regular urea than fall application (27.7 bu/A and 8.9% grain protein). These results indicate possible N loss through leaching and/or denitrification from fall application of urea in 2010-2011. Annual crop-year rainfall from Oct 2010 through Sept 2011 was 21.6 in., significantly higher than the 2011-2012 crop year with 11 in. However, yield response to timing of urea application was reversed in 2012. The fall broadcast urea produced higher yield (31.9 bu/A) than spring broadcast urea (26.9 bu/A). In 2011, fall broadcast application of urea treated with a urease inhibitor [NBPT or N-(n-Butyl)-thiophosphoric triamide] plus a nitrification inhibitor (nitrapyrin) resulted in 20% more grain yield than regular urea broadcast in the fall. Yield in 2011 was not significantly different between fall application of ESN® and urea treated with the urease and nitrification inhibitors. When rainfall was low in 2012, regular urea broadcast in the fall resulted in similar grain yield compared to urea treated with the urease and nitrification inhibitors. Interestingly in 2012, the fall broadcast urea out-yielded ESN® applied with seed by 6.4 bu/A probably due to slow release of N from the ESN fertilizer due to droughty conditions. Therefore, the impact of inhibitors and controlled release polymer coating (ESN) on yield is affected by rainfall amounts received during the growing season. This study demonstrated that precipitation is a major factor determining optimal fertilizer placement, timing, and benefit of inhibitors or controlled release polymer coating for winter wheat production in central Montana. Final conclusions and recommendations will be made after the 2013 crop year data are available, and all three years of data are analyzed and interpreted. MT-17

North Dakota

Nitrogen Recalibration for Corn in North Dakota

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Field research on this project has progressed well. The third year of a four year project has been completed in the 2012 crop year. A total of 64 site-years of experiments have been conducted so far. Only eight site-year experiments have been abandoned and data not included because of problems with flooding (6 site-years), inadequate stand establishment (1 site-year) and deer damage (1 site-year). The data are being clustered and analyzed separately by combinations of soil texture and general geographic location, as well as length of time of no-till cropping [e.g. eastern North Dakota (ND) high clay soils; eastern long-term no-till soils; eastern ND medium textured soils; and West River soils]. This is done to improve the R-squared value for N response
curves, correlating total available N and corn yield. Grouping all the sites into one correlation curve does not seem effective. Not only are data being collected to assess yield response to total available N at the sites, but economic analysis is being done by generating gross returns per acre in dollars from application of N at the rates of total available N based on the three possible corn prices of 5, 6 and US$8. Supplemental N fertilizer rates are 0, 40, 80, 120, 160, and 200 lb N/A at each site.

Detailed research has been conducted at 38 of the 64 sites, mostly eastern ND sites, evaluating the effectiveness of using crop sensing technologies to estimate crop yield potential, and develop algorithms for in-crop variable rate supplemental N. The technologies being evaluated are GreenSeeker® and Crop Circle®. Readings are being taken at two crop stages (i.e. 5 to 6 leaf and 10 to 12 leaf stages). In practice, a grower will establish an N-rich strip (200 lb N pre-plant applied, width of the applicator and 100 ft. long). The side-dress applicator has at least one sensor and the appropriate algorithm for soil and location. The grower will use the N-rich strip as the base reference. Any readings below an established ratio will be fertilized to the appropriate rate with the applicator. This additional work is in the early stages and associated with a National Science Foundation grant. Field research will be completed in the 2013 crop year, and the final report is planned to be released in 2014. ND-16

Saskatchewan

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

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Project Cooperators: Claire Langlois, Dick Puurveen, and Brian Hellegards

This project, at the Indian Head Research Farm near Indian Head, Saskatchewan, consists of three experiments comparing regular granular urea, urea treated with Nutrisphere-N® (a polymer coating), and Super Urea® (including both urease and a nitrification inhibitors) at 45, 90 and 135 kg N/ha. All N treatments are side-banded at planting of the crops and in the spring. The experiments were conducted on spring wheat, barley and canola. The study was initiated in April 2008, and repeated in 2009 through 2012.

In 2012, the three annually seeded crops grew well due to adequate spring and early summer precipitation. However, warmer temperatures in early July, plus drier than normal weather conditions in late July and August was hard on canola flowering, seed set, and yield. Much of the canola growing area of the Northern Great Plains (NGP) region reported disappointing canola yields due to so called “flower blasting” reducing potential yields. Vegetative growth would have indicated average to above average yields but loss of viable and fertilized flowers significantly reduced yields. The barley and canola crops both showed a significant but modest response to added N, while the spring wheat crop didn’t. The moist early summer conditions and warm temperatures during early July probably resulted in a greater than normal mineralization of N from soil organic matter. N response in previous years of this study was greater. In 2012, there were little differences observed for all three crops as far as the form of N applied. Regular urea, Nutrisphere treated urea and Super Urea all showed similar yields. The modest or low response to N contributed to a challenge in observing differences between forms of N, and any possible form of N and N rate interactions. Also growing conditions were not conducive to leaching or denitrification losses that may have resulted in greater yields for the Nutrisphere treated urea and the Super Urea, compared to regular urea. The five years of results from this research will be grouped together and analyzed. A final project report will be completed in later 2013. SK-40F
Iowa

Variability in Soil Test Potassium and Crop Yield in Iowa

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Work was completed on the four year study on “Potassium Uptake, Recycling, and Soil-Test Temporal Variability in Soybean and Corn”. The initially planned project was improved upon by also evaluating P recycling. Main findings were that K recycling to soil from standing soybean plants at physiological maturity in the fall and from residue until early the following spring was much more complete and faster than for corn. About 65 to 70% of soybean plant K (except grain) was recycled by early December, and by early spring 80 to 90% was recycled to soil. In corn, the K release from plant tissue and residue was more gradual and about 45% of the K remained in the residue by early spring. Much less rainfall was needed to recycle a certain amount of K in soybean than in corn. There was a significant, increasing, linear relationship between K loss from residue and the additional soil-test K measured in the spring compared with the fall. Phosphorus loss followed a similar pattern to K from physiological maturity until harvest, but there was no significant residue P recycled to the soil from the fall until early spring for any crop, no relationship with rainfall, and no relationship between P recycled and soil-test P change from fall to spring. These results have great value to better understand very high temporal variability and uncertainty of soil-test K. IA-09F

Indiana

Corn Sulfur Response on a Sandy Soil in Northern Indiana

Project Leader: James Camberato, Purdue University, West Lafayette, Indiana. Email: jcambera@purdue.edu

An experiment was conducted to examine the response of corn to S fertilization on a Tracy sandy loam at the Pinney Purdue Agricultural Center in northwestern Indiana. Whole corn plants at V5 growth stage responded to S fertilization increasing from 0.25% S without S fertilization to 0.28-0.29% S with S fertilization. The form and rate of S fertilization had negligible effects on whole plant % S. Sulfur fertilization also reduced the N to S ratio (N:S) compared to the no S fertilizer treatment. Minor differences occurred among the form and rate treatments in N:S. Plant tissue % S and N:S in the untreated control were at levels generally considered sufficient. Corn earleaf S at silking ranged from 0.23 to 0.25% S across treatment means, and the N:S ranged from 13.4:1 to 14.4:1. Fused ammonium sulfate/ammonium nitrate (AS/AN) had higher % S and lower N:S than the Microessentials® MES-10™ fertilizer, but the difference was very small and both values were within sufficiency ranges. Corn grain yield was unaffected by S fertilization compared to the control treatment which did not receive any S. Although soil sulfate (SO$_4$-S) was low at the beginning of the growing season, the corn plants were apparently able to take up enough S to produce yields exceeding 200 bu/A. Grain moisture varied among treatment means from 22.2 to 22.6%. The fused AS/AN had lower grain moisture at harvest than the MES-10 fertilizer, but the difference was very small (about 0.2%). IN-28F
Comparative analyses of candidate second generation biomass species are needed to understand the hydrologic, agronomic, and environmental impacts of species deployment for biomass production. Our objective was to quantify tile drain event volume, nitrate concentrations, and load for upland switchgrass (c.v. Shawnee), Miscanthus x giganteus, and big bluestem (Andropogon gerardii) dominant mixed prairie, as well as tilled continuous maize control. Plants were grown in large, in-ground lysimeters at the Purdue University Water Quality Field Station near West Lafayette, Indiana on soils characterized predominantly as Drummer silty clay loam. Hourly drain flow was collected from 1995 to 2011 using tipping buckets fed by the 265 m² clay-lined lysimeters each draining a 0.1 m wide tile buried at a depth of 0.9 m. Nitrate concentration samples were collected as a mixed composite of tips accumulated every 24 to 72 hours during storm events from 1998 to 2011.

A paired regression analysis was used to mitigate environmental and climatic impacts on inter-tile variability to quantify shifts in total event flow. Miscanthus-transitioned tile mean event flow decreased significantly ($p<0.20$), while switchgrass-transitioned tile response varied across replicates, including significant decreases ($p<0.10$) and significant increases ($p<0.05$) in mean event flow. Average nitrate concentration decreased significantly in response to switchgrass and Miscanthus cropping system transitions. Nitrate concentrations were significantly lower in Miscanthus-transitioned tiles compared to switchgrass and mixed prairie system tiles once plants were established. Cumulative event nitrate loads were also significantly lower for all perennial plots compared to continuous maize control. Results suggest that although transition into switchgrass and Miscanthus predominantly decreases total event flow, increases in tile drain event flow may be observed due to site-specific conditions including preferential flow. Perennial crops improved tile nitrate concentrations significantly, which resulted in significantly lower net load from perennial system tile drains. IN-25
Michigan

**Evaluating Sources of Sulfur in Michigan Corn Nitrogen Programs**

Project Leader: Kurt Steinke, Michigan State University Plant and Soil Science, East Lansing, Michigan.
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Forms of a double-salt containing a 2:1 molar ratio of ammonium nitrate and ammonium sulfate have shown some potential to reduce ammonia volatilization and sulfate leaching. This 2012 field study compared forms of S in corn N programs for Michigan corn.

Fused forms of ammonium sulfate-nitrate did not differ from granular forms, and produced the same yields as a monoammonium phosphate product containing both sulfate and elemental forms of S. Drought conditions limited yield to an average of 125 bu/A, and possibly prevented expression of differences among these S sources. A repeat of this trial is planned for 2013. *MI-13F*

New York

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

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Project Cooperators: Bianca Moebius-Clune and Jeff Melkonian

This project aims to increase adoption of adaptive N management for corn production using better rates and timing of application. The new *Adapt-N* tool provides N fertilizer recommendations adapted to the spring rainfall and temperature conditions of the current season, using high-resolution weather data, a sophisticated computer model, and field-specific information on soil properties and soil and crop management. Based on experiences from past years, it is clear that a larger number of replicated strip trials are needed from multiple growing seasons. The objectives are to further validate the Adapt-N tool for on-farm use and promote grower adoption of Adapt-N as part of their tool kit for adaptive N management. The main hypothesis is that the Adapt-N tool provides more accurate estimates of the current season’s optimum N rate than conventional methods and tools.

In 2011 and 2012, field strip trials compared corn yields with Adapt-N recommended rates to those with growers’ conventional N management. In six of the 54 site-years in New York and Iowa, Adapt-N correctly identified the need for higher rates of N, while on average, its use increased profit by US$24/A. Results from 2011 identified an issue with the soybean credit used in the model, which was corrected for the 2012 version. The need for accuracy in soil and crop input data (particularly soil organic matter and expected yield) was also underscored. Opportunity for use of the tool with high-clearance application equipment guided by GPS at times later than typical side-dress was demonstrated by the participating crop consultants. Extension activities reached over 2,000 participants. *NY-10*
Long-term Optimum Nitrogen Rates for Corn Yield and Soil Organic Matter in Ontario

Project Leader: Bill Deen, University of Guelph Dept of Plant Agriculture, Guelph, Ontario. Email: bdeen@uoguelph.ca

Project Cooperators: John Lauzon and Greg Stewart

Decisions on optimum N rates are often made on the basis of single-year responses. Data are limited on the long-term impact on productivity and soil organic matter of rates higher or lower than these short-term optima. This controlled experiment was designed as a base for testing the application of dynamic soil-crop-atmosphere models as predictors of N rates for corn that optimize sustainability. The specific objectives include the assessment of short and long-term effects of N rate and application timing on productivity, environmental impact, profitability, and cropping system sustainability and the validation of crop models, such as Maize-N.

The drought of 2012 reduced yields in this trial by about 35% in comparison to the previous three years. Optimum rates of N application, and N use efficiencies also declined. This was the first year in which the optimum rates observed did not exceed recommended rates. Timing of application did not affect optimum rates or yields attained. Unexpectedly, short-term rates did not produce differences from long-term rates, even though this was the fourth year on the long-term check plots receiving only 30 lb/A of starter N each year. Agronomic efficiency in 2012 was 16 as compared to 23 to 31 lbs of grain yield increase per lb of N applied in the previous three years. Recovery efficiency in 2012 was 41% as compared to 53 to 61% in the previous three years. Late September soil nitrate concentrations were higher where application rates exceeded optimum rates. This project also receives support from the Ontario Agri Business Association, for sampling soil residual nitrate and soil organic carbon, and from the Canadian Fertilizer Institute, for measuring nitrous oxide emissions. This additional support enables a more complete assessment of sustainability. In 2013, following five years of treatments, measurements of changes in soil organic matter are planned.

Investigating Corn Hybrid Interactions with Nitrogen and Foliar Fungicides

Project Leader: David Hooker, University of Guelph, Ridgetown, Ontario. Email: dhooker@ridgetown.uoguelph.ca

Project Cooperator: Laura Sharpe

Producers recognize that corn hybrids can differ in their response to N fertilizer applications. This study was conducted to investigate such differences among six soon-to-be-released experimental hybrids from two major seed companies. In the 2012 field trial in Ridgetown, Ontario, Canada, hybrids showed large differences in response to N and plant density and their interactions, but little response to fungicides. Grain yield response to a higher N rate than normal varied among hybrids from 13 to 35 bu/A. Responses to a combination of high N and high population varied from 17 to 60 bu/A, depending on the hybrid. The hybrid that responded the most to higher population and N showed greater drought tolerance during a water deficit at the VT (tasseling) growth stage.

The most responsive and highest yielding hybrid produced 263 bu/A at an N rate of 224 lb/A, with agronomic efficiency of 0.64 bu/lb, with the high population without fungicide. The lowest yielding among the six hybrids produced 188 bu/A at 167 lb/A, with agronomic efficiency of 0.36 bu/lb, at the normal population with fungicide. While these results represent only a single growing season and site, they suggest that genetic improvement in hybrids may lead to yield increases as large as 40% resulting from an increase in N use by 34%. Plans to repeat this study in the 2013 season are in place.

Kenneth M. Pretty Graduate Scholarship

Project Leader: University of Guelph OAC Awards Committee Ontario Agricultural College Guelph, ON N1G 2W1

In November 2012, the Kenneth M. Pretty Graduate Scholarship was awarded to Yuki Audette, Ph.D. candidate in the School of Environmental Sciences at the University of Guelph, whose research is on soil P chemistry dynamics, especially in organically managed soils. “I believe this field should have more attention,” writes Yuki, “because soil P mechanisms are still not well understood and vital to both food security and environmental impact in the future.”
Virginia

**Evaluation of Ammonium Sulfate Nitrate in Virginia Snap Bean Production**

Project Leader: Mark Reiter, Virginia Tech Eastern Shore Agricultural Research and Extension Center, Virginia.
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Fresh-market snap beans occupy 5,500 acres in Virginia. Producers are interested in exploring sources and rates to improve N use efficiency. This trial compared five N sources (urea with dicyandiamide, ammonium nitrate, calcium nitrate, ammonium sulfate-nitrate, and urea-ammonium nitrate) at three rates.

In 2009, for spring-grown beans, urea with dicyandiamide increased yield by 25% over the control, while the other sources did not. For fall-grown beans, all N sources increased yield by 56% over the control, with an optimum N rate of 80 lb/A, and reduced symptoms of common rust (*Uromyces appendiculatus*). In 2010, an abnormally dry and hot summer hampered snap bean growth and, as a result, yields did not increase beyond 40 lb N/A. All N sources increased yields to a similar degree, except ammonium nitrate, which did not increase yields over the check. There were no responses to S applied either as gypsum or as ammonium sulfate-nitrate. In 2011, dry weather in May followed by an intense rainstorm in June resulted in poor yields and no response to applied N in spring beans. The fall beans responded positively to N but not to S. Ammonium sulfate-nitrate, urea, and urea with dicyandiamide produced higher yields than urea-ammonium nitrate or ammonium nitrate.

Spring snap bean yields in the 2012 growing season suggested that ammonium sulfate-nitrate produced highest yields, averaged across N rates. Highest yields were achieved with 120 lb N/A, averaged across N sources. Sulfur did not appear limiting in this study and did not offer a yield advantage in comparison to no-S treatments. Grade quality was not influenced by N source. In conclusion, based on spring and fall plantings in 2009, 2010, 2011, and 2012, ammonium sulfate-nitrate is an acceptable N fertilizer source for producers in the Mid-Atlantic and should be applied at a rate of 40 to 80 lb N/A.

**Evaluation of Ammonium Sulfate Nitrate in Virginia Sweet Corn Production**

Project Leader: Mark Reiter, Virginia Tech Eastern Shore Agricultural Research and Extension Center, Painter, Virginia.
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Virginia farmers grow over 3,000 acres of fresh market sweet corn. They are interested in exploring sources and rates to improve N use efficiency. This trial compared three N sources (urea-ammonium nitrate, ammonium nitrate, and ammonium sulfate-nitrate) at three rates. The first two N sources were compared with and without S, applied as gypsum, at a rate designed to supply the equivalent amount of S provided by ammonium sulfate-nitrate (65 lb/A).

Averaged over two seasons (2009 and 2010), the three N sources increased marketable yields by 30 to 65% using optimum N rates ranging from 110 to 170 lb/A. Agronomic efficiency at optimum rates ranged from 26 to 45 lb of marketable yield increase per lb of N applied. Sulfur added as gypsum did not increase yields, and sources did not show consistent differences across the two seasons. In 2011, excessive heat during silking caused limited kernel set and thus marketable yields were zero. Application of N increased total yield, but the small differences among sources are unlikely to mean anything for years in which a marketable yield is achieved. In 2012, application of N increased total and marketable yields, regardless of N source. Application of S did not significantly increase yields, but certainly did not reduce them either.

In conclusion, ammonium nitrate, urea-ammonium nitrate, and ammonium sulfate nitrate were found to be acceptable N fertilizer sources for sweet corn on sandy loam soils. In some years, plants may benefit from S additions. These findings support N management decisions that optimize food yields while minimizing risk of water contamination by N on the sandy loam soils of the Chesapeake Bay watershed.
Sulfur Fertility for Barley Production in the Mid-Atlantic

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Project Cooperators: Wade Thomason, David Moore, and Keith Balderson

Virginia consistently produces approximately 70,000 acres of barley per year. As with any grain, S fertility recommendations need to be established to ensure adequate supply for producing high yields. Sulfur fertilizer applications have become an important consideration for farmers in the mid-Atlantic utilizing sandy loam soils, since S deposition from the atmosphere has declined as a result of air pollution controls. We conducted a S source × S rate study to determine if S fertilizer applications were necessary.

At the two sites in 2011, the first year of the study, application of S boosted yields by 17% to an average of 96 bu/A. Using ammonium sulfate as a source produced 8% higher yields, on average, than either ammonium-sulfate nitrate or a combination of urea-ammonium nitrate and ammonium thiosulfate. Of the three S rates compared, from 10 to 30 lb/A, the lowest rate was sufficient for highest quality grain and highest yields.

The weather in 2012 was not as conducive, limiting top yields to 83 bu/A. Only one of the two sites showed a response to application of S. Ammonium sulfate-nitrate produced yields 20 bu/A higher than those produced by ammonium nitrate alone. The lowest S rate, 10 lb/A, was sufficient to produce the highest yields. As is typical, soil test S levels (7 and 8 ppm Mehlich-3) at the two sites were not predictive of crop response.

VA-24F
Colorado

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

Project Leader: Jessica Davis, Colorado State University Department of Soil and Crop Sciences, Fort Collins, Colorado. Email: davis@colostate.edu

Project Cooperators: Thomas Borch and Jeffrey L. Collett, Jr.

Ammonia (NH₃) deposition has been identified as a concern from both human health and environmental standpoints, and has recently been targeted by Colorado as a primary contributor to atmospheric and ecosystem changes in the Rocky Mountain National Park (RMNP). The Colorado Department of Public Health and Environment has estimated that 60% of the NH₃ deposition in the RMNP comes from agricultural activities with 40% from animal feeding operations and 20% from fertilizer. However, these estimates have not been verified by scientific measurement, and verification is important if future regulations require that agriculture be held accountable for NH₃-related ecosystem damage. One way to possibly track N to its original source is via N isotopic signatures (¹⁵N) since the ratio between the ¹⁴N and ¹⁵N isotopes is influenced by source.

A major goal of this project is to assess the effectiveness of isotopes as tracers, and in turn to determine sources of NH₃ contributing to N deposition in the RMNP. The original objectives were to 1) determine the major sources of NH₃ deposition in the RMNP based on N isotopic signatures of different NH₃ sources (i.e. agricultural, natural and industrial), and 2) quantify the relative contribution of NH₃ to the RMNP from animal feeding operations, synthetic fertilizers and other sources. Ammonia sampling (radiello) in the RMNP continued in 2012, as did analysis of wet deposition and soil emissions. Also, preliminary studies on urea hydrolysis and experimental development towards investigating Henry’s constant were initiated.

The larger dataset of N isotopes from the radiello study showed that wastewater remediation exhibited a significantly different isotopic value than dairy cattle, beef cattle and crop land. Furthermore, dairy cattle and beef cattle were significantly different, but crop land was not significantly different from either beef or dairy cattle. Hence, contrary to original speculation, this methodology cannot ultimately be used to effectively distinguish between (deposited atmospheric ammonia) N from fertilizer applied to crop land and N from manure. Thus, from this study, it is not possible to make a clear statement regarding the impact of N fertilizer on NH₃ deposition in the RMNP. **CO-13**

Kansas

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

Project Leader: Alan Schlegel, Kansas State University Southwest Kansas Research and Extension Center, Tribune, Kansas. Email: schlegel@ksu.edu

This long-term western Kansas study was initiated in 1961 to evaluate responses of irrigated continuous corn and grain sorghum to N, P and K fertilization. Furrow irrigation was used through 2000, and sprinkler irrigation since 2001. No yield benefit to corn from K fertilization was observed in the first 30 years and soil K levels remained high, thus the K treatment in the corn study was discontinued in 1992 and replaced with a higher P rate. Nitrogen treatments for corn and grain sorghum were 0, 40, 80, 120, 160, and 200 lb N/A. Phosphorus treatments for corn and grain sorghum were 0, 40 and 80 lb P₂O₅/A, and 0 and 40 lb P₂O₅/A, respectively. The K treatments for grain sorghum were 0 and 40 lb K₂O/A.
Corn yield in 2012 was well above the 10-year average, with maximum yield at 260 bu/A. Nitrogen applied alone increased corn yield by up to 84 bu/A, while N and P applied together increased yield up to 174 bu/A. Application of 120 lb N/A (with P) was sufficient to produce 82% of maximum yield in 2012, which was less than the 10-year average of 94%. The highest yield was produced with the highest N and P rates, 200 lb N and 80 lb P₂O₅/A. At this N rate, 40 lb P₂O₅ increased yield by 55 bu/A and 80 lb increased yield by 90 bu/A. Nitrogen fertilizer alone increased sorghum yield by about 70 bu/A, while N plus P increased yield by up to 100 bu/A. Application of 40 lb N/A (with P) was sufficient to produce about 79% of maximum yield in 2012. Potassium fertilization had no effect on sorghum yield. This is one of the few continuous, long-term crop nutrition studies in the U.S., and support is planned to continue in 2013. KS-23F

**Applied Fertility Management for Irrigated Soybean Production**

Project Leader: J. Randall Nelson, Kansas State University Department of Agronomy, Courtland, Kansas.
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Although irrigated soybean yields in North Central Kansas have trended upward in recent years, producers in the area are largely unsatisfied with yield performance. Past research from the Kansas State University (KSU) North Central Kansas Experiment Field near Scandia demonstrated that more intensive fertility management, including direct application of P and K, has the potential to significantly improve irrigated soybean yield. Despite these findings soybean producers have been slow to adopt more intensive fertility management programs.

This project, initiated in 2012, seeks to expand upon previous soybean fertility work by performing both a small plot study and a farmer field strip trial to increase awareness of irrigated soybean yield potential with proper fertility management. The small plot work was conducted at the KSU Irrigation Experiment Field, and the field scale study on a producer’s field in the same region. Small plot treatments included a zero fertilizer control, and all combinations of 30 and 80 lb P₂O₅/A, and 80 and 120 lb K₂O/A. The effects of N and S were evaluated at the higher P and K rates.

Soil test P in the small plot study was low (6.9 ppm Bray 1), and K was high (542 ppm). The zero fertilizer control yield was 53 bu/A, and yield with fertilizer input ranged from 59 to 63 bu/A. The effect of fertilizer treatments over the control was significant, but there was no significant difference among the fertilizer treatments. The field scale design was simpler, with a zero fertilizer control, one P (30 lb P₂O₅) and one K (80 lb K₂O) rate and a combination of the two. Yield monitor data were collected by the grower, and at the time of this report were being processed. KS-41

**Micronutrient Fertilization for High Yield Wheat Production in Kansas**

Project Leader: Dorivar Ruiz Diaz, Kansas State University, Manhattan, Kansas. Email: ruizdiaz@ksu.edu

Project Cooperators: Randall Nelson and James Shroyer

Kansas produces more wheat than any other state in the USA. With higher grain prices, technologies that deliver greater yield potential, and more intensive cropping have raised sincere questions about the benefit of S and micronutrients fertilization in high yield wheat production. Science-based information on the benefit of these nutrients is limited for the state. The objectives of this project, initiated in 2012, are to evaluate wheat response to S and micronutrients, determine economic return, and evaluate soil and tissue analysis as a diagnostic tool.

The project consists of two components 1) small plot studies, and 2) replicated strip trials in farmer fields. Small plot studies were established at four Kansas locations. Treatments consisted of S fertilizer and micronutrients (Zn, Cu, B, Mn, Fe) as individual treatments and in combination. The strip trial studies were conducted at five locations in farmer fields, simply comparing S + micronutrients (Zn, Cu, B, Mn, Fe) with an untreated control. Application rate of major nutrients was constant within sites. Producer yield monitors measured yield in the strip trials. Standard soil sampling and analyses (including micronutrients) were conducted for each study site. Tissue samples were collected for analysis of total N, P, K, and micronutrients.

Preliminary results suggest a small and inconsistent yield response to S and micronutrients. Yield response in the strip trials varied by soil type across the field, with sandy areas showing greatest potential. Soil and tissue samples for 2012 are currently under analysis. Initial results suggest that application of these nutrients may provide some yield “insurance” for highly variable fields; however, it must be emphasized that data are still being processed. KS-42
Nebraska

Soil Test Phosphorus Level and Yield Potential

Project Leader: Charles Wortmann, University of Nebraska-Lincoln, Lincoln, Nebraska. Email: cwortmann2@unl.edu
Project Cooperator: Tim Shaver

This University of Nebraska-Lincoln research project is designed to test whether maintaining high soil P availability is important to corn yield in enough years to justify the cost of building and maintaining high levels of soil P. The work was started in 2011 and is being conducted at three locations: the Haskell Agricultural Laboratory (HAL), the Agricultural Research and Development Center (ARDC), and the West Central Research and Development Center (WCREC) in Nebraska. All sites have a history of conservation tillage. The HAL site is rain-fed and the others are irrigated. The effect of five P treatments on yield of continuous corn is being compared under no-till and disk till conditions at all sites. Initial soil P level (Bray1-P) was less than 15 ppm at all sites. The five P treatments are: Bray1-P of <15 ppm - no P applied; P applied according to the UNL recommendation; Bray1-P raised and maintained at 25 ppm; Bray1-P raised and maintained at 35 ppm; and P applied based on removal. Initial P application was made before planting and tillage in the spring of 2011 assuming 12 lb P2O5 was needed to raise Bray-1 P by 1 ppm. Zinc was applied to minimize the chance of P induced Zn deficiency.

The rain-fed site (HAL) was severely affected by drought in 2012, with yields well below normal; however, the effect of tillage at HAL was evident in all treatments, with no-till out performing tilled plots due to water conservation. Yields at ARDC were affected by failure and delay in repair of the irrigation system in July. The effect of P treatments on yield was somewhat inconsistent in 2012, but there were some numerical effects that are worth noting. All P treatments in tilled and no till plots at ARDC yielded more than the control, and in the tilled plots the P build and maintain treatments were the highest yielding (25 bu/A over control). At WCREC, in the no till plots P fertilizer response over the control ranged from 29 to 50 bu/A. There was no consistently apparent advantage to the P build and maintain treatments in 2012. This study is planned to continue in 2013.

NE-14

Texas

Nutrient Removal by Fruit and Vegetable Crops in Texas

Project Leader: John Jifon Texas A&M Texas AgriLife Research & Extension Center, Weslaco, Texas.
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A balance between nutrient inputs and crop removal is required for effective long-term crop production. Although nutrient removal estimates are readily available for many field crops, such values for fruit and vegetable crops are rare. The objective of this project is to determine nutrient removal values for major fruits and vegetable crops grown in the Rio Grande Valley of south Texas. Nutrient removal rates from commercial citrus orchards (grapefruit and orange) were estimated in the 2011 to 2012 growing season. Ten grapefruit and five orange orchards were sampled for this investigation.

Grapefruit yield averaged 12 t/A fresh fruit. Nutrient removal for grapefruit averaged 23.5 lb N/A, 2.5 lb P/A, and 27.2 lb K/A. Orange yield averaged 8 t/A, and removal for orange averaged 23.4 lb N/A, 2.3 lb P/A, and 24.5 lb K/A. Estimates for total removal by grapefruit in 2012 were lower than those in 2011 due to in part to the lower fruit yield levels in 2012. Orange removal was not measured in 2011, but only in 2012. When put in terms of unit of production, there were substantial differences in grapefruit P and K removal between the two years, suggesting that removal is impacted by temporal and spatial variability. Nevertheless, the estimates collected in the course of this study give a broad view of nutrient removal by fruits.

TX-55
Alabama

Evaluation of Fertilizer Application Uniformity and Nutrient Distribution

Project Leader: John Fulton, Auburn University Biosystems Engineering, Auburn, Alabama.
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Project Cooperators: Charles Wood and Greg Pate

This project focused on the potential for segregation of fertilizer constituents [diammonium phosphate (DAP) and potash] when applied using a standard, spinner-type spreader. Standardized pan testing was conducted in which fertilizer mass and nutrient distribution data were collected and then analyzed.

Results indicated that fertilizer segregation is possible and is affected by spreader vane shape, spinner-disc speed, and application rate. In terms of nutrient distribution, particle size analysis supported the notion that segregation occurred mainly due to size variability among the constituents. DAP tended to be applied towards the end locations of the pattern; however, P concentration was also higher at the center portion of the swath generating a W-shaped pattern. The high application of DAP at the center is contributed to the ricocheting effect off the vanes and discs, but is being investigated further to understand. Potash distribution peaked on either side of the spreader centerline generating an M-shaped pattern, resulting in significant differences in how K and P are distributed with coefficients of variation (CVs) ranging between 17 and 37%, respectively. While fertilizer segregation can occur due to various factors (e.g. loading, particle size variation, vibration, etc.), the presence of peaks and valleys across the swath width during pan tests indicated that distribution using spinner-discs and vanes can be a large contributor and segregation of blended products is a potential concern when using spinner-disc spreaders if the correct spinner-disc speed is not selected and correct setup procedures not followed. High spinner speeds (800 rpm) increased the risk of segregation and increased pulverizing of soft or less dense fertilizers such as urea and low quality potash which resulted in W-shaped patterns with a significant peak behind the spreader.

Results from this study highlighted the importance of matching spinner-disc spreader setups to specific fertilizers. Until we can overcome known limitations and setup errors with these applicators, successful implementation of 4R Nutrient Stewardship, especially precision application, will be hindered in the US and Canada, especially as spread width increases to meet timing demands (A/hr) at the farm level. AL-21

Arkansas

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

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Field studies were carried out for the fourth year on ‘Alamo’ switchgrass yield response to N fertilizer in northwest Arkansas, and for the second year in eastern Arkansas. The latter location also had trials on P and K fertilization.

The N rate study in NW Arkansas (AR) in 2012 (harvested Oct. 8) showed a statistically significant increase in biomass yield with increments of fertilizer applied as urea in one application in early May. The response trends for 2012 and the 4-year mean were linear. The fitted regression for 2012 indicates that biomass yield increased by 11 kg/ha for every additional kg of N applied above the control. The regression for the 4-year means shows that biomass yield increased by around 20 kg per kg of N applied above the control. The important finding in the current trial is that relatively low N application rates (50 kg/ha) on an upland,
drought-prone soil in the Ozark Plateau result in yields of 11 to 12 t/ha (~5 t/A). For the fertilizer trials in eastern AR, there were no significant differences in biomass yield among treatments. There was a numerical response to N in that trial from 10.6 to 15.3 t/ha; however, high field variability among replications prevented a statistical significance. As for P and K, there were no apparent yield responses even though the soil was very low to low in Mehlich III extractable P (8 to 20 ppm) and low to medium in extractable K (50 to 100 ppm). Future work on these trials will include soil sampling every plot to correlate yield response to soil-test levels, which will be used for developing fertilizer recommendations for switchgrass as a bioenergy crop. *AR-33*

**Florida**

**Nitrogen Rate Study for Potato Production in Northeast Florida**

Project Leader: Lincoln Zotarelli, University of Florida Ag-Horticultural Sciences, Gainesville, Florida.
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Project Cooperator: Daniel Cantliffe

A study was conducted in three grower fields in 2011 and 2012 to determine the optimal N rate for commercial potato production in NE Florida. The potato crops at all locations were irrigated using seepage. Total seasonal N rates ranged from 100 to 300 lbs N/A. All plots received 50 lbs N/A as urea-ammonium-nitrate at fumigation (about 30 days before planting). Nitrogen was then side-dressed twice with ammonium nitrate at emergence (0, 50, 100 or 150 lbs N/A) and at the 6 to 8 in. growth stage (50 or 100 lbs N/A). Nitrogen content in the soil and N uptake into the plant were monitored throughout the season, and potato yields were compared among treatments for the two years of the study.

Before each of the potato seasons started, the residual soil N was about 7 ppm N. The pre-plant application of 50 lbs N/A to all treatments increased the soil N to 34 ppm measured at planting. However this residual decreased by more than 50% by the time the potato had the ability to uptake N at plant emergence (about 25 days after planting). Reduced soil N content coincided with recent heavy rainfall events. Following N treatments at emergence and at 6 to 8 in. growth stage, soil N increased relative to N treatment application. Fertilizer-N rates above 200 lbs N/A left 22 to 39 ppm N in the soil after harvest. Total potato yield ranged between 330 and 350 cwt/A with no difference in yield from the N fertilizer rates at either application stage. The potato tissues (leaves, stems and tubers) accumulated 100 to 125 lbs of N/A over a season of around 100 days. There was no difference in plant N accumulation among the emergence N applications. At the 6 to 8 in. growth stage, the addition of 100 lbs N/A as compared to 50 lbs N/A slightly increased plant N, without an increase in potato yield. *FL-30*

**Potassium and Phosphorus Fertilization of Grass Pastures**

Project Leader: Maria Silveira, University of Florida Range Cattle Research & Education Center, Ona, Florida.
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Pasture fertilization plays a vital role in the success of modern forage-based livestock production systems. The University of Florida recommends K and P fertilization of Jiggs and Limpograss hayfields and pastures; however, many forage production systems do not supply adequate K and P to replace that removed as harvested forage. Because these grasses use large quantities of K as compared to P, soil K deficiency often occurs first, particularly in the highly-yielding crops cultivated in sandy soils with low K-buffering capacity. The objective of this study was to evaluate Jiggs bermudagrass and Limpograss responses to K and P fertilization. The study was conducted at the University of Florida, Range Cattle Research and Education Center, Ona, Florida on a typical Spodosol. Treatments consisted of minimum fertilization regimens that can maintain optimum forage yield, nutritive value, and stand persistence. Because Limpograss is often conserved as a stockpile grass, this study will also investigate the effect of harvest frequency (4- vs. 2-times per year) on Limpograss responses to K and P fertilization. Potassium was annually applied at rates of 0, 40 and 80 lb K$_2$O/A and P was applied at rates of 0, 20 and 40 lb P$_2$O$_5$/A. Jiggs dry matter yield (DMY) increased linearly with K rates. Application of K at the 40 and 80 lb K$_2$O/A rates resulted in approximately 26 and 44% respective increases in cumulative annual DMY relative to the control treatments (no K added). No differences in DMY were observed in the first harvest when K was applied at rates of 40 or 80 lb/A. This response was due to the dry conditions experienced early in the season. However, during the second and third harvest, Jiggs DMY were consistently greater for the highest K rate. No effect of P or K fertilization was observed on Limpograss DM yields; however, harvest frequency affected yields. Limpograss harvested at 12-week intervals resulted in greater DM yields (3,128 t/A) than the 6-week interval (2,147 t/A). This difference corresponds to approximately 46% more biomass by just increasing the harvest interval. Potassium and P fertilization showed no effect on soil chemical properties. *FL-31*
Georgia

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

Project Leader: E. David Dickens, University of Georgia Warnell School of Forest Resources, Statesboro, Georgia.
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Project Cooperator: David Moorhead

Two fertilizer trials and an untreated control were established in 2004 near Bullard, Georgia, within a loblolly pine tree stand planted in 1978 and thinned in 2002-03. Fertilizer treatments examined NP, NPK and NPKSCu fertilization effects in one trial and NP, NPCu, NPKCu, and NPKSCu fertilization effects in a second trial. The one-time fertilizer applications were applied in February 2005. Fertilizer levels applied were 200 lb N, 50 lb P, 80 lb K, 60 lb S, and 5 lb Cu/A.

Six-year mean loblolly pine diameter increments measured at 4.5 feet above groundline (diameter at breast height or dbh) were greatest for the NP and NPKCu treatments with 27 and 28%, respectively, better dbh incremental growth than the control through six years. Six-year mean trees per acre (TPA) losses were greatest in the NPKCu treatment, which lost 8 TPA. The NPCu and NPKSCu treatments had the greatest six-year mean basal area growth (the combination of dbh and TPA) at 15 and 12% greater than the control, respectively. The NP and NPCu treatments six year height growth increments were 27 and 24% greater than the control, respectively, while the NP and NPKCu treatments six-year volume per tree increments were 35 and 37% greater than the control, respectively. 6-year mean volume per acre increments were 4.64 t/A/yr for the control, 4.78 t/A/yr for the NP, 5.55 t/A/yr for the NPCu, 4.72 t/A/yr for the NPKCu, and 5.07 t/A/yr for the NPKSCu treatment, resulting in the NPKCu treatment growing 0.90 t/A/yr (19%) more wood than the control during the six year period. The six-year NPCu chip-n-saw + sawtimber volume per acre increment was 199 ft³/A (18.5%) greater than the control. GA-26F

North Carolina

Soil Fertility Management for High Population, Narrow Row Corn Production

Project Leader: Carl Crozier, North Carolina State University Soil Science Department, Plymouth, North Carolina.
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Project Cooperators: Ronald Gehl, Alan Meijer, and Ronnie Heiniger

The objectives of this research were to determine the optimum N timing and rate in high population, narrow row corn production systems. Corn yield response and yield components (rows/ear, kernels/row, and kernel size) were compared among wide row (30- to 40-in.) and narrow row (15- to 20-in.) corn that received N fertilizer either all at planting, or with both starter fertilizer and side-dress N. A series of 13 N fertilizer response experiments were conducted on Tidewater, Coastal Plain, Piedmont, and Mountain region sites in North Carolina. Additional experiments with silage corn and with responses to P and K gradients were also conducted. Check plots (0 N) and a range of N fertilizer rates (40, 80, 120, 160, and 200 lb N/A) were applied both at planting and at sidedress (between V-6 and V-8 stage) to both wide- and narrow-row corn plots.

The N rate responses (averaged across sites, row spacing and application timing) found grain yield increases of 19% above yields with the lowest N rate. Examination of individual yield components in response to N rates found no changes in plant density or mean numbers of ears per plant, a 3% increase in mean numbers of rows per ear, a 17% increase in mean numbers of kernels per row, and an 8% increase in mean kernel weight. Thus, yield differences appear to be associated with N status later in the growing season, i.e., kernels per row and kernel weight achieve their final expression later in the season, while numbers of rows per ear becomes fixed at an earlier stage. The row spacing x N application timing interaction data demonstrate the importance of later-season N, at least for the narrow row corn. For narrow row corn, both grain yields and the numbers of kernels per row were greater with side-dress application than with all N at planting; while no such timing effect was evident with the wide rows. This is an important interaction to note, since side-dress application is more complicated with narrow row systems and would probably be discouraged without such evidence of increased yield potential. These data suggest a need to better understand N limitations during late season periods. These results are also expected to direct future research evaluating side-dress N options for narrow row corn systems and the predictability of optimum side-dress N rates. NC-21
Tennessee

Documenting Nutrient Deficiency and Accumulation Rate in Vegetables

Project Leader: Dharma Pitchay, Tennessee State University, Nashville, Tennessee. Email: dpitchay@tnstate.edu

When crops do not receive an adequate supply of any of the essential plant nutrients, deficiency symptoms may appear along with reduced growth rates and diminished harvest quality. Efforts to document mineral nutrient deficiency symptoms have primarily been focused on common grain crops. However horticultural crops account for about one-third of the total agricultural value in the U.S., but still receive much less scientific attention. Because of their smaller acreage, common fruit and vegetable crops are often relegated to “specialty” status, despite their large economic value. This project was designed to document mineral nutrition deficiency symptoms on a range of important horticultural crops grown in the greenhouse.

This project is currently growing a variety of plants in carefully controlled hydroponic solutions to collect high-resolution photographs of nutrient deficiency symptoms. The catalog of these pictures is completed for lettuce, blueberries and papaya. On-going work is now examining deficiency symptoms for peppers, eggplant and okra. As these crops are completed, the images will be added to the IPNI website. This project continues the work that Dr. Pitchay co-authored a few years ago in the book: Nutrient Deficiencies in Bedding Plants: A Pictorial Guide for Identification and Correction. TN-20

Improved Plant Response to Potash Fertilization Through Control of Seeding Diseases

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Project Cooperator: Angela McClure

Several studies have indicated that the commonly used potash fertilizer, muriate of potash, can increase losses of soybean and snap bean to seeding diseases. Supplementary studies suggest that this may be due to a loss in root Ca in very young seedlings that occurs with the application of a chloride (Cl⁻) salt. This project seeks to determine whether control of soybean and snap bean seeding diseases may be improved with an increase in seedling root Ca levels in the presence of potash fertilizer. Laboratory, greenhouse and field studies were conducted in west Tennessee in 2012 to determine the effects of seed-treated Ca supplements on the Ca content of seedling roots, seeding disease incidence, root rot, plant growth, and yield in treatments with and without K fertilizer.

Supplementing a standard soybean seed treatment (thiamethoxam + mefenoxam + fludioxonil) with Ca-lactate or Ca-formate increased the rate of radical growth of germinating seed and increased the growth of soybean seedlings grown in solarized field soil (pathogen-free). A greenhouse test using solarized field soil and in-furrow applications of granular Ca nitrate at rates equivalent to 4 and 8 lbs N/A indicated that these two rates were very injurious to seed germination. None of the seed treatment Ca supplements increased seedling emergence, seedling growth, plant height, or soybean yield in a field test (both with and without K fertilization) in soil naturally infested with Rhizoctonia solani, Macrophomina phaseolina, Pythium spp. and Fusarium spp. Treated seed were grown in solarized field soil to determine the effect of seed treatment Ca supplements on the Ca level in the roots of 10- to 13-day old seedlings. Analysis of soybean taproots using energy-dispersive analysis of x-rays found no increase in Ca levels with any of the Ca supplements evaluated. Supplementing a standard snap bean seed treatment (thiamethoxam + mefenoxam + fludioxonil) with Ca salicylate decreased snap bean root rot when plants were grown in a greenhouse test in pathogen-infested field soil. Additional growing seasons are needed to determine conclusively if an interaction between Ca-supplements, K fertilization, and seeding disease exists. TN-21
Improving Nitrogen Fertilizer Management in Surface-irrigated Cotton

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Project Cooperators: Pedro Andrade-Sanchez, Doug Hunsaker, and Eduardo Bautista

The land and canal infrastructure in central Arizona means that level-basin surface irrigation in raised beds is the predominant approach to cotton production. Nitrogen fertilizer is usually managed with preplant ground applications followed by “fertigations” dribbled into the canal. There is uncertainty about the efficacy and uniformity of N fertigations in surface irrigation systems. There are several ways to improve N management based on 4R principles. We investigated N application techniques (fertigation compared with knife injection). Soil-test based N management was compared with reflectance-based techniques, and two N sources (ammonium sulfate or urea ammonium nitrate). A N budget was constructed to account for all inputs and removals. Pre-plant soil nitrate (NO$_3$) was low in this study (23 lb NO$_3$-N/A). Nitrogen fertilizer applied was 132 lb N/A on the soil test-based N management treatments and 66 lb N/A on the reflectance-based treatments. Lint and seed yields were similar among all of the N-fertilized treatments, but significantly greater than the zero-N plots. Lint yield averaged 1,660 lb/A in the N-fertilized plots. Total N uptake at first open boll was positively related to N fertilizer rate but not influenced by N source. Amber NDVI (a graphical indicator used to analyze remote sensing measurements) showed N deficiency in zero-N plots before red NDVI.

Nitrogen uptake was very high from the unfertilized control plot (116 lb N/A). When this uptake is partitioned between 23 lb N/A of soil profile NO$_3$ and 16 lb N/A added in the irrigation water NO$_3$, then net N mineralization is estimated to provide 77 lb N/A. Recovery efficiency of N fertilizer was not affected by N treatment and ranged from 8 to 30%. While similar to values for furrow-irrigated cotton in West Texas, it is lower than that reported in other Arizona research (100 lb N/bale). The internal N use efficiency was greater than expected (40 lb N/bale), compared to previous Arizona data. Soil ammonium (NH$_4$) concentrations were low, but NO$_3$ concentrations were high in the subsoil. Inorganic soil N transects indicated that fertigation was as uniform as knifing N fertilizer. Nitrous oxide (N$_2$O) emissions were low in all N treatments during the 95-day measurement period following fertigation. The soil-test based-fertigation treatment lost only 0.2% of added N fertilizer as N$_2$O, which is in the range of N$_2$O losses from drip-irrigated cotton in other regions, but elevated above the unfertilized control. **AZ-08**

Nitrous Oxide Emissions from the Application of Fertilizers: Source Partitioning

Project Leaders: Johan Six, Formerly with The University of California

Project Cooperators: Charlotte Decock and Clifford Snyder

One of the undesirable N loss pathways from cropland is the emission of nitrous oxide (N$_2$O), a potent greenhouse gas and ozone depleting substance. This study explores the potential of alternative agronomic management practices to mitigate N$_2$O emissions from corn cropping systems in major corn producing regions in the USA and Canada by synthesizing available data from peer-reviewed literature. An acceptable number of side-by-side comparisons for meta-analysis was available for manure versus synthetic fertilizer, polymer coated urea versus conventional urea fertilizer application, synthetic fertilizer with vs. without
Soil Testing Verification in the Fall River Valley, Northeastern California

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Project Cooperators: D.B. Marcum and G.S. Pettygrove

Local farmers identify P and K management as important aspects of profitable crop production. The Olsen P test has been historically used to assess soil P status in this area, but crop consultants have increasingly requested other methods for measuring soil P status. Although relationships between the tests exist in the Midwest and southeastern US, there is no data supporting the relationship in this part of California. Our objectives were to compare extractants on soils from the most extensively mapped region in the Fall River, Big, and Cayton Valleys of northeastern California. These soils represent different major landforms and a range of the degree of soil weathering, which may influence systematic variations in soil K and P. Twelve sample sites in in Shasta and Lassen Counties in northern California were selected from fields used for alfalfa and orchard grass cultivation using surface and pressurized irrigation. Soils were extracted with Olsen P (0.5 M NaHCO₃), extractable K by ammonium acetate, and extractable P and K by the Mehlich 3 method.

For P, the results showed that Mehlich 3 extracted about twice as much P as does Olsen. Some of the data points clearly depart from the linear relationship, and we are investigating these departures in relation to other soil properties (especially pH, organic matter content, and volcanic soil properties). We are also investigating soil factors and fertilization history that influence the wide range in extractable P by either method. We hypothesize that soil chemistry and mineralogy have a strong influence on P status in these soils, due to the volcanic origin of the parent materials. For K, Mehlich 3 extraction results in about 10% more soluble K than does ammonium acetate. We hypothesize that the wide range of K values is a reflection of the mineralogy of the soil parent material. Parent materials from dominantly andesitic or rhyolitic sources are expected to have higher inherent K contents than parent material from basaltic sources due to the chemical composition of these rocks. Our preliminary results show that Mehlich 3 may be an acceptable soil test method for both P and K in these soils. More data from a wider array of soils are needed to increase confidence in these relationships. Further characterization of soil chemical and mineralogical properties is needed to better understand if these properties exert some sort of systematic control on soil P and K.

Western Nutrient Digest - A Regional Publication to Promote Nutrient Efficiency

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The University of Idaho started a state-wide quarterly publication in 2008 to highlight their current research in plant nutrition and fertilizer management. University funding for this publication was eliminated due to budget cuts and distribution of the Nutrient Digest ceased. New funding from IPNI has allowed this valuable electronic publication to begin again and further to expand to include ten states in the Western U.S. region. The range of topics addressed in each issue and variety of crops discussed has significantly expanded to include items of interest throughout the region. Contributing authors are solicited to write on topics that are
of current interest or that reports on important new research information. As the Digest continues to become better recognized in the Western U.S., it is anticipated that future funding will come from private industry to support the publication. Past copies of the newsletter are available at: http://www.extension.uidaho.edu/nutrient/newsletter.html. CA-00D

Utah

Mineral Nutrition of Leafy Lettuce and the Impact on Verticillium Severity

Project Leader: Brad Geary Brigham Young University, Provo, Utah. Email: brad_geary@byu.edu

A series of greenhouse hydroponic studies have been initiated to determine the optimal concentrations of N, P and K for lettuce growth. This project is being conducted with the assistance of undergraduate interns in an effort to encourage students to pursue further study in agricultural sciences. Once the proper parameters for lettuce nutrition are established, Verticillium inoculum will be added to the nutrient solution and the degree of infection will be determined. UT-08
Americas and Australia/New Zealand Group

Northern Latin America Program
Dr. Raúl Jaramillo, Director

Colombia

Nutrient Demand of Oil Palm Hybrids in Tropical America

Project Leader: Jose Alvaro Christiancho, Cenipalma Soil, Water and Mechanization Program (Programa de Suelos, Aguas y Mecanización), Villavicencio, Columbia

Project Cooperators: Diego L. Molina, Jorge S. Torres, Isaac T. Vera, and Eloina Mesa

The second phase of this study was initiated at three locations including Astorga (Tumaco Department), Hacienda La Cabaña (Casanare), and Unipalma de los Llanos (Meta) plantations. The soils at these locations were acidic (pH from 4.3 to 4.8) with very low P (3 to 5 ppm) and variable percent exchangeable Al (30 to 70%). In each location, two OxG planting materials were evaluated: “m1” from La Cabaña and “m2” from Unipalma. The plants were transplanted in the second semester of 2011, and the first fruit yield is expected only by the end of 2013 or in the first semester of 2014. Accordingly, only measurements of plant growth as height, leaf area of reference (9th) leaf (LA9), leaf number (LN), and transversal section area at the petiole base (PTS) have been collected so far. Also, measurements of leaf mineral content were obtained from samples taken from LA9, as the regularly used 17th leaf is not recommended measurements in young plants.

At all three locations, m2 plants had larger LA9, but remarkably, similar PTS areas for both materials (m1 and m2). Mineral concentrations of N, P and K for leaf 9 were similar for both materials, but Ca and B were higher for m1 compared to m2 by 20% and 33%, respectively. The larger biomass of m2 produced a disproportionately larger total absorption of N, P and K than m1 (about 20% increase). At the Astorga location, responses to N and P rates were observed. For example, about a 20% increase in plant height was observed with the highest N rate compared to the lowest N rate. The other two locations did not show a significant response to N or P. Boron did not affect the response of the plants, and B leaf concentration varied with B fertilizer rate only in m1, which suggested that m1 is a larger B accumulator than m2. The commercial dose recommended for conventional oil palm may be sufficient for m1 and small crosses like this, but as our analysis suggested, it is not adequate for larger breeding lines such as m2. Columbia-16

Ecuador

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

Project Leader: Franklin Valverde, INIAP, Quito, Pichincha. Email: frankiniap@yahoo.es

The Instituto Nacional Autónomo de Investigaciones Agropecuarias (INIAP) in agreement with IPNI decided to extend the activities of this project in two other provinces of Ecuador including Imbabura and Chimborazo - in north and central Sierra, respectively. Four locations, two in each province, were set within a range of altitude from 2,600 to 3,170 m. All locations had volcanic soils with slightly acidic to neutral pH (6 to 7.1), organic matter content slightly high (average of 2%), low available S (2 to 8 ppm), and adequate P (20 to 60 ppm). All locations can be considered as adequate environments for high altitude corn. At least for the first crop cycle, a full set of omission plots together with addition plots were set up with complete fertilization (CF), control (no fertilization or NF), and farmer practice (FP) treatments with three replicates in each location. Grain yield, total biomass, tissue nutrient content, and nutrient partition were measured. Also, leaf chlorophyll content was measured with an Apogee® meter, and Agronomic efficiency (AE) was calculated.
The differences in yields were highly significant among treatments at all locations. The highest yields were obtained with the CF treatment, and were 100 to 150% more than the yields with NF and FP treatments. The least reduction in maize yield with a nutrient omission was observed with -Mg, with almost no difference in yield with the CF treatment. The largest yield with a single element addition was obtained with +N followed by +P. The sites in the province of Imbabura had a maximum maize grain yield of only 3.4 t/ha, while sites in Chimborazo had a maximum maize grain yield of about 6 t/ha. The AE were 15 to 17 kg grain/kg N for CF and +N treatments. All treatments with N addition had significantly more chlorophyll (about 20 units more or 50% increase) than no N added (measured 114 days after planting). The study will continue with the addition of a recommended fertilization treatment. Ecuador-09

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

Project Leader: Diego Escobar, Cooperativa Agrícola Orellana (“CAO”, Orellana Agricultural Cooperative) La Concordia, Santo Domingo de los Tsáchilas. Email: diegofranciscoescobar@gmail.com

Project Cooperators: Gustavo Bernal, Cristian Vega, and Rommel Vargas

The specific objectives of this project are to develop a management tool for the Orellana Agricultural Cooperative (CAO) to estimate the agronomic and economic results of fertilizer use and to use this model to establish fertilizer trials for other oil palm growers. A Central Composite Design (CCD) factorial experiment was designed in order to study the effect of N, K and Mg fertilizer rates on the growth of immature plants and on fresh fruit bunch (FFB) yield and oil extraction rate. With our design, five rates of each nutrient were used. Plots of 36 plants were set for each treatment, but actual measurements were carried out only in the 16 internal plants (effective plot). As there was no FFB production in 2012, only leaf rate production, leaf area and leaf biomass were measured, and samples of a reference leaf were taken to measure nutrient content using tissue analysis.

Preliminary results suggest that for this site, Mg rates and K:Mg ratio are the main drivers of biomass growth, with maximum leaf biomass obtained with high rates of Mg (above 0.25 kg MgO per plant per year) and intermediate rates of K (about 1.6 kg K per plant per year). Fertilizer N and the interaction between N and K did not have a significant effect on leaf production and leaf biomass. The mineral analysis did not reflect significant changes in N, K or Mg contents among treatments, which may be due to the original reserves of the plant before the experiment began and because of the concentration of nutrients in smaller plants with less canopy. This study will continue indefinitely at the CAO plantation. The Ecuadorean Oil Palm Growers Guild (ANCUPA) plans to expand similar fertilizer trials in at least one new plantation. Ecuador-14
Asia and Africa Group

China Program

Northcentral & Northeast Region:
Dr. Ping He, Director

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

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This study was conducted to validate Nutrient Expert® (NE)-based fertilizer recommendations for winter wheat and summer maize in farmer fields and compare them with farmer fertilizer practice (FFP). For this, 18 on-farm experiments were conducted in Xinji and Zhengding cities in Hebei province. NE-based fertilizer recommendation plots received on average 182 kg N, 98 kg P$_2$O$_5$ and 78 kg K$_2$O/ha for wheat and 182 kg N, 74 kg P$_2$O$_5$ and 82 kg K$_2$O/ha for maize, while farmer fertilizer practice (FFP) plots received an average of 371 kg N, 180 kg P$_2$O$_5$ and 30 kg K$_2$O/ha for wheat; and 305 kg N, 39 kg P$_2$O$_5$ and 49 kg K$_2$O/ha for maize.

Results showed that the NE treatment had significantly higher wheat grain yields (7 t/ha), profits (US$2,181/ha), agronomic efficiency of N (5.3 kg/kg), and partial factor productivity of N (39 kg/kg) than FFP (6.7 t/ha, $1,901/ha, 2 kg/kg, and 18.2 kg/kg, respectively). For maize, however, the NE treatment had almost similar grain yields (8 t/ha) and profits ($1,994/ha) as the FFP (7.9 t/ha and $1,921/ha, respectively), but had significantly higher agronomic efficiency of N (4.9 kg/kg vs. 2.6 kg/kg), and partial factor productivity of N (44 vs. 27.6 kg/kg) than FFP. The study demonstrated that NE was an effective fertilizer recommendation method for wheat and maize crops in Hebei. Hebei-NMBF

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

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Nutrient Expert® (NE) is a new, computer-based decision support tool developed to assist local experts to formulate fertilizer guidelines for maize (corn), and is based on the principles of site-specific nutrient management (SSNM). This tool comes in handy, especially when soil testing facilities are not easily accessible, which makes timely fertilizer recommendations difficult. This study was conducted to validate NE-based fertilizer recommendations for spring maize in farmer fields and compare them with farmer fertilizer practice (FFP). For this, 17 on-farm experiments were conducted in four different counties in Heilongjiang province. While each individual site had a site-specific rate applied, on average the NE-based plots received 168 kg N, 61 kg P$_2$O$_5$ and 84 kg K$_2$O/ha, while the farmer fertilizer practice (FFP) plots received an average of 169 kg N, 58 kg P$_2$O$_5$ and 52 kg K$_2$O.

Grain yield (10.8 t/ha) and profit (US$3,181/ha) were higher in NE-based treatment plots than in the FFP plots, where corresponding values were 10.0 t/ha and $2,954/ha. Also, higher agronomic (18.1 kg/kg) and recovery (32%) efficiencies of N were obtained using NE-based fertilizer recommendations versus FFP, where corresponding values were 13.1 kg/kg and 25%. This was likely due to the fact that NE-based treatment used N, P and K fertilizers in greater balance than that used in the FFP. Thus, results of this study showed a good promise for NE-based fertilizer recommendations to extend to farmers. Heilongjiang-NMBF

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

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This study was conducted to validate Nutrient Expert® (NE)-based fertilizer recommendations for winter wheat and summer maize in farmer fields and compare them with farmer fertilizer practice (FFP). For this, 20 on-farm wheat and 17 on-farm maize experiments were conducted in Hebi and Zhengzhou, Henan province. NE-based fertilizer recommendation plots received on average 183-97-90 kg N-P$_2$O$_5$-K$_2$O/ha for
Results from the first year of this study showed that grain yields (7.4 t/ha and 11.6 t/ha for wheat and maize, respectively) and profits (US$2,138/ha and $3,640/ha for wheat and maize, respectively) in NE were higher than those in FFP treatments. The corresponding yield values were 7.1 and 11.0 t/ha and profits were $2,008/ha and $3,412/ha in FFP for wheat and maize, respectively. Also, higher agronomic efficiency of N (8.0 kg/kg for wheat and 8.6 kg/kg for maize), N recovery efficiency (13% for wheat and 26% for maize), and partial factor productivity of N (40 kg/kg for wheat and 66 kg/kg for maize) were obtained using NE-based fertilizer recommendations than using FFP, where the corresponding values were 7.9 and 5.4 kg/kg, 12 and 26%, and 36 kg/kg and 63 kg/kg for wheat and maize, respectively. The NE treatment did not always reduce fertilizer rate (slightly higher N rate for maize was used in this study in NE compared with FFP), but applied N, P and K fertilizers in greater balance than in FFP in this study. 

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

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This study was conducted to validate Nutrient Expert® (NE)-based fertilizer recommendations for spring maize in farmer fields and compare them with farmer fertilizer practice (FFP). Twenty-six (26) on-farm experiments were conducted in four different villages in Gongzhuling city, Jilin province. NE-based fertilizer recommendation plots received, on average, 150-57-69 kg N-P₂O₅-K₂O/ha, respectively, while FFP plots received an average of 203-107-92 kg N-P₂O₅-K₂O/ha, respectively.

Results from the second year of the study showed that grain yield (12.3 t/ha) and profit (US$3,534/ha) obtained in NE-based treatments were similar to those obtained in the FFP, where the corresponding values were 12.1 t/ha and $3,374/ha. However, significantly higher agronomic efficiency of N (17 kg/kg) and partial factor productivity of N (83 kg/kg) were obtained using NE-based fertilizer recommendations than using FFP, where the corresponding values were 12 kg/kg and 63 kg/kg, respectively. Also, 26% less fertilizer N was used in the NE-based treatment than that used in the FFP. Thus, results of this study demonstrated the promise of NE tool as a viable alternative to soil testing for making fertilizer recommendations.

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

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This study was conducted to validate Nutrient Expert® (NE)-based fertilizer recommendations for spring maize in farmer fields and compare them with farmer fertilizer practice (FFP). Twenty on-farm experiments were conducted in three different counties in Liaoning province. NE-based fertilizer recommendation plots received, on average, 161-69-89 kg N-P₂O₅-K₂O/ha, respectively, while FFP plots received an average of 237-76-44 kg N-P₂O₅-K₂O/ha, respectively.

Results from the second year of this study showed that NE achieved more grain yield (11.5 t/ha) and profit (US$3,774/ha) than the FFP treatment (10.9 t/ha and $3,520/ha, respectively). Moreover, significantly higher agronomic efficiency of N (13 kg/kg) and partial factor productivity of N (72 kg/kg) were obtained using NE-based fertilizer recommendations than using FFP, where the corresponding values were 6.3 kg/kg and 46 kg/kg. The study demonstrated that NE was an effective fertilizer recommendation method in Liaoning.

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

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This study was conducted to validate Nutrient Expert® (NE)-based fertilizer recommendations for winter wheat and summer maize in farmer fields and compare them with farmer fertilizer practice (FFP). For this, 13 on-farm experiments for winter wheat and 16 on-farm experiments for summer maize were conducted in Linfen, Shanxi province. NE-based fertilizer recommendation plots received, on average, 176-90-69 kg.
N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O/ha for wheat and 150-61-61 kg N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O/ha for maize, while FFP plots received an average of 273-106-29 kg N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O/ha for wheat and 264-42-20 kg N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O/ha for maize.

Results of the study showed that grain yields and profits in NE (9.7 t/ha and US$2,835/ha for wheat and 9.5 t/ha and $3,499/ha for maize) and FFP (10 t/ha and $2,907/ha for wheat and 9.1 t/ha and $3,490/ha for maize) treatments were statistically similar. However, significantly higher agronomic efficiency of N (7.2 kg/kg for wheat and 8.9 kg/kg for maize), N recovery efficiency (18% for wheat and 31% for maize), and partial factor productivity of N (55 kg/kg for wheat and 75 kg/kg for maize) were obtained using NE-based fertilizer recommendations than using FFP, where the corresponding values were 5.5 and 5.3 kg/kg, 16 and 15%, and 37 and 43 kg/kg for wheat and maize, respectively. With NE, 36% and 43% less fertilizer N were used than that used in FFP for wheat and maize, respectively. The study demonstrated that NE was an effective fertilizer recommendation method in Shanxi. Shanxi-NMBF.
Nutrient Management and Balanced Fertilization in Inner Mongolia

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Balanced fertilization trials were conducted in irrigated potato, oil sunflower and irrigated maize in Inner Mongolia to demonstrate yield response, nutrient use efficiency and economic benefit with balanced fertilization.

For irrigated potato in Wuchuan County, application of 240-90-165 kg N-P$_2$O$_5$-K$_2$O/ha produced the highest yield of 33 t/ha, which was 27, 6 and 8% more than the yields obtained in N, P and K omission plots. The agronomic efficiencies were 29 kg tuber/kg N, 21 kg tuber/kg P$_2$O$_5$ and 15 kg tuber/kg K$_2$O, while total recovery efficiencies were 24, 14 and 32%, respectively. The amount of nutrients required for each tonne of tuber yield were 5.5 kg N, 2.1 kg P$_2$O$_5$ and 7.8 kg K$_2$O. The average benefit with K application was US$263/ha.

For sunflower in Wuyuan County, application of N-P$_2$O$_5$-K$_2$O (KCl) at 225-75-135 kg/ha, respectively, produced a seed yield of 3.94 t/ha, which was 16, 10 and 9% more than the yields obtained in N, P and K omission plots. Among the K fertilizers used, KCl and K$_2$SO$_4$ produced similar yields at the same K rate. The agronomic efficiencies were 2.5 kg/kg N, 4.9 kg/kg P$_2$O$_5$ and 2.5 kg/kg K$_2$O. The amount of nutrients required for producing each tonne of seed were 45 kg N, 18 kg P$_2$O$_5$ and 86 kg K$_2$O. Oil sunflower required an average N: P$_2$O$_5$: K$_2$O ratio of 1:0.4:2.2. Potassium application resulted in $22/ha more profit, on average, than in the K omission treatment.

A trial with sprinkler irrigated maize conducted in Dalate County of Erdos indicated that the application of N-P$_2$O$_5$-K$_2$O at 270-120-180 kg/ha produced 13 t/ha maize grain, which was 21, 10 and 15% more than the yields obtained in N, P and K omission plots. The agronomic efficiencies were 10.4 kg/kg N, 10.8 kg/kg P$_2$O$_5$ and 10.6 kg/kg K$_2$O. Potassium application resulted in $442/ha more profit, on average, than in the K omission treatment.

Nutrient Management and Balanced Fertilization in Main Crops in Ningxia Province

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Two experiments on determining optimal K rates for cabbage and rice were conducted in 2012 in Ningxia Province. The experiment on cabbage in Wuzhong City showed that along with the recommended application of 300 kg N and 150 kg P$_2$O$_5$/ha, application of 75-300 kg K$_2$O/ha produced 3.2 to 5.9 t/ha (13 to 24%) more yield and 548 to US$972 more benefit than without K application. The optimal rate of K application was determined as 150 kg K$_2$O/ha, which also resulted in better quality cabbage crop with high vitamin C and soluble sugar contents, and high total soluble solids.

For rice grown in Lingwu City, application of 30 to 60 kg K$_2$O/ha increased rice yield by 10 to 11%, but further increase in K rates (>60 kg K$_2$O/ha) resulted in less yield increase (0.4 to 2%). The highest rice yield was obtained with the application of 270 kg N, 90 kg P$_2$O$_5$ and 60 kg K$_2$O/ha. Economic analysis showed that the highest income ($183/ha) was obtained with the application of 30 kg K$_2$O/ha. Ningxia-NMBF
**Effect of Long-term Application of Potash and Straw Return on Wheat Yield and Soil K Balance in Qinghai Province**

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This long-term field experiment (conducted since 1993) with irrigated spring wheat in northeastern Xining City of Qinghai Province has six treatments including: NP, NPK, NP with 50% straw return (NP+50% ST), NP with 100% straw return (NP+100% ST), NPK with 50% straw return (NPK+50% ST), and NPK with 100% straw return (NPK+100% ST).

Results from the last 20 years of data indicated that the yield of spring wheat increased with the application of N, P and K fertilizers combined with straw. Along with N and P application, straw return and/or fertilizer K application improved the protein content of wheat grain and had no negative effects on grain quality. Compared with the control treatment without K and straw addition, fertilizer K application and/or straw return decreased soil bulk densities by 1.2 to 7%, increased the amount of soil water-stable aggregates (>0.25mm), and improved the stability of soil aggregate. The light fraction of soil organic matter, total organic matter, and soil N, P and K contents were also all increased with fertilizer K application and/or straw return. The soil available K content was 280 mg/kg in the NPK+100% ST treatment, which was about 2.6 times the available K content in the control treatment. Thus, appropriate amounts of fertilizer K application and/or straw return in addition to N and P fertilization can improve wheat yield/quality and soil fertility. A 50% straw return rate can replace fertilizer K application in the local agricultural practice.

**Nutrient Management and Balanced Fertilization in Apple and Kiwi in Shaanxi**

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Trials were conducted in 2012 in Shaanxi Province to evaluate the effect of balanced fertilization on yield and quality of kiwi and drip-irrigated apple. The first experiment was conducted in a 10-year old apple orchard in Fengxiang County, where the nutrient recommendation was 0.6 kg N, 0.24 kg P$_2$O$_5$ and 0.3 kg K$_2$O/tree (1,667 trees/ha). Twenty percent of the NPK was applied basally after previous year harvest, 30% was applied when sprouts emerged in spring, and the remaining 50% was applied during the fruit expansion stage. All fertilizers were applied through drip fertigation except farmer practice (FP) where NPK rate was the same as recommendation, but applied by furrow around the tree. The recommended NPK treatment with fertigation produced 62.4 t/ha apple fruit, which was 10.4 t/ha (+20%), 4.1 t/ha (+7%), 8.4 t/ha (+16%), and 2.8 t/ha (+5%) more than the yields obtained with 1/2N, 1/2P, 1/2K, and FP treatments, respectively. Similarly, the recommended treatment gave a return of US$6,265/ha, $2,403/ha, $5,105/ha, and $1,778/ha more than the incomes obtained with 1/2N, 1/2P, 1/2K, and FP treatments, respectively.

In the study in Yangling City with kiwi fruit, the recommended NPK rate of 0.23-0.12-0.12 kg N-P$_2$O$_5$-K$_2$O/tree (2,000 trees/ha) produced 42 t/ha of kiwi fruit, which was 8, 10 and 32% more than the yields obtained with 1/2N, 1/2P, 1/2K, and FP treatments, respectively. Similarly, the recommended treatment gave $1,841, $2,413 and $6,238/ha more income than the 1/2N, 1/2P and 1/2K plots, respectively. The recommended NPK plus an additional application of 7.7 kg/tree farmyard manure produced 7% more yield and $1,841 more benefit over the recommended rate of NPK, indicating secondary or micronutrient deficiency which was not dealt with by NPK. The recommended rate of NPK also improved fruit quality parameters like single fruit weight, vitamin C content, total soluble sugar content, and ratio of sugar to acid.

**Best Management Practice for Potassium Application in Potato in Northwest China**

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Fifteen on-farm trials with two treatments including an optimum (OPT) and OPT-K, were conducted in randomly selected rainfed and irrigated potato fields in Inner Mongolia and Gansu. The effect of K source and time of application on potato tuber yield and quality were also studied in the two provinces.

In Inner Mongolia, K application increased tuber yield by an average of 12 and 8%, starch content by 7.6 and 4.5%, and decreased the reducing sugar content by 25 and 17% for rainfed and irrigated potato, respectively. In Gansu, K application again increased tuber yield by 7.7 and 8% and decreased the reducing sugar content for rainfed and irrigated potato, respectively. However, it increased the starch content of rainfed potato, while decreased the starch content of irrigated potato. The average agronomic efficiency (AE) of K
Potassium Management for Improving Processing Tomato Yield and Quality in Xinjiang

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Potassium accumulation increased rapidly after 37 DAT, earlier than dry matter accumulation. Potassium accumulated by stem and leaves remained stable after 37 DAT, and the K uptake in later stages of tomato growth was mainly transformed to the fruit. At 96 DAT, K uptake again increased with increased rate of K application, with more K getting accumulated when K was also applied at flowering and/or fruiting stage than only as basal application. The greatest accumulation of K occurred when one half of the recommended K (120 kg K/ha) was applied at flowering and another half at fruiting stage. Therefore, sufficient K supply in later stages of tomato growth was important for biomass accumulation and K nutrition of processing tomato.

Rate and time of K application greatly influenced fruit yield. More fruit was obtained when K was applied in later plant growth stages as compared to applying all K as basal application. Application of 120 kg K/ha, with one half applied at flowering stage and the remaining half applied at fruiting stage, produced 3.4 to 12 t/ha more fruit and 268 to US$710 more benefit than other rates and times of K application studied.

At the rate of 120 kg K/ha, K sources did not significantly affect fruit yield, but affected some indices of fruit quality. Potassium nitrate (KNO₃) resulted in higher vitamin C content than K₂SO₄ and KCl. Fruit color, beta-carotene, soluble solid, and lycopene contents were not affected by K sources. Application of KCl resulted in more fruit yield, higher agronomic efficiency, and more economic benefit than K₂SO₄ and KNO₃ applications. NW Tomato K

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

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Potassium nitrate (KNO₃) produced similar or more tubers than potassium chloride (KCl) or potassium sulfate (K₂SO₄) in Inner Mongolia, but showed no such effect in Gansu. Basal K application or 50% basal plus 50% top-dressing of recommended K at the flowering stage both resulted in significantly more tuber yield than 100% top-dressing at flowering in Inner Mongolia, but there was no such effect in Gansu. However, at both locations, application of KCl or KNO₃ via basal or basal plus top-dressing at flowering resulted in greater agronomic efficiency (AE) than 100% top-dressing at flowering under both rainfed and irrigated conditions. Potassium source did not significantly affect tuber quality. Thus, the best management practice for K application in potato is to apply KCl or KNO₃ as basal or basal plus top-dressing in both rainfed and irrigated conditions. NW Potato K
time of K application on cotton yield and fiber quality were also studied in each province. The average soil exchangeable K values of selected cotton fields were higher in Xinjiang (244 mg/kg) and Shandong (267 mg/kg) than in Hebei (107 mg/kg) and Henan (126 mg/kg). Similarly, K supply values of cotton fields (represented by K uptake) were higher in Shandong and Xinjiang provinces than in Hebei and Henan provinces.

A major portion (50 to 64%) of plant K was accumulated in later stages of cotton growth (i.e. after flowering). This suggested that adequate soil K supply in the later stages of plant growth was important for cotton. There were quadratic polynomial relationships between soil exchangeable K and seed cotton ($R^2=0.26$) and between soil exchangeable K and lint yield ($R^2=0.23$). Fiber elongation, fibre strength, and spinning coefficient were positively correlated to soil exchangeable K. However, when soil exchangeable K was above 393 mg/kg, the quality of fiber decreased. Fiber length uniformity increased with the increase in K uptake. Total K uptake of cotton plants was positively related with fibre strength ($R^2=0.15$), fibre elongation ($R^2=0.51$), and spinning coefficient ($R^2=0.35$), and quadratic equations described these relationships better. Based on the one-year experimental data in 2012, the recommended K rates for cotton in Hebei, Henan, Shandong, and Xinjiang were calculated as 150, 120, 180, and 112 kg K$_2$O/ha, respectively, and the suitable time for K application time was found to be 50% applied at bud stage and 50% applied at boll stage.

Potassium Management in Apple Production in North China

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Investigations and field trials were conducted in apple orchards at selected sites in Shaanxi, Shandong, and Liaoning provinces to (1) demonstrate the current status of apple production and fertilizer use and (2) study the effects of source, rate, and time of potash application on fruit yield and quality. The K balance in apple orchards was also estimated.

Results showed that average N-P$_2$O$_5$-K$_2$O applied in apple orchards in Shaanxi, Shandong and Liaoning through fertilizers and manures were 734-465-325, 1,550-502-1,028, and 491-371-330 kg/ha, respectively. The average apple fruit yields obtained were 32, 49, and 15 to 21 t/ha. Nutrients (N, P and K) from manure accounted for 24, 23 and 36% of total respective nutrient application in Shaanxi, 5.2, 6.9 and 2.5% in Shandong, and 61, 55 and 49% in Liaoning. Application of 0.15 to 0.3 kg K$_2$O/tree through KCl or K$_2$SO$_4$ could meet the K needs of apple trees in the three provinces.

Application of K improved fruit quality (increased Vitamin C content and fruit hardness and reduced total acid). No significant differences existed between the effects of KCl and K$_2$SO$_4$ on fruit yield/quality at the same application rate of K$_2$O. Application of 50% of the recommended K fertilizer in later plant growth stages (such as after flowering and fruit expanding) could be beneficial for fruit yield and quality. Application of fertilizer K increased farmer incomes compared to the control (no K) treatment. The income generated from K application was highest in Shaanxi ($5,538 to US$22,152), followed by that in Liaoning ($1,031 to $9,976), while the least increase in farmer incomes with K application was observed in Shandong province ($431 to $1,215). NWCE Apple K ✦
Studies and Demonstration of Environmentally Friendly Fertilization Technology in Vegetables and Banana

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Vegetable planting area has increased to about 670,000 ha in Fujian Province, while Zhangzhou city, in the north of Fujian, is China’s banana planting city with excellent banana quality and flavor. Therefore, vegetables and banana planting play an important role in agricultural production in Fujian province. However, farmers in Fujian overfertilize banana and vegetables year after year. Our investigation showed that vegetable and fruit planting posed high risk of N and P pollution in agriculture. Therefore, to improve fertilizer utilization rate and prevent N and P pollution, the Soil and Fertilizer Institute, Fujian Academy of Agricultural Science, conducted research and demonstration trials on some efficient fertilization technologies for vegetables and banana. Two banana, three vegetable, and three rice fields were chosen in Pinghe and Zhangzhou counties of Fujian province. A total of 186 soil samples, 180 plant samples, and 30 groundwater samples were collected and analyzed.

The results showed that best fertilizer (BF) treatment (630 kg N/ha, 75 kg P$_2$O$_5$/ha and 750 kg K$_2$O/ha) had an average banana yield of 44,593 kg/ha, which was an increase of 9% over the no potash treatment that yielded 40,485 kg/ha. Similarly, the BF treatment increased net income of the banana farmer by RMB 4,416/ha over the no potash treatment. Based on the research data from 18 banana field trials in recent years, an equation for potash fertilization has been worked out as: $Y = 907.08 \exp(-0.001586X)$, where $Y$ is the recommended fertilizer K rate (kg/ha) and $X$ is the tested value of soil available K (mg/kg). Therefore, the optimum fertilization rates for banana in Fujian are 583 kg N/ha, 75 kg P$_2$O$_5$/ha and 694 kg K$_2$O/ha with a ratio of 100:13:119. *Fujian-10*

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

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Anhui is one of the major cotton growing provinces in China with two major cotton growing regions—the Yangtze river and Yellow river basins. Cotton is grown in the region on about 400,000 ha with a recent annual average production of 350,000 t. The soils of the Yangtze region belong to fluvial outwash or gray clay sand with low P and K (50 to 100 mg/kg). The Huaibei cotton region belongs to the Yellow river plain which has yellow fluvo-aquatic and Shajiang black soils. These soils are rich in soil organic C and N, and medium in P and K. These contrasting soil types call for the need to develop a scientific, balanced fertilization technology to improve cotton productivity, nutrient use efficiency, and farmer profits in the region.

In 2012, the scientists from Anhui Agricultural University conducted two cotton fertilization field trials in Wuwei and Taihe counties, and one cotton fertilization pot trial in the university. The results of field and pot trials showed that, based on currently applied N and P fertilizers, potash application increased cotton yield from 3.3 to 3.7 t/ha (+11%). The optimum fertilization rates for cotton in the region were determined to be 225 kg N/ha, 150 kg P$_2$O$_5$/ha, and 112 kg K$_2$O/ha, respectively. The result of demonstration trials showed that the optimum fertilization plot yield was 4.1 t/ha, which represented an increase of 559 kg/ha (+14%) over the yield in farmer fertilization practice (3.6 t/ha) and an increased economic benefit of 16%. *Anhui-19*
Ecological Effect and Utilization Rate of Potassium for Different Potassium Efficiency Cotton Genotypes

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This project was implemented by Huazhong Agricultural University. It is important to identify cotton genotypes with higher nutrient efficiency and understand the mechanisms of response to K deficiency among genotypes to help in breeding high K efficiency genotypes. We selected a high K use efficiency genotype 103 and a low K use efficiency genotype 122 from 86 varieties and four different families in the last five years. Based on the two genotypes selected, experiments were conducted with the objectives to: (1) study their differences of agricultural character responses under K deficiency conditions, (2) study the genotypes which are more efficient in K uptake and utilization of soil K, and (3) discover the ecological effect of applying K fertilizer for different K efficiency cotton genotypes. A hydroponic experiment was conducted to find out the difference in K+ absorption mechanism between K-efficient cotton genotype 103 and K-inefficient cotton genotype 122 in low K conditions after growing them under low K stress treatment (2 mg/L) and normal K treatment (20 mg/L) with four treatments. The K concentrations used were 0.015, 0.03, 0.06, 0.12, 0.24, and 0.48 mmol/L.

Results showed that under normal K treatment, the K absorption pattern of the two cotton genotypes was significantly different. The value of Km (constant of K absorption dynamic equation) was 0.14 mmol/L for K-efficient genotype 103 and 1.13 mmol/L for K-inefficient genotype 122, which indicated that genotype 103 has higher affinity to K+ than genotype 122. Values of Vmax (maximum K absorption volume) were 3.76 umol/hr/g RFW (ratio of unit fresh tissue weight) for genotype 103 and 12.2 umol/hr/g RFW for genotype 122. This implied that high-affinity K transporter proteins might contribute to K absorption from environment or K channels which could work in low K condition for genotype 103. As for genotype 122, its low K affinity and high Vmax implied that there might be other ion channels in charge of K absorption. Values of Km were 0.21 mmol/L for genotype 103 and 0.36 mmol/L for genotype 122, indicating that both of the two genotypes have high affinity to K+ in the environment, but genotype 103 had a higher affinity to K+.

The data demonstrated that genotype 103 have better low-K adaptability than genotype 122. This research also explained the difference in low K resistance between two cotton genotypes from the perspective of K absorption kinetics. Huabei-37

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

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Project Cooperator: Xiaokun Li

This project was implemented by Huazhong Agricultural University. A total of 17 on-farm trials on winter rapeseed fertilization were conducted in seven provinces along the Yangtze River basin in 2012. Nitrogen fertilization trials were located at 10 sites, while P and K fertilization trials were conducted at the other seven sites. Five N fertilization rates were evaluated along with applications of 90 kg P2O5, 120 K2O and 15 kg/ha borax. Four P fertilization rates were evaluated along with applications of 180 kg N, 120 kg K2O and 15 kg/ha borax, while four K fertilization rates evaluated along with applications of 180 kg N, 90 kg P2O5 and 15 kg/ha of borax.

For N, results showed that N application in winter rapeseed increased seed yield and economic benefit with the highest values (2.8 t/ha and US$2,213/ha, respectively) obtained with 360 kg N/ha application. Compared to the treatment without N fertilization, the average rapeseed yields increased by 608 (49%), 1,148 (100%), 1,356 (115%), and 1,398 (125%) kg/ha when 90, 180, 270, and 360 kg N/ha were applied, while the average economic benefit values increased by $482, $911, $1,076, and $1,110/ha, respectively. However, seed yields did not differ significantly when N application rate exceeded 270 kg N/ha.

For P, results showed that P application also increased seed yield and economic benefit of winter rapeseed with the highest values (2.4 t/ha and $1,894/ha, respectively) obtained with 180 kg P2O5/ha application. With P2O5 applications of 45, 90 and 180 kg/ha, average yields increased by 575 (45%), 728 (57%) and 794 (65%) kg/ha and average economic benefit values increased by $456, $578 and $630/ha, respectively, over the no P treatment.

For K, results showed that seed yield and economic benefit of winter rapeseed increased with K application rates, with the highest values (2.3 t/ha and $1,859/ha) obtained with 240 kg K2O/ha application. With K2O applications of 60, 120 and 240 kg/ha, average yields increased by 13, 21 and 22% and average economic benefit values increased by $186, $298 and $316/ha, respectively, over the no K treatment. The response of winter rapeseed to K application was lower than that to the application of either N or P. Huabei-39
**Study on Nutrient Management Technology for Vegetables in Wuhan**

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In 2012, an on-farm fertilization trial on eggplant was completed. Results showed that with the increase in N fertilization rates, eggplant yield and tissue nitrate content increased gradually. With the increase in P fertilization rates, eggplant yield increased at first up to 180 kg P₂O₅/ha application and then decreased. Vitamin C (Vc) content in eggplant also had a positive correlation with P fertilization rates, with increasing Vc values as P fertilization rates increased from 60 to 180 kg P₂O₅/ha. With the increase in K fertilization rates, just like with P, eggplant yield increased at first and then decreased. When fertilizer K rates increased from 240 to 360 kg K₂O/ha, single eggplant weight, yield, soluble protein, and soluble sugar contents were increased, while nitrate content was reduced. Thus, the optimum NPK fertilization rate of eggplant was found to be 360 kg N/ha, 135 kg P₂O₅/ha and 240 kg K₂O/ha. Results also indicated the uptake ratios of N: P₂O₅: K₂O as 1: 0.35: 1.76 in the early eggplant growing stage and 1: 0.40: 0.98 in the late eggplant growing stage.

The intelligently controlled drip irrigation system in the experimental field increased fertilization efficiency quite significantly. *Hubei-40*

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

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Project Cooperators: Nie Jun and Liao Yulin

This long-term project, started in 2005, is being implemented by the Soil and Fertilizer Institute, Hunan Academy of Agricultural Science. The objective is to collect and compile all the relevant information on N in relation to rice cropping and it’s environmental impact to improve the efficiency of rice production. In 2012, a summary of results collected in recent years (2005 to 2012) from the analysis of 2,367 field experiments was prepared. Partial factor productivity (PFP), agronomic efficiency (AE), apparent recovery efficiency (RE), and physiological efficiency (PE) of early rice, late rice, and middle-season rice varieties in Hunan province were calculated.

The effect of applying N, P and K fertilizers on yield of early rice, later rice and middle-season rice was investigated over seven paddy soil areas. Results showed that the average contribution rates of soil nutrients to early rice, later rice and medium rice were 65, 62 and 59%, respectively. Mean yield increases with N, P and K applications to early rice, late rice and medium rice were 8%, respectively. The critical indices of alkali-hydrolysable N, Olsen-P, and available K for rice were 120, and K applications to early rice, late rice and medium rice were 165 kg N/ha, 98 kg P₂O₅/ha, and 120 kg K₂O/ha. Similarly, the maximum fertilization rates to later rice were 203 kg N/ha, 80 kg P₂O₅/ha and 135 kg K₂O/ha, while the economic fertilization rates were 150 kg N/ha, 53 kg P₂O₅/ha and 60 kg K₂O/ha. The maximum fertilization rates to middle-season rice were 165 kg N/ha, 43 kg P₂O₅/ha and 62 kg K₂O/ha. The maximum fertilization rates to medium-season rice were found to be 48, 122 and 87 kg/kg, respectively; and AEs of N, P₂O₅, and K₂O were found to be 11, 12 and 9.7 kg/kg, respectively; and REs of N, P₂O₅, and K₂O were found to be 32, 12 and 36%, respectively. *Hunan-16*

**Balanced Fertilization Technology in Sweet Potato**

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Project Cooperators: Wang Jidong, Ning Yunwang, and Zhang Hui

Sweet potato cultivation is quite extensive in China. But in many sweet potato growing regions, the application rates of fertilizers, especially K, are very low. According to our survey, many farmers applied compound fertilizers, like 15-15-15, to sweet potato instead of other commonly available K fertilizers (like KCl) because of high prices. This has led to a situation where there is under application of K in sweet potato in China. Since K is essential for sweet potato growth, both yield and quality of sweet potato have been steadily decreasing in the past few years.

This project was implemented by the Resource and Environment Institute, Jiangsu Academy of Agricultural Science. In 2012, field trials were conducted to determine the optimum (OPT) application rates of N, P and K fertilizers in sweet potato in Jingmen city of Hubei province, Laiqiao town of Anhui province, Nan’an city of Fujian province, and Liuhe street in Nanjing of Jiangsu province. Results from the trial in Jiangsu province...
showed that the balanced fertilizer (BF) treatment with application of 112-162-260 kg/ha of N-P$_2$O$_5$-K$_2$O, respectively, obtained significantly higher sweet potato yield of 63 t/ha, which amounted to a yield increase of 8.3 t/ha or 15% and net income increase of RMB 5,851/ha over the CK treatment where no K was applied (i.e. application of 112-162-0 kg/ha of N-P$_2$O$_5$-K$_2$O, respectively). Other provinces also showed similar results. Jiangsu-11

**Transformation, Interaction and Bioavailability of Nutrients in the Fertisphere**

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This project is being implemented by the Nanjing Institute of Soil Science, Chinese Academy of Science. Results so far have indicated that the movement of P in soil is usually less than 6 cm, and that the P moving distance in grey alluvial soil is shorter than in paddy soil. No significant change occurred in the P moving distance in soil with or without the application of oxalic acid and fertilizer P. However, this application reduced P fixation by soil and increased the moving rates. Further, the release rate and moving distance of coated mono-ammonium phosphate (MAP) in soil increased with the increase in soil temperature. Therefore, when soil temperature increases, coated MAP could increase the P use efficiency during the growing season.

The transformation of P in soil is closely related to fertilizer type and soil characteristics. Initially, P fertilizers applied to the soil form soluble P. But mono-calcium phosphate (MCP) and MAP can be fixed more easily than di-ammonium phosphate (DAP). In black soil, MAP gets mainly transformed to Al-P and Fe-P, while in grey alluvial soil, it is mainly transformed to Ca$_8$-P. Similarly, in a paddy soil, MAP is mainly transformed to Fe-P, Ca$_2$-P, Ca$_{aq}$-P, and Al-P, thereby, keeping a balance. Flooding leads to the formation of Al-P and Fe-P. On a paddy soil, broadcast P fertilizer would greatly increase the P concentration in groundwater, thereby, increasing the risk of P loss by runoff. Phosphorus fertilization with banding or row placement in fields could greatly reduce P loss.

Fertilizer K application together with ammonium N fertilizers could improve the availability of K fertilizers in the fertisphere of paddy soil. The influence of ammonium on K availability is larger than the influence of K on ammonium availability. Nanjing-11

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

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Project Cooperator: Xiaoqin Chen

This project was implemented by the Nanjing Institute of Soil Science, Chinese Academy of Sciences. In 2012, the cooperators conducted a wheat pot culture experiment with nine soils, which differed in K status and K buffering capacity from different regions of China. During the whole growing season, different tissues of wheat plant were sampled and tested according to the growing stages. The tissue K contents were measured and compared among different organs and growing stages. The relationships between tissue K contents and soil K availability as indicated by various methods were evaluated to find a better method for soil K availability evaluation.

Results showed that K contents at elongation and heading stages of the first (counting from plant top), second, third and fourth leaves could be used as diagnostic indices of wheat K nutrient status at different stages. Whether or not the K contents in diagnostic organs reached 35.3 g/kg, 31.6 g/kg, 23.6 g/kg, 15.9 g/kg at elongation stage or 22.8 g/kg, 17.1 g/kg, 14.6 g/kg, 13.6 g/kg at heading stage for the first, second, third, and fourth leaves, respectively, could be used as wheat K supply indices. Results also showed that both sodium tetraphenylboron (NaBPh$_4$) (0.2 mol/L, 0.5h) and cold nitric acid (HNO$_3$) extraction methods (2 mol/L, 0.5 h) were effective in evaluating soil K availability for wheat. Based on the mathematical function obtained from the relationship between soil available K content and yield reduction of wheat (taking 10% loss in yield as the critical point), the critical values for soil available K were 388 mg/kg and 190 mg/kg for the NaBPh$_4$ and HNO$_3$ methods, respectively. The modified HNO$_3$ method (two successive 30 min. extractions with 0.5 M HNO$_3$ at a volume/weight ratio of 100) was also as good as the NaBPh$_4$ method for measuring soil available K. Nanjing-12
**Study on Fertilizer Regulation and Recommendation Technique for Greenhouse Vegetables in Shanghai**

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Project Cooperator: Song Ke

This project was implemented by the Soil and Fertilizer Institute, Shanghai Academy of Agricultural Science. Shanghai has a long history of strawberry cultivation. About 5,000 ha area in this region is currently under strawberry cultivation, and a great potential exists for the future expansion. In 2012, a field experiment was conducted in Dahong Village, Pudong to study the effects of N and K fertilization on yields and quality of strawberry in Shanghai. The trial had seven treatments of N-P$_2$O$_5$-K$_2$O (kg/ha) including: 0-150-300, 150-150-300, 300-150-300; 450-150-300, 300-150-0 (CK), 300-150-150, 300-150-450.

Results indicated that applications of 300 kg N, 150 kg P$_2$O$_5$ and 450 kg K$_2$O/ha constituted the optimal (OPT) fertilizer management strategy for strawberry. The OPT treatment produced a strawberry yield 37 t/ha, which was an increase of 81% over the no K (300-150-0) treatment yield of 21 t/ha. Similarly, the OPT treatment gave better profit of US$47,612 and better quality (contents of soluble solids, Vitamin C, sugar, and acid, as well as solid/acid ratio) strawberry over the CK treatment.

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

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Project Cooperators: Zhang Yong-song and Zhang Qichun

This project was implemented by Zhejiang University. In 2012, soil samples from a Chinese Cambisol under three cropping systems were collected vertically to a depth of 200 cm and then analyzed to evaluate the effect of manure application on soil P quantities, forms and the potential environmental implications under different land use patterns.

Results showed that calcium-bound P was the most abundant P fraction in the soil, followed by residual P. Organic P only accounted for less than 5% of total P in most of the soils. Manure application increased the levels of inorganic P (Pi), with higher proportions of Pi in labile forms than stable forms. After manure applications for 8 to 5 yr, available P (Olsen P) and degree of P saturation (DPS) values of the 0 to 20 cm layer at all sites exceeded the threshold for Olsen P (60 mg/kg) and DPS (30%), and the risk of P loss was significantly increased. The DPS values were generally lower than 30% below 20 cm, indicating a minimal risk of P loss via leaching from deeper soil. The on-going practice of manure application not only increased the size of each of the labile and non-labile P pools, but also caused a shift in the relative sizes of different pools, regardless of the cropping systems. Long-term application of organic manure(s) might cause P accumulation in top soil, thereby, increasing the risk of P loss through surface runoff and leaching.

Results also showed that P loading in all experimental soils, irrespective of the different soil extractions used for analysis, were low below the 40 cm depth, with most P concentrated in the 4 to 6 cm depth. High simulated rainfall led to lower soil water extractable P (Pw) concentrations, and higher leachate dissolved reactive P (DRP) and total P (TP) in comparison with low simulated rainfall. Based on the relationships between Pw and corresponding degree of P saturation (DPS) indices, the critical levels of DPS indicating P leaching could be identified at 19% DPSM3(Ca) and 13% DPSM3(Ca+Mg). The DPSM3(Ca) and DPSM3(Ca+Mg) values were above the thresholds in the top 30 cm of soil, but below the thresholds at a soil depth of 30 to 40 cm. Intensive rainfall can significantly increase P leaching, which can also be enhanced by manure application in the fallow season.

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

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Project Cooperators: Fusheng Yuan, Qixiang Luo, Gang Sun, Changxu Xu, Duogen Xiong, and Wenxue Zhang

This project was implemented by the Soil and Fertilizer Institute, Jiangxi Academy of Agricultural Science. In 2012, 29 on-farm fertilizer experiments were conducted in 11 provinces including Jiangxi, Hunan, Guangxi, Fujian, Zhejiang, Heilongjiang, Jiangsu, Anhui, Hubei, Sichuan, and Yunnan. The experiments mainly included eight treatments, and were conducted simultaneously in both high-yield and low-yield fields. Single-rice cropping system experiments were conducted in seven provinces (Hubet, Sichuan, Jiangsu, Zhejiang, Anhui, Yunnan and Heilongjiang), and double-rice cropping system experiments were conducted in four provinces (Jiangxi, Hunan, Fujian, and Guangxi). All provinces involved in the project have: (1) built five levels of soil nutrient evaluating indices, (2) analyzed the last 10-year rice plant nutrient utilization trend with results showing a decreasing trend in nutrient utilization with fertilizer input increase, (3) analyzed the
agronomic efficiency, which again showed a decreasing trend in the last 10 years, and (4) built a database on nutrient application method and timing according to actual rice production and the preliminary rice high efficiency nutrient management technology system.

For the double-rice cropping system, the optimum (OPT) fertilizer application rates were calculated as 150 kg N, 90 kg P₂O₅, 150 kg K₂O, and 15 kg ZnSO₄/ha as base fertilizer for early rice and for late rice, the OPT were calculated as 180 kg N, 60 kg P₂O₅, 150 kg K₂O, and 1 kg ZnSO₄/ha. For the single-rice cropping system, the OPT was calculated as 240 kg N, 150 kg P₂O₅, 150 kg K₂O, and 1 kg ZnSO₄/ha. The results also showed that N nutrition has the highest contribution rate to rice yield, followed by P, K, and Zn nutrition.

The results of N fertilizer use pattern experiments showed that when fertilizer N was split-applied as 40% basal and 20% each at tillering, panicle initiation and grain formation stages (the double-season rice received fertilizer N at 180 kg/ha, the single-season rice received fertilizer N at 240 kg/ha, all fertilizer P was applied basally, and fertilizer K was applied half at seeding (basal) and half at panicle initiation stage), rice obtained highest yields in five of the 11 provinces, and rice grain yields increased by 5.5 to 8.0% (6.8% and 494 kg/ha on average) compared to the 100% N applied as basal treatment. *Jiangxi-30* ✤
Effects of Nutrient Management on Potato Yield on Acid Soils in Chongqing

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Acid soils account for one-third of the total land area in Chongqing, southwest China. Soil acidity usually reduces the availability of plant nutrients and hinders crop growth. The objective of this experiment was to study the effects of different basic materials, P sources, and N and K rates on the availability of P and potato yield in an acid soil (pH 4.5) in Chongqing. Treatments included three types of basic materials (aglime, fused Si-Ca fertilizer, and fused Ca-Mg phosphate), two types of P fertilizers (fused Ca-Mg phosphate and single superphosphate), three rates of N (90, 180, 270 kg/ha), and four rates of K (0, 45, 90, and 135 kg/ha) in different combinations. The optimal fertilizer rate (OPT) was set as 180-90-150 kg N-P$_2$O$_5$-K$_2$O/ha plus either 1.5 t aglime/ha, 2.25 t fused Si-Ca fertilizer/ha, or fused Ca-Mg phosphate. Sixty percent of the fertilizer N and 50% of the fertilizer P were applied basally (at seeding) and the remaining amounts were applied at tuber swelling stage. All the other fertilizers and amendments were applied at seeding.

At the end of the cropping season, soil available P and K increased significantly with an increase in the rates of fertilizers applied. Soil available P content increased by 3 to 4 times with the addition of fused Si-Ca superphosphate and aglime, and by 4 times with the addition of fused Ca-Mg phosphate over the addition of single superphosphate. The soil available P in the single superphosphate treatment after harvest was identical to that tested before the experiment. Potato tuber yield increased significantly with an increase in N, P and K rates and either leveled off or declined at each rate set for the OPT treatment. The addition of either fused Si-Ca fertilizer or aglime on the basis of OPT significantly increased tuber yield by 3,100 kg/ha (16%) or 2,537 kg/ha (13%), while the addition of fused Ca-Mg phosphate significantly reduced tuber yield by 2,482 kg/ha (-13%). Thus, the increase or decrease in yield by amendments was not attributed to additional Ca or Mg, but to the effects of increased pH and Si. Soil test values revealed that fused Si-Ca fertilizer and aglime raised soil pH from 5 to 5.5, while fused Ca-Mg phosphate only increased pH by about 0.2 pH units.

Chongqing-BFDP-2011-02

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

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Potassium chloride (KCl) and potassium sulfate (K$_2$SO$_4$) are the two commonly used K fertilizers for vegetable production in China. However, vegetable growers fear that KCl may affect vegetable yield and quality as many field vegetables are sensitive to chloride (Cl$^-$), especially in early growth stages. We conducted field experiments in Jiulongpo District of Chongqing to verify the effects of KCl and K$_2$SO$_4$ on yields and quality of lettuce and Chinese cabbage. The experiment had nine treatments with two K sources (KCl and K$_2$SO$_4$), two K application rates (0 and 100 kg/ha), and four different application timings (with or without splitting - viz., one basal application, basal + top dressing at rosette stage in a 50:50 ratio, basal + top dressing at cupping or head forming stage in a 50:50 ratio, and two top dressings at rosette stage and cupping stage in a 50:50 ratio) on the basis of 300-90-100 kg N-P$_2$O$_5$-K$_2$O/ha.

Potassium application significantly increased the yields of lettuce and Chinese cabbage by 10 to 15% over the K omission treatment. However, no yield differences were observed between the two K sources used (KCl and K$_2$SO$_4$). Maximum lettuce yield was obtained for the treatment with split K application as basal + top dressing at cupping stage in a 50:50 ratio, while maximum Chinese cabbage yield was obtained with two top dressings at rosette stage and cupping stage in a 50:50 ratio. Contents of Vitamin C, amino acids, and soluble sugar varied with fertilizer sources and application timings for both vegetable crops. Nitrate content decreased with splitting KCl application, but increased significantly with splitting K$_2$SO$_4$ application in lettuce.
Potassium use efficiency was much higher when KCl was split applied during later growth stages of the two vegetables. On the other hand, with K$_2$SO$_4$, K use efficiency was higher when it was applied during early crop growth stages and regardless of whether it was applied as basal or in splits. The results indicated that KCl and K$_2$SO$_4$ are almost equally good for the production of lettuce and Chinese cabbage when used properly.

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

Project Leader: Lixian Yao, Guangdong Academy of Agricultural Sciences Soil and Fertilizer Institute, Guangzhou, Guangdong. Email: lyaolx@163.net

Litchi is one of the most favorable subtropical fruits grown in China. To get high yields and quality of litchi, special care is needed for its mineral nutrition. Among all the essential nutrients, insufficient or over supply of N or K, or using improper fertilizer ratios of K$_2$O/N, usually reduces litchi yield and quality. High fertilizer K$_2$O/N ratios are known to cause fruit cracking, which results in economic loss to the growers.

We conducted a three-year field experiment to determine the optimal fertilizer ratios of K$_2$O/N for litchi production in Guangdong. Treatments included five K$_2$O/N ratios (0.6, 0.8, 1.0, 1.2, and 1.4) with five replications (trees). Each tree received a total amount of 0.36, 0.48, 0.60, 0.72, or 0.84 kg K$_2$O in combination with a fixed rate of P, Ca, Mg, Zn, B, and Mo based on soil testing. Nitrogen, P, K, Ca, and Mg were split applied at four times, viz., at after-harvest, before-blossom, after-blossom and fruit swelling stages, and the micronutrients were applied at after-harvest stage only.

Results showed that litchi yield increased slightly, but consistently with an increase in K rate and leveled off at 0.72 kg K$_2$O/tree, i.e., a K$_2$O/N ratio of 1.2 in three years. At this ratio, the single fruit weighed 7 to 10% more than the lowest K treatment and 8 to 9% more than the highest K treatment. The photosynthesis rate, anti-oxidation activity of the leaves, growth rate, fruit quality, and economic returns were maximum at K$_2$O/N ratios of 1.0 to 1.2. In summary, a K$_2$O/N ratio of 1.0 to 1.2 can be recommended for high yield and quality of litchi in Guangdong.

**Nutrient Demands of a Banana Variety**

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Project Cooperators: Guoliang Li and Baomei Yang

Banana is one of the most popular tropical and subtropical fruits. Several cultivars of banana are being grown that vary considerably in nutrient requirement. To better understand the nutrient demands of different cultivars and recommend cultivar-specific nutrient management to growers, a widely grown banana cultivar—Pisang awak (*Musa ABB Pisang Awak*)—was selected by analyzing contents of essential nutrients plus silicon (Si) in different organs of the plant. Three representative whole banana plants were sampled from a banana plantation that had received balanced application of fertilizers along with good field management practices during the growing season.

Results showed that the quantity of different nutrients required by this banana cultivar varied considerably. To produce 100 kg fruit, it required 3.56 kg N, 1.66 kg Si, 0.90 kg K, 0.45 kg Ca, 0.19 kg Mg, 0.13 kg P, 94 g Mn, 86 g S, 39 g Fe, 3.3 g Zn, 1.1 g B, 1.1 g Cu, and 21 mg Mo. These values were much higher (1.74 times for N, 2.81 times for P, 2.04 times for K, 1.47 times for Ca, 1.32 times for Mg, 1.91 times for S, 4.03 times for Fe, 17.77 times for Mn, 3.82 times for Zn, and 2.58 times for B) when compared with nutrient uptake values of another cultivar, viz., Brazil banana (*Musa AAA Giant Cavendish cv. Baxi*). The percentage of nutrient removal in fruit to total uptake at maturity was in the order of P (29.1%) > Cu (23.6%) > Mg (20.8%) > N (20.5%) > S (18.4%) > Mo (18.1%) > B (15.7%) > K (14.9%) > Ca (14.5%) > Zn (13.6%) > Si (6.6%) > Mn (5.6%) > Fe (2.6%). This indicated that nutrient removal by fruit was not proportional to its total uptake. Further analysis indicated that one third of N and 64.3% of Mn were accumulated in leaves, about 50% of K, Si and Mo were accumulated in the pseudo-stem, most of Ca, Mg, S, and B were accumulated in leaves and pseudo-stem, 61.5% of Fe was accumulated in roots, Cu was accumulated in pseudo-stem and fruits, and Zn was accumulated in pseudo-stem and corm.

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

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Red dragon fruit is a high value fruit that has become quite popular in Guangxi, with the area under cultivation expanding rapidly in recent years. However, there is a lack of appropriate nutrient management information to guide growers in the use of fertilizers efficiently while cultivating red dragon. Therefore, a
field experiment was conducted to test the optimal rates of N, P and K fertilizers for obtaining high yields of red dragon fruit in Guangxi. It consisted of eight treatments: optimal treatment (OPT) with applications of 411 kg N, 188 kg P₂O₅, 675 kg K₂O, 150 kg MgO, and 1.3 kg B/ha, OPT-N, OPT-P, OPT-K, OPT-1/2K, OPT+1/2K, OPT-Mg and OPT-B and replicated three times. Nitrogen was used as urea, P as single superphosphate, fused calcium-magnesium phosphate in a ratio of 2:1, Mg as MgSO₄, and B as borax. All fertilizers were split applied in late January, late April, early July, and late August.

Results showed that the OPT treatment significantly increased red dragon fruit yield compared to N, P and K omission treatments. Compared to the OPT treatment yield, N, P, K, Mg, and B omission treatments led to yield reductions of 7.5 t/ha (38%), 4.5 t/ha (23%), 3.3 t/ha (17%), 2.0 t/ha (10%), and 0.5 t/ha (2.7%), respectively. Cutting K fertilizer by half increased fruit yield by 950 kg/ha (4.9%), while increasing K fertilizer by half reduced fruit yield by 367 kg/ha (-1.9%) as compared to the yield in OPT treatment. This implied an over-projected initial OPT K rate for red dragon fruit in this experiment and that a reduction in OPT K rate is needed. The agronomic efficiencies of N, P, O₃, and K₂ were 18, 24 and 5 kg fruit/kg, respectively. Though addition of B did not significantly increase fruit yield, its agronomic efficiency (410 kg fruit/kg B) was the highest of all nutrients in the study, likely due to it’s low use rate. Guangxi-BFDP-2012

Effect of Different Fertilizer Treatments on Chili Pepper Production in Hainan

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The study was aimed to further fine-tune the optimal fertilizer rates determined in the previous two years of field experiments on chili pepper, one of the most widely grown vegetables in winter in Hainan, China. In 2011, the optimal rates of N and P were determined to be 300 and 60 kg/ha for high yield chili production. This year, six K rates (0, 60, 120, 180, 240, and 300 kg K₂O/ha) were evaluated. The source, timing, and placement of fertilizers and field management remained the same as in 2010 and 2011.

Results showed that chili pepper yields increased significantly with increasing K rates, but leveled off at 240 kg K₂O/ha. This K rate, in combination with the optimal N and P, produced 552 kg/ha (18%) more chili pepper yield and US$284 more economic return than the K-omission treatment. Furthermore, this treatment also achieved higher K use and agronomic efficiencies than any other treatments. Thus, based on the data from three years of the trial, 300 kg N, 60 kg P₂O₅ and 240 kg K₂O/ha can be recommended as the optimal nutrient management strategy to chili growers in Hainan. Further, if a soil test indicates a high soil P, fertilizer P can be omitted from the fertilizer program for every other crop season. Hainan-08

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

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The objective of this project was to evaluate the effect of application of different rates of N, P and K fertilizers on maize yield and nutrient losses from Sichuan’s sloping farmlands during the summer rainy season. Treatments consisted of six rates of N (0, 225, 300, 375, 450, 600 kg N/ha), three rates of P (0, 150, 300 kg P₂O₅/ha), and two rates of K (0 and 150 kg K₂O/ha) with three replicates and a plot size of 8 m. Nitrogen was used as urea (N 46%), P as mono-ammonium phosphate (N 11 % and P₂O₅ 44%), and K as KCl (K₂O 60 %). Nitrogen was split applied at seeding, seedling, elongation, and tasseling stages in 10:20:20:50 ratio, respectively, while P and K fertilizers were applied in full at seeding.

Results showed the application of 225-150-150 kg N-P₂O₅-K₂O/ha, respectively, as the optimal fertilization strategy, which produced the highest maize kernel yield. These results were in agreement with previous year results. Once N rates were above or below 225 kg N/ha, the maize yields dropped. All the NPK treatments considerably reduced water runoff when compared with N, P, or K omission treatments. The reduction in runoff ranged from 16 to 24% due to applied N, -2.4 to 18% due to applied P, and 16% due to applied K. Soil erosion, however, reduced from 13 to 37% in three N rate treatments (225, 300 and 375 kg/ha), from -30 to 21% in two P treatments (150 and 300 kg P₂O₅/ha), and 24% in the K treatment (150 kg K₂O/ha) when compared with N, P or K omission treatments. The increased soil erosion in treatments receiving higher N rates was probably due to poor crop growth (about 16% reduction in biomass), thereby, decreasing the soil cover and increasing the impact on soil particles from direct rain drops. Losses of N through water runoff increased significantly with an increase in N rates, while loss of P and K did not change much with increased P rates. The quantity of nutrients lost from the field decreased with advancing maize growing season. The total amounts of nutrients lost during the maize growing season were 10 to 46 kg N, 0.6 to 1.0 kg P, and 4.3 to
8.6 kg K/ha. The results imply that overdose of N (rather than P and K) would impose considerable threat to the environment. *Sichuan-BFDP-09*

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

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This research project was initiated in Yunnan province in 2011 to investigate the performance of controlled release urea (CRU) in a high fertility sloping land soil under plastic mulch in humid climate with irregular drought spells in summer. In 2011, because CRU granules were placed too close to the soil surface at seeding time, it resulted in some of the CRU granules remaining intact or with partially N release even at harvest time due to the protection of plastic mulch on soil surface from rainwater infiltration. This year, the CRU placement was done at 5 cm below the soil surface. The experiment included four N rates (0, 120, 180, and 240 kg N/ha) replicated three times. Each rate of N was tested with paired CRU and regular urea (RU) for strict comparison of CRU effect. Besides, one treatment with 40:60 of RU split application (i.e. 40% basal application at seeding and 60% as a top-dressing 63 days after seeding) was compared with another treatment of 40:60 of RU: CRU applied as one basal application at seeding. All treatments received equal rates of P and K fertilizers that were applied basally.

Similar to the results obtained in 2011, all CRU treatments, with the exception of RU split application, produced significantly higher maize yields compared to RU treatments. Maize yields were increased with an increase in N rates, but leveled off at 180 kg N/ha (i.e. 75% of the full N rate) for both RU and CRU. Thus, the highest maize yield was obtained at 75% of full rate CRU, which was 886 kg/ha (8%) higher than the yield with RU treatment (180 kg/ha). Different from the results in 2011, the 40:60 RU split application treatment produced maize yields similar to 40:60 CRU split application treatment. Agronomic efficiency of both CRU and RU treatments decreased with increase in N application, ranging from 7.7 to 13 kg kernels/kg N for CRU and 6.5 to 8.6 kg kernels/kg N for RU. With the increase in CRU placement depth, maize yield was improved as compared to in 2011, and the N release from coated urea granules was verified to be more complete at maize harvest. *Yunnan-BFDP-2011*
Development of a Soil Fertility Map as a Decision Support Tool for Fertilizer Recommendations for Citrus in India

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Citrus is a highly nutrient responsive crop. But its productivity in India is low due to multiple nutrient deficiencies, caused by generalized fertilizer application. Application of GIS technology in mapping the fertility status of soil and fruit yields has been useful to provide the desired accuracy and effectiveness in fertilizer recommendations. Geo-referenced soil samples were collected from the upper 0 to 20 cm of a Khasi Mandarin orchard at Umsaitining Ribhoi district of Meghalaya at four grid sizes (10 m x 10 m, 20 m x 20 m, 40 m x 40 m, and 60 m x 60 m).

The predicted fruit yield in the orchard varied from 21.2 to 142.3 kg/tree, 16.4 to 151.4 kg/tree, 15.2 to 148.2 kg/tree, and 18.2 to 112.4 kg/tree under grid sizes of 10 m x 10 m, 20 m x 20 m, 40 m x 40 m, and 60 m x 60 m, respectively. Collected soil samples were analyzed for different parameters, and predicted values from GIS-based fertility maps varied [soil pH (3.2 to 6.8), organic C (1.11 to 3.12 g/kg), KMNO₄-N (132 to 172 mg/kg), Olsen-P (5.2 to 10.1 mg/kg), NH₄OAc-K (138 to 572 mg/kg)] for different sampling grid sizes. Similar variations were observed in the predictability of soil micronutrients (DTPA-Fe, DTPA-Mn, DTPA-Cu, and DTPA-Zn) with fertility maps using different grid sizes. Spatial variograms of these parameters suggested 40 m x 40 m as the optimum grid size for soil sampling and for predicting fruit yield in orchards in northeast India. A Nagpur mandarin orchard at Ladgaon (Katol) area of Nagpur district in Maharashtra was also identified for soil fertility assessment. Surface samples were collected in grid sizes of 20 m x 20 m, 40 m x 40 m and 60 m x 60 m, and analyzed for available nutrients. Available N (96 to 131 mg/kg), available P (8 to 17 mg/kg), available K (104 to 201 mg/kg), available Fe (6 to 16 mg/kg), available Mn (4 to 11 mg/kg), available Cu (0.4 to 0.9 mg/kg), and available Zn (0.4 to 1 mg/kg) in the orchard varied in relation to fruit yield of 10 to 79 kg/tree. The studies highlighted within and between location variability of nutrients, and the need for site-specific nutrient management to optimize yields in mandarin orchards in India. India-003

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

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On-farm nutrient omission trials were conducted for the wheat crop in Agra district during the winter season. Treatments included ample application of NPKS (180 kg N, 90 kg P₂O₅, 100 kg K₂O, and 40 kg S/ha), and subsequent omissions of N, P and K from the ample treatment. Two other treatments were also included in the study to compare the yields between the state recommended (SR) fertilizer rates (120 kg N, 60 kg P₂O₅, 40 kg K₂O/ha) and Nutrient Expert® (NE)-based fertilizer recommendation rates (140 kg N, 68 kg P₂O₅, 81 kg K₂O/ha for a target wheat yield of 6 t/ha). Omission of N, P and K from the ample NPK treatment reduced grain yield by 38, 21 and 23%, respectively. The ample NPK treatment produced the highest wheat grain yield (5.8 t/ha) followed by NE (5.6 t/ha), and the least grain yield was observed in the N omission (3.6 t/ha) treatment. The conventional recommendation (SR) proved suboptimal for wheat and yielded significantly lower than the NE recommendations at all locations. Interestingly, the highest net return was observed in the SR treatment (INR 57,673/ha) followed by NE (INR 56,143/ha), but the benefit:cost ratio was highest (2.25) in the NE treatment.
For the experiment on pearl millet grown in rainy season in the same region, five treatments included ample NPKS (120 kg N, 70 kg P2O5, 100 kg K2O, and 30 kg S/ha) and four N, P, K, and S omission plots (-N, -P, -K, and -S). Maximum grain (4.2 t/ha) and stover yields (8.2 t/ha) of pearl millet as well as farmer income (INR 25,659/ha) were observed in the ample NPKS treatment. The yield reductions in pearl millet due to N, P, K, and S omissions from the ample treatment were 34, 22, 11, and 5%, respectively. At the maximum production level in the ample treatment, pearl millet removed 74, 8.5, 26, and 8.5 kg/ha in grain and 40, 9.1, 185, and 10.1 kg/ha in straw of N, P, K, and S, respectively. Higher amounts of residual soil organic carbon (3.9 g/kg), and available N (213 kg/ha), P (12 kg/ha), K (224 kg/ha), and S (11 kg/ha) were recorded under the ample treatment. *India-006*

**Site-Specific Nutrient Management for Rice-Wheat in Punjab**

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Project Cooperator: Naveen Gupta

This study was initiated to determine the indigenous soil nutrient supplying capacity in wheat growing areas of Punjab and to validate Nutrient Expert® (NE) for wheat, a decision support tool for field-specific nutrient recommendation for wheat in Punjab. On-farm experiments in wheat were established at 42 farmer fields in six different districts (Ludhiana, Sangrur, Fatehgarh Sahib, Amritsar, Gurdaspur, and Bathinda) of Punjab. The nutrient omission trials comprised of four treatments including: (-N) ample PK, (-P) ample NK, (-K) ample NP, and ample NPK with a targeted yield of 6 t/ha under zero (ZT) and conventional (CT) tillage. The NE trials in rice-wheat and cotton-wheat systems comprised of five treatments including: NE recommendation with N applied as 80:20 split (80:20), NE recommendation with N applied as 80% basal and the remainder through GreenSeeker® estimation (80:GS), NE recommendation with N applied as 50:50 split (50:50), state recommendation (SR), and farmers’ fertilization practice (FFP).

The trials showed that average yield was lowest in case of N omission (1.79 to 1.98 t/ha). The average grain yield in ample NPK and (-K) plots under ZT was 5 and 1% higher than under CT, respectively. However, the average grain yield was 6% higher in (-P) plots under CT as compared to under ZT systems. In the NE trial, average grain yield was highest in the 50:50 treatment under both ZT and CT scenarios. The average grain yield in the 50:50 plot under ZT was 5, 12, 16, and 21% higher than 80:20, 80:GS, SR, and FFP treatments, respectively. The corresponding values in CT plots were 9, 9, 16, and 21%. Similar trend was observed in the cotton-wheat system, where the average grain yields in the 50:50 plot were 6, 7, 13, and 24% higher under ZT and 15, 12, 5, and 22% higher under CT than 80:20, 80:GS, SR, and FFP treatments, respectively. Results from the current study showed significant site differences in yield and growth parameters of wheat grown under contrasting tillage systems and provided an estimate of indigenous nutrient supplying capacity of soils across the State. Such information is essential for site-specific nutrient recommendations for wheat. The recommendations from NE improved wheat yields as well as farmer profit over the existing nutrient management practices (SR and FFP). *India-007*

**Site-Specific Nutrient Management for Rice-Wheat in Haryana**

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Nutrient Expert® (NE) for Wheat, a new, computer-based fertilizer recommendation tool, was evaluated against existing nutrient management practices under zero tillage (ZT) and conventional tillage (CT) practices in several farmer participatory trials under the Cereal Systems Initiative for South Asia (CSISA) project in Haryana, India. The trials (29) compared four treatments including: NE-based recommendation with N splitting as 80% basal and 20% at 2nd irrigation (NE 80:20), NE-based recommendation with N splitting as 33% basal, 33% at 1st irrigation, and 33% at 2nd irrigation (NE 33:33:33), state recommendation (SR), and farmers’ fertilization practice (FFP). Maximum wheat grain yield was observed in NE 33:33:33 (5.5 t/ha) treatment followed by NE 80:20 (5.2 t/ha) under ZT scenario. The SR (5.1 t/ha) and FFP (4.8 t/ha) treatments produced significantly lower yields than NE 33:33:33 treatment under zero tillage. A similar trend was observed under conventional tillage.

In another set of farmer participatory field trials, the NE-based recommendations were supplemented with GreenSeeker® (GS) optical sensor-based N prescriptions (NE + GS) at Feekes 7/8 growth stage and were compared with SR and FFP. The results of the trials (11) revealed that NE and NE + GS yields were on par, but both were significantly higher than FFP yields under both zero and conventional tillage practices. Results from NE validation trials in Haryana suggest that NE-based recommendations, with due cognizance to soil nutrient supplying capacity and plant demand for a targeted yield, showed remarkable yield gain over FFP and SR under both tillage scenarios. Farmers in intensive production systems of northwest India apply
nutrients in an unbalanced manner. Potassium application in wheat is either lacking or is applied in lesser than required amounts. As K plays a key role in stress tolerance and grain filling, no- or reduced-K application often results in poor grain filling and lower yields. The NE-based recommendations estimated the nutrient requirement in wheat under varying growing environments (tillage, residue management practices) in the validation trials quite accurately, and therefore, NE for wheat can act as an effective tool for the extension agents to provide field-specific nutrient recommendations to wheat farmers for improved yield and farm profit. India-008

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

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Project Cooperator: Vishal Bahadur Shahi

This study was initiated under the Cereal Systems Initiative for South Asia (CSISA) project to assess the nutrient supplying capacity of maize and wheat growing soils in the lower-gangetic Plains region of India. The information generated from the study was expected to help develop and improve the Nutrient Expert® (NE) decision support tool for disseminating site-specific nutrient management (SSNM) recommendations to small-holder maize and wheat farmers in the region. Nutrient Expert® for maize and wheat, developed in 2009-2011, were validated in six districts of Bihar. The trials comprised of three treatments including: NE-based fertilizer recommendation (NE), State Recommendation (SR), and Farmers’ Fertilizer Practice (FP).

Results from the evaluation trials (8) showed that highest average winter maize yield was in the NE treatment (7.8 t/ha) and over 9 t/ha yield was achieved in two locations. Estimated attainable yields for each location by NE were achieved in six out of eight locations using the NE recommendation. Corresponding yields in SR and FP were 7.3 and 7.5 t/ha. Average N+P₂O₅+K₂O use in NE, SR and FP were 277, 245 and 273 kg/ha, and the NE recommendations achieved 0.3 t/ha of extra average yield using the same quantity of fertilizers as used in farmers’ practice. The NE treatment grossed higher economic return of INR 3,000 over the FP at the current price of maize. Similar evaluation trials in wheat (11) showed that NE recommendations produced highest average yield of 5.4 t/ha in wheat across six districts of Bihar. Average yields in SR and FP were similar (5 t/ha). The total N+P₂O₅+K₂O used in NE, SR and FP were 270, 220 and 240 kg/ha, respectively. The NE recommendation used 18 kg/ha extra N and 55 kg/ha of extra K₂O and similar quantity of P₂O₅ over FP to achieve 0.4 t/ha of extra yield, resulting in gross profit of about INR 5,000 and gross return over fertilizer cost of about INR 3,189 at existing market prices of N, K₂O and wheat. The evaluation trials showed that NE effectively captured the differences in wheat growing environment across locations, and NE recommendations produced better yield and profits for the two major staple food crops of India. NE could be of interest to the extension community working with farmers. India-009

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

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This project was initiated to synthesize information on farmer typologies (farmer groups classified by economic and social status), based on access and use of nutrient inputs, and apply the Nutrient Expert® (NE) decision support tool to conduct analysis on the agronomic and economic benefits of nutrient management for various categories of farmers in Eastern India.

Results from a recently completed farmers’ survey revealed that farmers’ risk perception plays an important role in nutrient management of maize. It was evident that higher quantities of fertilizers are used in Khagaria (Bihar), Sahebgunj (Jharkhand), and Nabarangpur (Odisha) districts, where a relatively risk-free winter maize crop is grown under irrigated conditions and farmers have good access to input and output markets. Farmers that grow irrigated winter maize in areas with good market access usually have access to better knowledge and inputs, such as hybrid seeds, fertilizers, plant protection chemicals etc., through both government and private industry extension services, which allows them to achieve relatively higher yields (8 to 10 t/ha). Such farmers often go beyond applying only macronutrients (N, P and K), and include the required secondary and micronutrients in their fertilization schedule. Ranchi farmers, on the other hand, grow maize under rainfed conditions in depleted red and lateritic Alfisols, where productivity is typically low. As a consequence, farmer investment on fertilizer input is also low here due to risk perception.

The frequency of use of farm yard manure (FYM) and other fertilizers by farmers was also assessed from the survey data. Farmers in most districts use some amount of organic manure (OM) and highest number of farmers using OM were found in Ranchi (Jharkhand) and Bankura (West Bengal) districts. Survey results revealed that
farmers of these two districts are typically resource poor and have lesser access to inorganic fertilizer, both in terms of cost and distance to input market, which probably is the reason for their higher dependence on OM. As expected, urea is used by most farmers as they are aware of its necessity for crop growth as well as its relatively low cost. Farmer awareness about di-ammonium phosphate (DAP) is also quite high and more than 70% of the surveyed farmers use it. Muriate of Potash (MOP or KCI), on the other hand, is used by only about 50% percent of the surveyed farmers, which is probably associated with less awareness about the importance of K in maize production among the farmers.

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

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The current project was initiated to estimate the magnitude and variation in soil K supplying capacity in different soils of Bangladesh using a plant-based approach. The results are expected to help develop field-specific nutrient recommendation tools, like Nutrient Manager® (NM) for rice and Nutrient Expert® (NE) for maize, by International Rice Research Institute (IRRI) and IPNI, respectively, in collaboration with International Maize and Wheat Improvement Center (CIMMYT).

Eighteen soil samples were collected from Dinajpur, Rangpur, Bagura, Rajshahi, Nawabganj, Sirajganj, Tangail, Faridpur, Jhinaidah, Sathkhira, and Comilla districts representing diverse soil mineralogy and K fertility levels. Pot experiments with rice and maize were conducted with two treatments (zero-K and 100 mg K/kg soil) and four replications, while other limiting nutrients were applied in ample quantity to avoid any deficiency except that of K. In 2012, up to four rice crops and up to five maize crops were cultivated in pot experiments. Each rice crop was harvested at booting stage and number of tillers, plant height, straw and root dry weight were recorded. Maize was harvested at V10 stage and plant height as well as plant and root dry matter were recorded. The rice crop in K-applied pots accumulated higher dry matter (biomass) than K-omission pots in 7, 10, 13, and 14 of the 18 pots after the first, second, third, and fourth crop, respectively; and the dry matter (biomass) of maize in K-applied pots was significantly higher than in K-omission pots in 1, 12, 5, 11, and 11 out of 18 pots after the respective five crops.

For both rice and maize crops, the ranges of exchangeable K in studied soils were 0.061 to 0.410 cmol/kg, 0.062 to 0.410 cmol/kg, and 0.044 to 0.266 cmol/kg after the first, second and third crops, respectively, while the non-exchangeable K ranges were 0.062 to 0.410 cmol/kg, 0.038 to 0.359 cmol/kg, and 0.016 to 0.376 cmol/kg after the first, second and third crops. Farmer participatory trials have been established at 12 locations in Rajshahi, Rangpur and Comilla districts to confirm results from the pot study for soil K supplying capacity and also for evaluation and validation of NM and NE for boro rice and rabi maize, respectively.

**Bangladesh-06**
Asia and Africa Group
South Asia Program
East Region:
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**GIS-based Spatial Variability Mapping of Agricultural Holdings for Precision Nutrient Management in Red and Lateritic Soil Zones**

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This project tries to assess the correlations between soil parameters, yield and actual crop response to applied nutrients in red and lateritic soil zone of West Bengal, with the specific objective of assessing the efficiency of using GIS-based spatial variability maps of agricultural holdings. Plot-to-plot fertility assessment is the basic requisite for precision nutrient management, especially where spatial evaluation of soil fertility is important. However, large scale adoption of this practice is a problem in India due to small land holdings and inadequate soil testing facilities. GIS-based soil fertility mapping provides a good opportunity to assess the spatial variability in fertility status, thus, aiding in precision nutrient management. A total 45 soil samples were collected from a 76 ha area of Meherpur village in Birbhum district, West Bengal and analyzed for relevant soil properties. Yield data for monsoon rice and winter wheat crops were also collected from these plots. These data were used for developing GIS maps for the study area, which indicated eight management zones. On-farm trials, covering all these management zones, were carried out using the following seven treatments: farmers’ practice, targeted yield approach, management zone approach, and soil test-based NPK, NP, NK, and PK fertilization strategies.

Rice grain yield was highest (ranging between 3.98 and 4.41 with a mean of 4.22 t/ha) in the targeted yield approach treatment, though management zone approach and soil test-based NPK fertilization treatments also had similar yield averages (i.e., 3.90 and 3.96 t/ha, respectively). Grain yield was mostly affected by the omission of N followed by omissions of P and K in fertilization schedules. A similar study with wheat as test crop was carried out using the following seven treatments: farmers’ practice, targeted yield approach, management zone approach, and soil test-based NPK, NP, NK, and PK fertilization strategies.

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

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Project Cooperator: Sushanta Kumar Pattanayak

This study compared a site-specific nutrient management (SSNM) strategy with state recommendation (SR) (i.e., 20 kg N, 40 kg P₂O₅, 40 kg K₂O, 45 kg S, 2.5 kg Zn, 1.0 kg B, and 500 kg Ca/ha), farmer practice (FP) (i.e., 23 kg N, 76 kg P₂O₅, 56 kg K₂O, and 11 kg S/ha), and seven nutrient omission plots (i.e. - N, - P, - K, - Ca, - S, - Zn, and - B). The locations chosen for the study were an experimental station at Bhubaneswar and a farmer field in village Deoda of Jajpur district. Soil at the experimental station was acidic (pH 5.4), sandy loam in texture, low in organic C (OC) (4.7 g/kg), high in available P (67 kg/ha), and low in available K (113 kg/ha), Zn (0.5 ppm), S (5 kg/ha), and B (0.3 kg/ha). Soil in the farmers’ field was acidic (pH 4.9), low in OC (3.1 g/kg), medium in available P (30 kg/ha), and low in available K (71 kg/ha), Zn (0.15 ppm), S (6 kg/ha), and B (0.31 kg/ha). The SSNM recommendation, calculated based on soil test results for both the study sites,
was 30 kg N, 40 kg P, 60 kg K, 56 kg S, 3.3 kg Zn, 1.5 kg B, and 1,300 kg Ca/ha. Groundnut crop was grown under rainfed conditions at both the locations.

The SSNM treatment recorded significantly higher pod yields (1.5 and 1.4 t/ha) over the SR (1.0 t/ha at both locations) and FP (1.1 and 1.1 t/ha) treatments at both experimental locations, respectively. However, N omission, among all the treatments, recorded maximum pod yields of 1.7 and 1.9 t/ha at both locations, and the yield decrease in SSNM over N omission was 9 and 15%, respectively. This suggested the need to change N management strategy in SSNM. Omissions of P, K, S, B, Zn, and Ca from the SSNM recommendation resulted in 18, 7, 21, 18, 6, and 33% yield reduction, respectively, at the experimental station in Bhubaneswar, while the corresponding figures on the farmer’s field were 25, 18, 24, 29, 9, and 34%, respectively. Thus, maximum yield reduction on the farmer’s field was observed with omission of Ca followed by omissions of S, P, B, K, and Zn. However, at the experimental station, yield reduction followed the order Ca > B > P > S > K > Zn. The results were disseminated to farmers through training programs conducted in the area, and were used to improve the productivity and profitability of groundnut in the region. This project was completed in 2012. India-015

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

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Project Cooperators: M.C. Meena, Anand Swarup, M.L. Jat, R. K. Gupta, and Animesh Singh

On-farm trials in a maize-wheat cropping system were conducted in 18 cultivators’ fields in Bihar and West Bengal under the Cereal Systems Initiative for South Asia (CSISA) project. The objective was to study the effect of nutrient omissions on crop yield and nutrient uptake under different tillage systems. Emphasis was given to establishing the experiments within a relatively small geographical area with a wide variation in soil texture, landscape, and other critical factors affecting the indigenous supply of N, P and K. The nutrient omission trials were set up in Jamui, Purnea, Samastipur, Begusarai and Vaishali districts of Bihar and Nadia and Uttar Dinajpur districts in West Bengal. The experiment had eight treatments including: ample NPK, ample PK (-N), ample NK (-P), ample NP (-K) under both zero- (ZT) and conventional (CT) tillage practices.

Average yields of maize in the ample NPK treatment were 5.1 and 4.7 t/ha under ZT and CT, respectively. Nitrogen omission treatment yields differed between ZT (3.3 t/ha) and CT (3.8 t/ha) practices. The higher reduction of yields in the N omission treatment in zero till was probably related to higher immobilization of N in these plots as 30% anchored rice residues were left undisturbed while planting the crop. Average yields in P and K omission treatments were quite similar for each tillage practice (4.5 t/ha for ZT and 4.2 t/ha for CT). Post-harvest plant analysis showed that the average N, P, and K concentrations in the maize grain were 1.6, 0.3, and 0.4%, respectively, while the average straw nutrient contents across all sites were 1, 0.1, and 1.2%, respectively. Average N, P and K uptake values in the ample NPK treatment were 153, 21 and 102 kg/ha, respectively, under ZT, and 144, 22 and 74 kg/ha, respectively, under CT practices. Omission of N significantly reduced uptake of nutrients in both tillage practices. The reduction of K uptake due to N omission was more prominent in ZT (41 kg/ha) than in CT (12.5 kg/ha) plots, and may be related to higher reduction of yield (about 0.5 t/ha) in the ZT N omission plots as compared to in the CT plots. The results were used in the development and improvement of Nutrient Expert® for Maize for South Asia for dissemination of improved nutrient management practices to smallholder maize farmers. India-017

v
Improving Nutrient Use Efficiency and Profitability in Rainfed Production Systems

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A study was conducted to determine the effect of balanced nutrient use and conservation tillage on productivity, profitability and nutrient use efficiency in a maize-horsegram cropping sequence. Data revealed highest maize grain (4.7 t/ha) and stover (7.9 t/ha) yields with the optimum nutrient treatment, followed by yields under B omission (4.4 and 6.9 t/ha), S omission (4.2 and 7.2 t/ha), while the lowest productivity was observed in the control plot (1.3 and 3.5 t/ha). No significant difference in grain and stover yield of maize was observed among the tillage systems. In horsegram, yields varied significantly from 264 to 443 kg/ha in the conventional tillage (CNT) system with highest yield recorded in S omission plot (443 kg/ha) followed by optimum treatment (418 kg/ha). In the conservation tillage (CST) system, yields were in the range of 464 to 643 kg/ha, with optimum treatment showing a lower yield (578 kg/ha) as compared to yields obtained with omission of S (643 kg/ha), P (635 kg/ha), N (618 kg/ha), and Zn (596 kg/ha). The lowest yield was again recorded in the absolute control treatment (464 kg/ha). The higher yield in CST could be attributed to high nutrient uptake in this system. In CST, N, P and K contents in horsegram seed were in the range of 1.6 to 2.6, 0.2 to 0.7, and 0.8 to 1.2% across different nutrient treatments, whereas, the corresponding values in CNT were 1.5 to 2.5, 0.2 to 0.6, and 0.7 to 1.0%, respectively. Initial soil reaction (pH) of 5.1 increased to 5.6 after the harvest of horsegram in both the tillage systems, whereas the initial soil organic carbon of 0.34% increased slightly to 0.43% in the CNT and to 0.41% in the CST treatment. Optimum nutrient treatment had the highest residue cover (45%) followed by omission of Zn (42%), K and S (41%), and B (40%) with the least residue cover noticed in absolute control plot (31%). Also, N, P, K, S, and Zn efficiencies were increased to 11, 16, 14, 13, and 21% due to integrated effect of balanced nutrient use coupled with conservation tillage. Higher net returns (INR 26,571/ha) and benefit:cost ratio (2:1) were noticed in optimum nutrient treatment under CST as compared to INR 22,529/ha and 1.9, respectively, under CNT. Practicing CST with better nutrient management improved nutrient use efficiency and increased productivity and profitability of farmers in this semiarid tropical area. Funding for this project was completed in 2012, and final results are expected by mid-2013. India-014

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

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In this study, Nutrient Expert® (NE) for hybrid maize was used for site-specific nutrient management in Tamil Nadu. The survey on nutrient use indicated that Tamil Nadu has a uniform state recommendation (SR) of 135, 63 and 50 kg/ha N, P2O5 and K2O for all maize growing areas in the state, whereas N, P2O5 and K2O use in farmers’ practice (FP) varied from 147 to 332, 48 to 79 and 48 to 352 kg/ha, with averages of 225, 67 and 201 kg/ha, respectively. The corresponding N, P2O5, and K2O use with NE software varied from 130 to 210, 27 to 47, and 29 to 55 kg/ha, with an average of 182, 42 and 43 kg/ha, respectively. Thus, the NE-based fertilizer recommendations reduced N, P2O5, and K2O use by 43 (19%), 25 (37%) and 158 (78%) kg/ha, respectively, over FP.
During the kharif (monsoon) season, NE increased maize yield by 0.62 t/ha and economic benefit (i.e., gross return above fertilizer costs or GRF) by INR 10,172/ha, with a significant reduction in fertilizer cost of INR 4,256/ha over FP. The corresponding figures over SR were 1.15 t/ha and INR 11,242/ha with a minimal reduction in fertilizer cost (INR -282/ha). During the rabi (winter) season, grain yield with NE was significantly increased by 14 and 4% over FP and SR, respectively. NE reduced fertilizer cost by INR 4,849 and 2,414/ha over FP and SR, respectively, thereby increasing GRF by INR 10,993 and 504/ha, respectively. Thus, the improvement in maize yield using NE fertilizer recommendation could primarily be attributed to the balanced application of nutrients. The NE decision support tool recommended the application of secondary and micronutrients (especially S, Zn, Mn, Fe, and B) at 8 of the 12 locations in the study area.

In a related study, at 6 of the 12 locations in kharif and rabi seasons, maize crop did not receive preparatory cultivation and were grown under no-till conditions (CA). Nutrient recommendations from NE were tested against FP and SR under conventional (CT) and CA during both the growing seasons. Across seasons, NE recorded higher grain yield in CA (9.3 t/ha) as compared to CT (8.4 t/ha), and the magnitude of yield increase in CA over CT was higher in kharif (20%) than in the rabi (3%) season. Thus, NE offered solutions for providing field-specific fertilizer recommendations, and improved maize yield and economics in Tamil Nadu. This project was completed in 2012. India-018

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

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This study was initiated to intensify the pearl millet-wheat cropping system through balanced application of nutrients for a targeted system yield as well as by inclusion of a legume crop in the system. Pearl millet-wheat is a common cropping system in dryland areas of India. However, system yields are often low due to inadequate and unbalanced nutrient application to the crops. In the present study, eight nutrient application treatments (T1: Farmers’ Practice; T2: 3.75 and 3 t/ha target yield of pearl millet and wheat, respectively; T3: 4 and 4 t/ha target yield of pearl millet and wheat, respectively; T4: 4.5 and 5 t/ha target yield of pearl millet and wheat, respectively; T5: 5 and 6 t/ha target yield of pearl millet and wheat, respectively; T6: N Omission from T5; T7: P Omission from T5; and T8: K Omission from T5) were used in five farmers fields with three replications in Agra district of Uttar Pradesh. Green gram will be planted after winter wheat on residual soil fertility.

Preliminary results at the end of the first season of pearl millet crop in 2012 showed that the average yield in farmers’ practice was 3.2 t/ha. Treatments T2, T3, T4, and T5 produced average yields of 4.1, 5, 5.6, and 6 t/ha, respectively. Nutrient applications rates for the treatments (T2 to T6), based on uptake requirement of targeted pearl millet yield and nutrient use efficiency, achieved the pre-determined target yields. Omission of N, P and K from T5 caused pearl millet yield loss of 3.2 (T6), 2.5 (T7), and 1.1 (T8) t/ha respectively as compared to T5. The average agronomic efficiencies of N, P$_2$O$_5$ and K$_2$O across sites were 21, 26 and 16 kg grain/kg of nutrient.

The current average yield of pearl millet in India is about 0.7 t/ha, with Uttar Pradesh having the highest average productivity of 1.6 t/ha. Results from the present study showed that a yield of 6.0 t/ha of pearl millet could be achieved with balanced and adequate application of nutrients. Winter wheat has now been planted after pearl millet. The appropriate nutrient rates for different targeted yields of wheat have been estimated using Nutrient Expert® (NE) for Wheat, a nutrient decision support tool developed by IPNI to facilitate the application of site-specific nutrient management principles and 4R Nutrient Stewardship in on-farm situations. India-019
Asia and Africa Group
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Best Management Practice for Crop Nutrition of Mature Oil Palm

Project Leader: Christopher R. Donough, Consultant Agronomist and Oil Palm Breeder, IPNI Southeast Asia Program, Sabah, Malaysia. Email: crdonough@gmail.com

This project aims to implement, test and refine the Best Management Practice (BMP) concept, specifically the fertilization and nutrition approaches, for yield intensification to increase productivity, profitability and sustainability of palm oil production in mature oil palm plantations. The ultimate goal will be to standardize the use of BMPs for nutrient management within the industry. The project will be implemented between 2011 and 2015 in one plantation in Kalimantan, Indonesia, and will deploy a two-pronged approach including commercial block scale implementation of fertilizer management strategies, complemented by block embedded omission plots. Commercial block scale testing of application practices will contribute to more efficient fertilizer application management by the plantation and will contribute information for general fine tuning of nutrient BMPs. We will use 12 commercial blocks. Blocks are being distributed in sets of four within two estates of the plantation. Each set of four blocks contains two BMP blocks where fertilizers are applied in four splits –one with a high fertilizer rate (BMP 1), the other with a low fertilizer rate (BMP 2), and two reference blocks where all IPNI SEAP BMPs are deployed but fertilizer application follows current standard practice –one with high fertilizer rate (BMP 3), the other with low fertilizer rate (BMP 4). Fertilizers are applied as blended mixes including N-P-K-Mg-B.

While it is too early to arrive at definite conclusions, the trends in the last quarters are very encouraging. BMP 1 and 2, which are IPNI SEAP nutrition procedures, are performing well after the residual effects from previous years of management have likely disappeared in the commercial blocks of the trial. SEA-05

Malaysia

Plantation Intelligence to Upscale Best Management Practice in Oil Palm

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This research project was started to develop an approach and performance indicators that facilitate up-scaling of the Best Management Practice (BMP) concept from commercial block scale to the whole plantation and to plantation groups. The ultimate goal will be to standardize the use of BMPs for yield intensification management within the industry. The project will be implemented between 2012 and 2015 in several plantations in Indonesia and Malaysia. Plantation data on management and specifically on fertilizer use and responses will be sought. Establishing an effective data management system is critical or the database soon becomes unmanageable. We will manage routinely collected plantation production and management information. Analysis will include assessment of spatial variations in management practices, including fertilizer use, yield response to management and to N, P or K and return to investment on fertilizer. Interpretation will start with a basic set of insights and expand to more specific detail and leading to site specific performance indicators. Performance indicators are linked to IPNI SEAP Best Management Practices, and can be generated on a routine bases using data routinely collected by plantations, and thereby are expected to facilitate systematic deployment of BMPs in plantation management. The general purpose
of analysis and performance is to support change towards a more profitable and intensive use of BMPs and fertilizer in oil palm plantations. Key agents of change are plantation managers.

The SEAP Project Team was put together in early 2012, with consultancy agreements signed with advisors on oil palm agronomy, agricultural management/plant physiology, and statistics. Memorandums of Agreement (MOA) were developed and signed with industry sponsors and plantation partners, with a few more plantation groups expected to sign in 2013. Statistical analysis of plantation data from the previous BMP project was completed for one plantation site. A roadmap for data analyses and publication of research results from a previous oil palm BMP project was developed in late 2012. A data management system review was completed for one site in 2012. Data availability for other plantations was identified in November. Through this process, estates are enabled to identify better ways to implement BMPs for yield intensification, on full plantation scale, and across groups of plantations. \textit{SEA–06}

**Nutrient Expert® Development and Assessment**

Project Leader: Thomas Oberthur, IPNI Southeast Asia Director, Penang, Malaysia. Email: toberthur@ipni.net

This study was initiated to evaluate the Nutrient Expert® (NE) for Hybrid Maize (NEHM) in farmers’ fields in Indonesia and the Philippines, and to develop, test and refine new versions of NE for maize in China, India, and Africa and NE for wheat in China and India. At the end of 2012, NEHM recommendations have been field tested against existing fertilizer management practices in 534 farmers’ fields or locations. In 129 fields in Indonesia and Philippines, NE increased average maize yield by 1.1 t/ha and profit by US$280/ha/crop with moderate increases in fertilizer P (11 kg P$_2$O$_5$/ha) and K (18 kg K$_2$O/ha) over farmer’s fertilizer practice (FFP). In 82 field trials in India, NE again increased average maize yield by 1.1 t/ha and profit by US$259/ha/crop with lower fertilizer applications (37 kg N, 62 kg P$_2$O$_5$, and 39 kg K$_2$O lower than the fertilizer rates applied under FFP). In 323 field experiments in China, 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 US$94/ha over FFP and US$145/ha over OPT in China.

For NE with Wheat, field validation trials were conducted at 218 locations in China and at 186 locations in India. In India, NE increased wheat yield by 1.2 t/ha and profit by US$289/ha with increased fertilizer K application (+67 kg K$_2$O/ha over the FFP), while the corresponding figures over the state recommendation were +0.44 t/ha and +US$96/ha, respectively. In China, wheat yields with NE were comparable with yields under FFP, but profit under NE was higher than under FFP by US$132/ha/crop. Compared with the OPT, NE wheat showed comparable yields and profits. However, fertilizer N application rates were significantly lower with NE wheat than with FFP (by 113 kg N/ha) and OPT (by 73 kg/ha). NE wheat also reduced fertilizer P rates by 36 kg P$_2$O$_5$/ha and 30 kg P$_2$O$_5$/ha over FFP and OPT, respectively. Fertilizer K application rate, on the other hand, was higher with NE wheat by 19 kg K$_2$O/ha over FFP but was comparable with 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. \textit{IPNI–52}

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

Project Leader: Christopher R. Donough, Consultant Agronomist and Oil Palm Breeder, IPNI Southeast Asia Program, Sabah, Malaysia. Email: crdonough@gmail.com

This research project was started to implement, test, and refine the Best Management Practice (BMP) concept for yield intensification in order to increase productivity, profitability, and sustainability of palm oil production. BMPs were implemented in five full-size management blocks in six collaborating plantations in Sumatra (North, South) and Kalimantan (West, Central, and East) in existing mature plantings by IPNI and its plantation partners. Results from BMP implementation were compared with those achieved under standard plantation practices in five reference blocks.

Yield advantages with BMPs were significant at all project sites except one, where current yield is probably close to the site yield potential. Bunch yield with BMPs averaged 3.4 t/ha (+15%) higher due to +9% more and +6% heavier bunches. Crop recovery BMPs, including a short harvest interval, are important for high bunch yield in the short term, while other agronomic BMPs related to canopy and nutrient management are important for sustained or enhanced yield in the longer term. Cost per unit area was higher with implementation of BMPs, but higher yields with BMPs improved profitability at the farm gate. In the final year of the project (2013), oil and kernel yields are being estimated. Early indications are that oil extraction rate (OER) with BMPs are slightly lower as more frequent harvests result in overall lower number of detached fruits per bunch in the harvested crop. This decrease in OER is, however, not enough to offset the higher bunch yield with BMP harvesting, so oil yield with BMPs is still projected to be higher.
Presentations from this research data were made at two key industry conferences, one in Malaysia and one in Colombia. Analyses will be continued in 2013 with the University of Goettingen in Germany, University of Western Australia, at a Malaysian university, and with plantation partner companies. At least two peer reviewed publications and a master’s thesis will be generated from this project. *SE403*

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

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Project Cooperators: IJM Plantations, Wilmar International, and Canpotex International

This research project was planned to implement, test, and refine the Best Management Practice (BMP) concept for yield intensification of oil palm crop. The objective was to increase productivity, profitability and sustainability of palm oil production in all growth stages (including nursery, immature, and mature development phases) of the crop. BMPs were implemented in five full-size management blocks in two collaborating plantations in Sumatra (Indonesia) and Sabah (Malaysia) in re-plantings of existing plantations by IPNI and its plantation partners. Results from the BMP implementation will be compared with those achieved under standard plantation practices in five reference blocks.

In late 2011, BMP implementation at the Sabah project site had produced about 70% of the seedlings for transplanting into the main nursery. The remaining 30% of seedlings were produced in the pre-nursery during 2012. In parallel, land preparation was also started at the site in late 2011 for three BMP blocks and three reference blocks. Transplanting of seedlings from the main nursery into the field blocks started in the second half of 2012. Currently, about 200 ha have been planted, and the remaining 150 ha will be planted in 2013. The first dataset was compiled from monitoring of the nursery phase. Work on the second site in Sumatra started in 2012. Pre-nursery and main nursery for clones and DxP (dura and psifera) crosses have been set up. Nursery operations are running according to the plan. In parallel, field preparation has started in the selected blocks. Transplanting into the field at this site will start in 2013.

Through this process, estates are enabled to identify better ways to implement BMPs for yield intensification, and decisions on larger investments in BMPs are based on practical, commercial-scale evidence. This project is unique in its design as it is including all growth stages of the oil palm and proposes monitoring over a period of 8 years (2018). *SE404*
Asia and Africa Group  
Sub-Saharan Africa Program  
Dr. Shamie Zingore, Director

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

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In smallholder farming areas in sub-Saharan Africa, site-specific nutrient management (SSNM) recommendations are important to enhance efficient use of scarce nutrient resources, taking into account considerable variability in soil fertility exists within and between farms. Over the past two years, multi-locational on-farm nutrient omission trials have been conducted in pilot sites in Zimbabwe and Kenya to establish maize yield response to application of macronutrients (NPK), selected micronutrients (Zn, B), manure applications, and liming under variable soil fertility conditions. The experiments also sought to establish nutrient-determined maize yield gaps in major maize growing areas in Kenya and Zimbabwe and assess balanced fertilizer management strategies to optimize maize production under rainfed conditions.

In Zimbabwe, maize productivity was significantly influenced by nutrient management across sites. Maize yields across sites ranged from 0.3 to 0.8 t/ha for the control and 2.1 to 5.0 t/ha for the NPKS treatment. Using NPKS-mean yield of 3.6 t/ha as the attainable yield, the corresponding N, P and K response factors were 0.6, 0.5 and 0.1, respectively, indicating poor response to K and highest response to N application. Nitrogen and P remain the most limiting nutrients, and complementary organic nutrient management approaches should be employed to increase soil C and sustain soil productivity. Variable N application strategies must be an integral component of farmer management if losses related to fertilizer investment are to be minimized under the risky rainfed production system. The results showed the importance of nutrient management to enhance water use efficiency, with rain water productivity increasing from 0.38 to 1.13 kg grain/mm in the control treatments to 3.15 to 7.66 kg grain/mm in the NPKS treatment.

In Kenya, attainable yields across sites ranged from 4 to 7 t/ha under sub-humid conditions in central Kenya and 1 to 3 t/ha under semi arid conditions in eastern Kenya. A strong interaction between N and P was observed; with average N yield response of 2.5 t/ha and average P yield response of 2.2 t/ha. Strong responses to manure and lime applications were also observed in acidic soils that had low soil organic C levels. A significant maize yield response to secondary and micronutrients was observed on sandy soils, which covered 30% of the cropping area in the high potential site.

Results showed high variability in nutrient responses within each of the study sites, and highlight the importance of developing site-specific balanced nutrient management strategies to support sustainable maize production intensification in sub-Saharan Africa. Zimbabwe-01

Nutrient Management for Grain Legume Crop Production Intensification in Africa

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Grain legumes are an important source of dietary protein and income for farmers in most parts of sub-Saharan Africa. In the past, grain legumes have been grown mainly as subsistence food crops, but there has been a rapid increase in their commercial importance over the past five years, mainly driven by increased demand from the agro-processing industry. The ability to fix atmospheric N makes grain legumes an excellent component within the farming systems dominated by maize because they provide supplementary N. Despite the major opportunities that grain legume crops provide to improve human nutrition, household income and soil N budgets in Africa, their contribution has been curtailed by several factors including low priority given to proper nutrient management.

Multi-location nutrient omission trials were initiated in Western Kenya and Central Uganda to assess the impact of P, K, S, and micronutrients on the productivity of soybean. Additional manure and lime treatments were added to the full fertilizer treatments to evaluate the effects of integrated nutrient management on
soybean productivity. In Uganda, the mean soybean grain yield was 0.85 t/ha in control plots, which increased significantly to 1.8 t/ha with the application of inoculum and NPK basal fertilizers. Yields were further significantly increased to 2.2 t/ha with additional application of S and micronutrients. Maximum yield of 3.8 t/ha was obtained when manure was added to the full fertilizer treatment. In Western Kenya, yields in control plots ranged substantially from 0.1 t/ha in degraded soils to 2.4 t/ha in fertile soils that had received large additions of manure in the past. In degraded soils, inoculation had no effects on soybean yields, and yields were only increased to a maximum of 0.5 t/ha in the full fertilizer treatment. However, soybean yield increased substantially to 1.3 t/ha when lime and manure were applied to the full fertilizer treatments. On fertile soils, maximum yields of 2.5 to 3.6 t/ha were achieved with full fertilizer treatments. These results highlight good potential for soybean production intensification with balanced nutrient management, and strong responses to nutrient application across all sites in Africa. In degraded soils, application of manure, lime and other organic resources in addition to fertilizers is necessary to significantly increase soybean yields.

Maize Intensification in Mozambique (MIM) - An Industry Response to the Abuja Declaration on Fertilizer for an African Green Revolution

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For four years, IPNI has been working in Mozambique with IFDC (an International Center for Soil Fertility and Agricultural Development) to help smallholder farmers improve their livelihoods through intensifying maize production. Our objective is to demonstrate the use and value of fertilizers and other ‘best agricultural practices’ (i.e., improved seed, crop protection and tillage system) to help Mozambican farmers move from subsistence to commercial farming. This project compliments regional IFDC activities linking farmers with agri-input suppliers and traders, NGOs, farmers’ organizations, extension services, and other partners, thus strengthening the value chain of maize production in the country.

Demonstrations evaluating agronomic and economic benefits of hybrid seed, NPKS fertilizer, fertilizer rates, and conservation agriculture have been implemented on high potential and productive farming areas in Manica and Sofala Provinces in Central Mozambique, and Zambezia Province in Northern Mozambique. Yields were higher for hybrid maize which yielded 1.2 t/ha without fertilizer compared with 0.7 t/ha for farmer-saved seed. The application of NPKS fertilizer and hybrid seed tripled maize yields and increased income by US$400/ha from that of the normal practice of farmers planting saved-seed and not using fertilizer. Conservation tillage and use of herbicides to control weeds reduced costs of production by 30% compared to conventional tillage. However, yields under conservation tillage were on average 20% lower than those under conventional tillage due to poor weed control and this resulted in lower net income for conservation tillage.

The national average production for maize in Mozambique is less 1 t/ha, and fertilizer use in maize production less than 5 kg/ha. The results from the demonstrations showed that the yields can be increased to 3 t/ha with moderate rates (50-100 kg/ha) of NPKS fertilizer and hybrid seed, indicating good prospects for maize production intensification. The International Fertilizer Industry Association (IFA) and the International Potash Institute (IPI) are also providing financial support for this project. IPNI-11 ✤
Improvement of Recommendations on Potash Fertilizer use and Adjustment of Currently used Soil Potassium Test Interpretation Classes in Intensive Cropping Systems

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Project Cooperators: State centers and stations for agrochemical service (SCAS) of the Ministry of Agriculture of the Russian Federation

During the last 15 years in Russia, both nutrient use (rates) and ratios have changed with a larger decline in the share of P and K fertilizers relative to N fertilizer. The adjustment of nutrient rates considering soil type, fertility status and crop management factors has, therefore, gained high priority for research experiments in current cropping systems. With long-term removal of K exceeding K inputs, negative K budgets are being observed in various agricultural zones of the country. Nevertheless, Russian agriculture has paid little attention to the optimization of K status in arable soils. Such an attitude towards K regime regulation in agricultural systems is largely due to the imperfect assessment of soil K fertility. Routine soil test K interpretation classes used in practical work to develop fertilizer K recommendations give some evaluation of soil K status. Unlike in some other countries, the current soil test K interpretation classes are not based on soil texture.

This new research project will focus on the optimization of K fertilizer rates in current intensive cropping systems that involve crops that respond well to K (e.g., sugar beet, maize, rape, and soybean) and on checking the measurement potential of routine soil test methods depending on the regional soil properties and adjusting the current interpretation classes based on results from short-term field experiments executed on large industrial farms located in Central Russia (Lipetskaya, Voronezhskaya, Belgorodskaya oblast) and South of Russia (Rostovskaya oblast). First results from this project are expected in December 2013. Russia-01

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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Project Cooperators: Khristenko Anatoly, Nosko Boris, Gladkii Ulia, and Istomina Evgenia

The project aims to provide an accurate assessment of K status of arable soils, determine the demand for K fertilizers, establish the efficiency of K fertilizers in the soils of the main soil-climatic zones, and work out fertilizer recommendations for maize, wheat, and sugar beet grown on Chernozems. In 2012, the agronomy efficiencies of K fertilizers for winter wheat, grain maize, and sugar beet by climatic zone and soil type have been estimated from the database containing information on crop response to K fertilizer applications. This database has been compiled through field trials conducted in Ukraine by State Agrochemical Service stations and geographic data network experiments during the last 40 years. The
major factors determined to affect the efficiency of K fertilizers in different climatic zones of Ukraine are the level of precipitation and temperature during growing season, as well as soil K content. The mathematical equations showing relations between soil K levels and agronomic efficiency of K fertilizer, as well as between hydrothermal coefficient (the ratio of the sum of precipitation during the year to the sum of active temperature during the grown season) and agronomic efficiency of K fertilizer for winter wheat, grain maize, and sugar beet have been not yet been determined.

In 2011, a field experiment to determine K fertilizer requirements of a forage maize-wheat-sugar beet crop rotation commonly found in the steep-forest zone of Ukraine, was established. The efficiency of four different K fertilizer rates (varying between 30 and 120 kg of K₂O/ha) with two combinations of NP was studied. Results obtained showed a high efficiency and economic expediency of applying K fertilizers to forage maize. The optimization of N and P supply contributes to the increase in the return on K fertilizers. The highest economic effect was obtained when 90 kg N, 90 kg P and 40 kg K/ha were used. The local application of K fertilizers (before pre-plant cultivation) significantly increased the yield of maize green mass by 14 to 18%. Due to adverse weather conditions 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 (varying from 1.7 to 2.4 t/ha). During summer drought, K fertilizers contributed up to 10% of yield increase in plots with optimized NP. Ukraine-01 ❖
**Eastern Europe/Central Asia and Middle East Group**

**Russia Program**

**South & Eastern Region:**

Dr. Vladimir Nosov, Director

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**Improvement of Winter Wheat Mineral Nutrition on Calcareous Common Chernozems**

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A K omission plot demonstration trial in winter wheat was initiated in fall 2012. It is a one-season demonstration experiment conducted on farmer’s field (Egorlyk District, Rostov Oblast, Southern Russia) in one replication to show the effects of K fertilization to growers in the region, who normally skip K fertilization. Two fertilizer treatments were studied: N40P26 (farmer practice) and N40P26K40. Plot size is about 19.5 ha. Winter wheat was grown after sunflower. The variability of soil fertility parameters is also being studied in this project, including nitrate N, Olsen P, exchangeable K, P, and K extracted using routine extraction with (NH₄)₂CO₃ solution. Results from this trial (initial soil fertility parameters and winter wheat grain yield) will be due in the end of summer 2013. *IPNI-32*
Egypt

**Balanced Fertilization of Major Crops in Egypt**

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The objectives of this project were to determine the effect of balanced fertilization on the yield of major crops of the common cropping systems in Egypt and promote and extend to farmers the most efficient fertilization and irrigation techniques. For this, field experiments were conducted at three locations with the following seven treatments including no fertilizer (control), NPK according to the farmer’s practice (FP), NP at the recommended rates by Egyptian Ministry of Agriculture (MOA), NK as recommended by MOA, NPK as recommended by MOA, NPK based on soil testing, and NPK based on soil testing + micronutrients.

For all crops and at all three locations, balanced fertilization helped maximize yield and yield components. At the El-Behira site, wheat grain yield was the highest (7.2 t/ha) for the NPK+micronutrients treatment, whereas control and FP treatments resulted in the lowest yields (2.5 and 4.6 t/ha, respectively). Similar trend was observed for the maize crop, where the highest yield (8.5 t/ha) was obtained with the NPK+micronutrients, while lowest yields were observed in control (3 t/ha) and FP (5.6 t/ha) treatments.

Results at the El-Monofia site were similar with highest (7.9 t/ha) wheat grain yield observed in the NPK+micronutrients treatment, while control and FP treatments resulted in lowest yields of 4.1 and 4.8 t/ha, respectively. Again, the maize crop recorded highest yield (12.8 t/ha) with NPK+micronutrients, while control and FP treatments resulted in lowest yields of 10.3 and 11.6 t/ha, respectively. Due to some administrative reasons, no experiments could be conducted at the third (Ismailia) site. *Egypt-01*

Syria

**Balanced Fertilization of Major Crops in Syria**

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In Syria, application of mineral fertilizers is highly skewed towards N, which has led to the depletion of other nutrients like K, P and micronutrients in many soils. The objectives of this project were to determine the effect of balanced fertilization on the yield of major crops of the common cropping systems in Syria and promote and extend to farmers the most efficient fertilization and irrigation techniques. For this, both on-farm and on-station experiments were conducted at four different locations in Syria with different permutations and combinations of macronutrients (NP, NK, PK, NPK, etc.) and fertilizer rates varying from 75 to 150%.

Results obtained from the wheat experiment conducted at Dera’a Azrou site indicated that the highest wheat grain yield (2.56 t/ha) was obtained with balanced fertilization (i.e., when all three macronutrients were applied) at 72, 38 and 35 kg/ha of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O, respectively. In contrast, the lowest grain yield (1.8 t/ha) was obtained when no fertilizers were added, while no significant differences were observed among other treatments. The results obtained from the citrus experiment conducted at another site in Northern Syria (Jablah) to study the interactions between N and K indicated that the highest yield of 14.8 t/ha was obtained.
with the application of 1.9 kg potassium sulfate applied in one dose per tree in combination with a three-way split application of N at a rate of 0.5 kg ammonium nitrate per tree. The lowest yield (8.4 t/ha) was obtained when no fertilizers were added. Due to the current political situation in Syria, we could not conduct experiments at two sites (Central Syria [Al-Ghab Hamah] and Northern Syria [Al-Furat Basin-Dair Al-Zoo].

Syria-01

Turkey

Balanced Fertilization of Major Crops in Turkey

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The objectives of this project were to evaluate the effect of K fertilizer application on yield and production of different crops grown under different soil and climatic conditions in Turkey and transfer the knowledge and technology of fertilizer application to growers, fertilizer company dealers, and decision makers in Turkey. Field experiments were conducted at three locations to investigate the effects of different rates of K application from two sources (KCl and K\(_2\)SO\(_4\)).

Results from the maize experiment in Adana indicated that the highest maize grain yield (12.8 t/ha) was obtained with the application of 60 kg K\(_2\)O/ha as KCl, while a similar application of K\(_2\)SO\(_4\) produced maize grain yield of 11 t/ha. The lowest yield (8.3 t/ha) was obtained when no K was applied. Results from the watermelon field experiment at the same site indicated that the highest watermelon fruit yield of 55 t/ha was obtained with the application of 120 kg K\(_2\)O/ha as KCl, while a similar application of K\(_2\)SO\(_4\) produced 41.6 t/ha of watermelon fruit. The lowest watermelon yield (33.8 t/ha) was again obtained when no K was applied. Results from the cotton experiment at Cotton Research Station, Nazilli Kivilicim, Aydin, indicated no significant differences among all treatments including the control on any of the cotton yield variables (seed yield, fiber yield, fiber length, fiber strength, fiber fineness, fiber maturity). Turkey-01