INTERNATIONAL PLANT NUTRITION INSTITUTE

Research Projects

GROWING THE RIGHT WAY

2010

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Interpretive Summaries

One of the strategic goals of the International Plant Nutrition Institute (IPNI) is to "facilitate research on environmentally responsible 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. The Foundation for Agronomic Research (FAR), our sister organization, assists us in providing financial support for these projects.

This past year we provided financial and in-kind support to over 100 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 2010

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

Special Projects

Maize Intensification in Mozambique

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For 2 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 and crop protection) 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 have been implemented on productive farming areas in Manica and Sofala Provinces in Central Mozambique and Nampula and Zambezia Provinces in Northern Mozamique. Balanced fertilization with N, P, K, and S and hybrid seed have increased yields and income several-fold from that of the normal practice of farmers planting saved seed and not using fertilizer. The national average production for maize is about 1 t/ha. The International Fertilizer Industry Association (IFA) and the International Potash Institute (IPI) are also providing financial support for this project. *IPNI-11*

Best Management Practices for Sustainable Crop Nutrition in Bulgaria

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Project Cooperators: Toni Tomov, Damian Mihalev, Lilia 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. The project involves five Bulgarian organizations: The University of Forestry, Agricultural University, Nikola Poushkarov Institute of Soil Science, Executive Soil Resources Agency (Ministry of Agriculture), and the National Plant Protection Service (Ministry of Agriculture). 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, existing nutrient uptake and removal information for target crops, and identification of information gaps; 3) Conduct of field nutrient omission plot trials on target crops; 4) Development of tools for site-specific nutrient management that incorporate the national soil survey GIS and other project results into nutrient management software for delivering updated recommendations to farmers and farmer advisers; 5) Outreach activities to assure appropriate use of the developed tools.

To date, past soil test surveys have been processed and historical cadastral units have been transferred to the current land identification system allowing identification of pilot regions from which new data are needed. A database was structured for past soil fertility research and to accommodate new project data. In 2009, 27 omission plot trials (NPK or NPKMg as complete treatments) were conducted of which 22 were harvested and 5 were abandoned due to unfavorable weather conditions (freezing or drought). Crops tested were wheat, barley, maize, sunflower, potato, tomato, pepper, apricots, peaches, chokeberry, and wine grapes. Out of 22 trials, yield increases to application of N, P, or K were 10% or greater at 13, 9, and 10 sites, respectively. Quality parameters are also being measured for the food crops and some differences were measured in 2009. However, additional site-years will be required before these data can be interpreted. *IPNI-14*

Global Maize

Global Maize Project in Brazil: Itiquira, Mato Grosso

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Project Cooperators: Eros A. B. Francisco (MT Research Foundation), Scott Murrell (IPNI USA), Aildson P. Duarte (Research IAC), Adriel F. Fonseca (UEPG).

Cropping system intensification will be necessary to meet the future demands for corn. The established 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.

This experiment was initiated in November 2009 at Itiquira, Mato Grosso. This is an Oxisol site that has been under cultivation for 20 years. The experiment has a split-plot design with the main plots involving three types of cultivation systems and the sub plots being three levels of N input plus a control. The levels of cultivation are: (1) farmers' practice (FP) of soybean followed by corn, (2) FP + a forage crop (Brachiaria decumbens)in the winter, and (3) EI involving a 3-year complete crop rotation cycle of soybean, corn (second crop), forage, soybean, crotalaria, regular corn, and forage. The EI treatment will occur three times, alternating the initiation point of the crop rotation to permit the production of corn every summer. The levels of N input are 30, 60 and 90 kg N/ha plus a control with no N added. The results for the first year of cultivation will be available by mid 2010. 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 in Brazil: Ponta Grossa, Paraná

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Project Cooperator: Adriel F. Fonseca (UEPG), Gabriel Bartz (ABC Foundation), Scott Murrell (IPNI USA), Aildson P. Duarte (Research IAC), Eros A. B. Francisco (MT Research Foundation).

Cropping system intensification will be necessary to meet the future demands for corn. The established 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.

This experiment is located in Ponta Grossa, Paraná. At experiment initiation in April/May 2010, all winter treatments will be established. The soil in the area is an Oxisol that has been under no-till cultivation for 6 years. The experiment has a split-plot design with the main plots involving three types of cultivation systems and the sub plots being three levels of N input plus a control. The levels of cultivation are: (1) farmers' practice (FP) involving a 2-year complete crop rotation cycle of black oats, corn, wheat, and soybean, (2) FP + silage production, and (3) EI of black oats + forage peas, corn, black oats, and soybean. The EI treatment will occur twice, alternating the crop rotation initiation point to permit the production of corn every summer. The levels of N application are 60, 120, and 180 kg N/ha plus a control with no N added. This is a long-term project intended to influence current opinions on how to best manage cereal production in the region. *IPNI-19*

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

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Project Cooperator: Dr. Jiagui Xie and Ms. Xiufang Wang

A long-term field experiment was initiated at Liufangzi, Gongzhuling City, in Jilin to investigate the ability of ecological intensification (EI) practices to improve yields over time, compared to farmer practices (FP), while minimizing adverse environmental impacts. In this first year, a split-plot design with four replicates was used. The maize plots consisted of two treatments: EI (180-75-90-20-5 kg N-P_2O_5-K_2O-S-Zn/ha) and FP (251-145-100 kg N-P_2O_5-K_2O/ha). The three split plots were: 1) N applied in all years; 2) N applied in 2 of 3 years; and 3) no N applied any year. The site represents the typical mono-cropping system of spring maize. Spring maize was planted on May 4 and harvested on September 29.

Results indicated that an average grain yield of 8.5 t/ha was obtained in the EI treatment, which was 14.2%

greater than FP. Agronomic efficiency (kg grain yield increase per kg N applied) was 20.5 kg grain/kg N in the EI treatment and 9.4 kg grain/kg N in the FP treatment. Partial factor productivity (kg grain yield per kg N applied) was 47.3 kg grain/kg N with EI and 29.7 kg grain/kg N with FP. The apparent recovery efficiency of N (increase in kg N uptake per kg N applied) was 28.3% for EI and 20.9% for FP. Compared to FP, the EI treatment increased P and K uptake, but not N uptake. *IPNI-20*

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

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Project Cooperator: Mr. Chunjie Li

A long-term field experiment was initiated at Dahe Experimental Station in Hebei Province to investigate the ability of ecological intensification (EI) practices to improve yields over time, compared to farmer practices (FP), while minimizing adverse environmental impacts. In this first year, a split-plot design with four replicates was used. Main plots consisted of EI (240-60-90 kg N-P_2O_5-K_2O/ha) and FP (140-138-0 kg N-P_2O_5-K_2O/ha). Subplots were: 1) N applied in all 3 years; 2) N applied in 2 of every 3 years; and 3) no N applied. The site represents the typical rotation system of summer maize and winter wheat. Summer maize was planted on June 15 and harvested on September 30, while winter wheat was planted in the same plot after the summer maize harvest.

A grain yield of 8.1 t/ha was obtained by the EI treatment, which was 6.4% more than FP. Agronomic efficiency (kg grain yield increase per kg N applied) was 4.0 kg grain/kg N in the EI treatment and 4.9 kg grain/kg N in the FP treatment. Partial factor productivity (kg grain yield per kg N applied) was 33.7 kg grain/kg N with EI and 54.3 kg grain/kg N with FP. The apparent recovery efficiency of N (increase in kg N uptake per kg N applied) was 19.1% for EI and 15.8% for FP, respectively. Compared with FP, the EI treatment increased N and K uptake, but not P uptake. *IPNI-21*

Global Maize Project in India: Ranchi, Jharkhand

Project Leader: Dr. Rakesh Kumar, Birsa Agricultural University, Department of Soil Science & Agricultural Chemistry, Kanke Ranchi, Jharkhand 834006. Telephone: +91 0651-2450621. Fax: +91 0651-2450621. E-mail: rkssacbau@rediffmail.com

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

This project was initiated to optimize nutrient management for improved productivity within the maize-wheat cropping system. The working objective includes a quantitative estimation of the attainable yield potential of maize and wheat from a system perspective, estimation of the indigenous nutrient supplying capacity of soils, and using such information to develop a strategy of nutrient management to maximize system productivity. Different N management strategies for timing and rate are being assessed in the cropping system to provide additional input for developing a scientific approach for nutrient management in Jharkhand. The strategies developed will be evaluated for both agronomic and economic performance and will help assess short-term and long-term effects of intensive maize-wheat production systems from a nutrient management perspective. The experimental design for maize and wheat incorporates three sub-experiments that run simultaneously for: Experiment A) long-term system evaluation of an ecologically intensified (EI) system and farmers' practice (FP) in maize-wheat; Experiment B) studying the effect of N rate and timing and real-time N management on productivity of maize-wheat; and Experiment C) estimation of indigenous nutrient supplying capacity of soils to evaluate an alternate approach of plant-based, site-specific nutrient management. The results from experiment B and C will be utilized to continuously improve the EI treatment in experiment A for the development of guidelines of best management practices.

Significant yield differences were observed between treatments in the first season of maize. However, yield levels were lower than expected due to an in-season hailstorm and subsequent yield loss. The yield under FP was found to be 1.4 t/ha lower than the current EI treatment. In all experiments, N was found to be most limiting, leading to a yield loss of 3 to 3.5 t/ha when N was omitted from the fertilization schedule. The yield loss due to omission of P and K, as compared to the optimum treatment, was in the range of 0.7 to 0.9 t/ha at an optimum yield level of 4.6 t/ha. One season of field data from the maize experiment showed that 160 kg N/ha split between three applications (basal, crown root initiation, and panicle initiation stages) produced the highest yields. Treatment-wise soil and plant samples are currently being analyzed to assess nutrient uptake in maize and residual soil fertility. *IPNI-22*

Global Maize Project in India: Dharwad, Karnataka

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Project Cooperator: Mr. Y.R. Aladakatti

This project was initiated to optimize nutrient management for improved productivity within the maize-wheat cropping system of this region. The working objective includes a quantitative estimation of the attainable yield potential of maize and wheat from a system perspective, estimation of the indigenous nutrient supplying capacity of soils, and using such information to develop a strategy of nutrient management to maximize system productivity. Different N management strategies for timing and rate are being assessed in the cropping system to provide additional input for developing a scientific approach for nutrient management in Karnataka. The strategies developed will be evaluated for both agronomic and economic performance and will help assess short-term and long-term effects of intensive maize-wheat production systems from a nutrient management perspective.

The experimental design for maize and wheat incorporates three sub-experiments that run simultaneously for: Experiment A) long-term system evaluation of an ecologically intensified (EI) system and farmers' practice (FP) in maize-wheat; Experiment B) studying the effect of N rate and timing and real-time N management on productivity of maize-wheat; and Experiment C) estimation of indigenous nutrient supplying capacity of soils to evaluate an alternate approach of plant-based, site-specific nutrient management. The results from experiment B and C will be utilized to continuously improve the EI treatment in experiment A for the development of guidelines of best management practices.

Data have been collected from the experiments and are currently being analyzed. *IPNI-23*

Global Maize Project in Argentina: Balcarce, Buenos Aires

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Project Cooperators: Guillermo Studdert, Anibal Cerrudo, Roberto Rizzalli, Pablo Barbieri, Hernan Echeverria, Liliana Picone, Cecilia Videla, Jose Luis Costa, Virginia Aparicio, 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/doublecropped soybean, with both crop phases occurring each year. Soil samples were collected during site establishment to characterize initial conditions, especially soil carbon content in the whole soil profile. Treatments include current farmer practice (FP) and ecological intensification practice (EI). Treatments differed in either cultivar, planting date, pest and weed control, or nutrient management practices.

Wheat crops in the 2009/10 season developed under a lack of precipitation, which adversely affected crop development and tillering. Wheat yields at Balcarce were 4,129 kg/ha for FP and 4,497 kg/ha for EI, with significant differences between treatments. Maize was planted in October and November for the FP and EI treatments, respectively. Double cropped soybean was planted immediately after the wheat harvest in January. Emissions of nitrous oxide (N_2O) and CO_2, as well as nitrate (NO_3^-) leaching will be measured in the 2010/11 growing season. Ancillary field experiments were established to examine various factors of ecological intensification including: the interaction of N with maize plant population, N use efficiency for maize hybrids released in recent years, and an evaluation of cover crops as a source of carbon and N for a subsequent maize crop. *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, 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/doublecropped soybean, with both crop phases occurring each year. Soil samples were collected during site establishment to characterize initial conditions, especially soil carbon content in the whole soil profile. Treatments included current farmer practice (FP) and ecological intensification practice (EI). Treatments differed in either cultivar, planting date, pest and weed control, or nutrient management practices.

Wheat crops in the 2009/10 season developed under excellent climatic conditions at Oro Verde. Wheat yields were 4,613 kg/ha for FP and 4,456 kg/ha for EI and were not significantly different. Maize was planted in October and November for the FP and EI treatments, respectively. Doublecropped soybean was planted immediately after the wheat harvest in January. Emissions of nitrous oxide (N_2O) and CO_2, as well as nitrate (NO_3^-) leaching will be measured in the 2010/11 growing season. Ancillary field experiments were established to examine various factors of ecological intensification including: the interaction of N with maize plant population, N use efficiency for maize hybrids released in recent years, and an evaluation of cover crops as a source of carbon and N for a subsequent maize crop. *IPNI-25*

Global Maize Project in the United States: Ames, Iowa

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Project Cooperator: Dr. John Sawyer

Iowa has the largest area planted to maize of all corn producing states in the U.S. and it also has yields that are among the highest in the country. Iowa is within the Mississippi River Basin, which is an area of intense environmental scrutiny due to issues related to hypoxia in the Gulf of Mexico. Examining the gap between average and potential yields provides important information about future production growth in this state as well as other areas in the U.S. Midwest. Attaining greater production requires the identification of combinations of management practices that allow corn hybrids to fully express their genetic potential while limiting nutrient losses. These management practices are conceptualized by the term "ecological intensification (EI)." Field experiments are being planned for the 2010 cropping season that compare current farmer practices to what scientists at this center currently believe comprises EI practices. Within this study, N use efficiency will be measured to determine if EI practices can achieve both higher production levels as well as greater N use efficiency. *IPNI-26*

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

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Project Cooperators: Dr. Sylvie Brouder and Dr. Tony Vyn

A new model of research is desperately needed to meet the increased global demand for food, feed, and fuel. In 2009, IPNI assisted Purdue University in writing a proposal that was funded by the United States Department of Agriculture to plan Purdue's Long-Term Agroecology Program (LTAP). This project will address major research questions related to management impacts on interactions among soil N, carbon, water use efficiency, and the resultant ecosystem services from U.S. corn-based production. The overarching theme is ecological intensification. The program is multi-disciplinary and will include integration of research conducted at different locations with systematic data aggregation and curation, thereby permitting on-going data accessibility and re-purposing.

Existing resources provide the foundational elements of the field research. The resources being considered for inclusion are IPNI's Global Maize Centers and Purdue University's Water Quality Field Station, Long-Term Tillage Research Facility, Long-Term Drainage Research Facility, the Purdue Agricultural Centers, and the Crop Diagnostic Training and Research Center. *IPNI-27*

Global Maize Project in Mexico: Celaya, Guanajuato

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Project Cooperator: Dr. Benjamin Zamudio

The corn producing areas of tropical Latin America provide a diverse set of climatic conditions that result in a wide range of yield potentials, and consequently, nutrient requirements. In tropical areas, latitude and altitude have a profound effect on yield. For these reasons, it is necessary to determine yield potential and attainable yield under the best known management practices. It is also necessary to quantify the effect of such management on nutrient use efficiency, particularly N. The study was conducted at Celaya, Guanajuato State, with an altitude 1,830 meters above sea level. The experiment will be in the field for at least 10 years. Treatments in 2009 were: 1) best crop management including all needed nutrients and optimal plant population (with amounts adjusted each year according to past results achieved); 2) farm practice including

all changes made by farmers during the study period; 3) treatment 1 without N application; and 4) treatment 1 with N application in 2 of 3 consecutive years.

Best crop management + N and a plant density of 125,000 plants/ha achieved a highest yield of 13.8 t/ha; best crop management - N and 125,000 plants/ha produced 5.8 t/ha; farm practice + N and 90,000 plants/ha produced 12.7 t/ha; and farm practice - N and 90,000 plants/ha produced 4.9 t/ha. Results were influenced by a long drought that affected Mexico throughout 2009. The yield potential using the "Hybrid-Maize" model and NASA weather data was 23 t/ha. *IPNI-28*

Global Maize Project in Mexico: Toluca, México

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The corn producing areas of tropical Latin America provide a diverse set of climatic conditions that result in a wide range of yield potentials and consequently nutrient requirements. In tropical areas, latitude and altitude have a profound effect on yield. For these reasons, it is necessary to determine yield potential and attainable yield under the best known management practices. It is also necessary to quantify the effect of such management on nutrient use efficiency, particularly N. The study was conducted at Tocula, Mexico State, at an altitude of 2,370 meters above sea level. The experiment will be in the field for at least 10 years. Treatments in 2009 were: 1) best crop management including all needed nutrients and optimal plant population (with amounts adjusted each year according to past results achieved); 2) farm practice including all changes made by farmers during the study period; 3) treatment 1 without N application; and 4) treatment 1 with N application in 2 of 3 consecutive years.

Although drought affected this site, best crop management + N and 90,000 plants/ha produced the highest yield of 7.6 t/ha, while the same plant density under best crop management - N produced 5.2 t/ha. Farmer practice + N and 70,000 plants/ha produced 7.0 t/ha, while the same plant density under farm practice - N produced 4.8 t/ha. The yield potential using the "Hybrid-Maize" model and NASA weather data was 13.7 t/ha. *IPNI-29*

Americas and Oceania Group:

North America

Northeast Region: Dr. Tom Bruulsema

Maryland

Building a Maximum Yield Cropping System for Corn, Wheat, and Doublecropped Soybeans in Maryland

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Project Cooperator: William Kenworthy

The goal of this study is to develop a management program that increases crop yield, input efficiency, and profit potential in a predominantly no-till cropping system. This cropping system consists of four crops planted over 3 years, including: no-till soybeans in corn stubble, followed by minimum-till wheat double-cropped with no-till soybeans, and then no-till corn.

In research on the Eastern Shore of Maryland, N use efficiency in corn and wheat has improved when ammonium sulfate (AS) was blended with either urea or ammonium nitrate (AN). Research in 2009 again confirmed that blends containing an amount of AS sufficient to supply 30 lb/A of S produced corn yields higher than those achieved with granular urea applied pre-plant. Despite a drought year, these blends produced corn yields of around 120 bu/A with a total application of 120 lb/A of N. Blends of ammonium nitrate with ammonium sulfate and urea produced yields as high as those with ammonium sulfate and urea in no-till and higher than those with ammonium sulfate and urea in strip-till. *MD-06F*

Ammonium Sulfate and Ammonium Sulfate Nitrate Application on White Potatoes

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Project Cooperator: David Armentrout

Managing plant nutrition for potatoes can be challenging since the crop's nutrient demands are high, and so is its potential for impact on soil and water quality. This experiment examines the effects of N sources for potatoes grown in rotation with wheat, soybeans, and corn within strip-till and no-till management systems.

In 2009, urea and ammonium sulfate applied pre-plant proved to be equally effective for increasing potato yield. Highest potato yields were obtained when urea and ammonium sulfate were applied pre-plant, followed by side-dressing with urea and ammonium sulfate nitrate. *MD-14F*

Ohio

Impact of Phosphorus and Potassium Fertilization and Crop Rotation on Soil Productivity and Profitability

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Project Cooperator: Edwin Lentz

Growers in the eastern U.S. Corn Belt often fertilize the whole rotation rather than the individual crops. Typically, in the fall prior to corn planting, farmers supply enough P and K to satisfy the nutrient needs of both corn and the following soybean crop. This practice has proven to be a viable option for corn-soybean rotations on soils with adequate nutrient levels, but questions arise for producers in a 3-year rotation of corn-corn-soybean. In 2006, studies assessing P and K fertilization strategies were started in three locations. Two rotations were compared: corn-corn-soybean, and corn-soybean. These rotations were fertilized following

soybeans, at P and K rates corresponding to zero, once, and twice the crop removal for the rotation. Corn yield was increased at one location by application of both P and K fertilizer. Optimum fertilization boosted yields from the 213 to 215 bu/A range to 223 to 225 bu/A. The other two locations did not show consistent yield increases. In 2007, each location had corn in the first rotation and soybeans in the second. Neither crop responded to the P and K treatments, even though the soybean crop produced yields as high as 66 bu/A. Drought reduced corn yields to a range of 122 to 159 bu/A. Changes in soil test levels are being monitored. In 2008, K treatments boosted soybean yields by 7 to 10 bu/A, and the high rate of P increased corn yields by 22 bu/A at the Western Research Station, the only location not affected by drought. At the East Badger location, P treatments increased corn yields by 9%. At the Northwest Research Station, drought reduced corn and soybean yields to about half of normal, and there were no responses to P or K treatments.

In 2009, responses to the 4 years of application of P and K occurred at only one of three sites, and were small (less than 5%). Changes in soil test P are responding to applied P. But soil test K is more puzzling, with no response to applied K in several instances. These mysteries will require further investigation. These current yield response observations provide useful support for extensionists receiving questions from producers in light of their concerns with fertilizer prices. The experiment is continuing in 2010. *OH-16F*

Ontario

Optimizing Application of Phosphorus and Potassium to Processing Tomatoes under Drip Irrigation in Ontario

Project Leader**:** Dr. Tiequan Zhang, Research Scientist, Agriculture and Agri-Food Canada, Greenhouse and Processing Crops Research Center, Harrow, Ontario N0R 160. Telephone: 519-738-2251, 476. E-mail:zhang@agr.gc.ca

Recent research has indicated that processing tomatoes require higher rates of N when grown with fertigation. The objective of this research is to determine optimum rates of P and K for the higher yields obtained in this production system. Four rates of P, from 0 to 180 lb P_2O_5/A, were applied in a factorial combination with four rates of K from 0 to 640 lb K_2O/A, in a drip-irrigated system fertilized with N at 240 lb/A. Soil test levels for P and K varied from year to year, but were generally high, representative of those of typical producer fields.

From 2006 to 2009, marketable yield responded to P and K, each in 2 of the 4 years. Yields were boosted 5% and 11% by P at soil test P levels of 37 to 65 ppm. Potassium increased soluble solids content and also raised marketable yields by 10% and 12% at soil test K levels of 160 to 233 ppm. Vitamin C was increased 1 year in 3 by P, but not by K. Neither P nor K influenced lycopene concentrations in any of the 4 years. The positive yield and quality impacts measured at these relatively high soil test levels support current nutrient use practices of progressive growers, but opportunity to improve fertilizer uptake efficiency remains, particularly for P. The field research was completed in the 2009 growing season, and the project completion is planned for early 2010. *ON-28*

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

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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: (1) assessment of short and long-term effects of N on productivity, environmental impact, profitability, and cropping system sustainability; and (2) validation of crop models, such as Hybrid Maize, for simulating yield potential, seasonal growth and yield, and fertilizer N management requirements.

The 2009 growing season was the first in which treatments were applied. Economically optimum rates of N were 15% higher than recommended for the pre-plant application, and 32% higher than recommended for the side-dress application, possibly because of a relatively cool, wet, and long growing season. Corn grain N concentration was 0.60 to 0.66 lb/bu at rates of N sufficient for maximum economic yield. Residual soil nitrate increased sharply when N rates exceeded the economic optimum, and were higher for side-dress than for pre-plant N applications. This project also received support from the Ontario Agri Business Association, for sampling soil residual nitrate and soil organic carbon. The project implementation so far forms an excellent basis for achieving the long-term objectives. *ON-29*

Virginia

Evaluation of Ammonium Sulfate Nitrate in Virginia Snap Bean Production

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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.

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).*

These first-year 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. *VA-22F*

Evaluation of Ammonium Sulfate Nitrate in Virginia Sweet Corn Production

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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).

The N sources increased marketable yields by 16 to 50% using optimum N rates ranging from 110 to 125 lb/A. Agronomic efficiency ranged from 11 to 35 lb of marketable yield increase per lb of N applied. Sulfur added as gypsum did not increase yields, but ammonium sulfate-nitrate produced higher yields than the other two N sources.

These first-year 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. *VA-23F* ❖

Americas Group

North America

Northern Great Plains Region: Dr. Tom Jensen

Alberta

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

Project Leader: Dr. Dick Puurveen, University of Alberta, Sustainable Resources Department, 761 General Services Bldg., Edmonton, AB T6G 2H1. Telephone: 780-988-5454. E-mail: puurveen@ualberta.ca

Project Cooperators: Claire Langlois, Guy Lafond, Brian Hellegards

Spring wheat was grown for the N experiment at Ellerslie, Alberta, but cool and dry conditions experienced from April to July affected yield potential in the region. This could not be compensated by more favorable moisture and temperatures that appeared later in the growing season. No significant differences in grain yield were observed between the selected N fertilizer forms [urea, urea treated with Nutrisphere-N® (a polymer coating), Super Urea (including both urease and nitrification inhibitors), and Environmentally Smart Nitrogen or ESN® (designed as a semi-permeable, polymer-coated urea source)]. Differences between fertilizer placement methods (banded at planting versus surface broadcast) or N rates (60 and 120 kg/ha) were also not observed.

In the P experiments, significantly higher yields were observed for dry granular monoammonium phosphate (MAP) compared to liquid ammonium polyphosphate (APP) at Ellerslie. In most years that are warmer and more moist, advantages for MAP over APP are not observed. Yields at Ellerslie responded to P rate as they increased from 3,659 to 4,839 kg/ha as P rate increased from 7.5 to 30 kg P_2O_5/ha. However, no significant difference was observed between regular P fertilizer compared to forms treated with the Avail® polymer additive. The Breton site was less responsive to P with no significant difference observed between the rates of P averaged for both form and with and without Avail®. However, a yield advantage was detected at the 30 kg/ha rate for MAP (3,350 kg/ha) compared to APP (2,728 kg/ha) and both forms resulted in greater yields with Avail® (3,664 kg/ha) than without Avail® (2,413 kg/ha). It is planned to repeat the experiments one more year at these two sites. *AB-26F*

Use of Large Urea Granules for Broadcast Application in No-till Cropping

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Spring wheat was grown for the N experiment at Ellerslie, Alberta, but cool and dry conditions experienced Research in Alberta and North Dakota has supported the use of urea granules larger than regular, ag-grade urea as a means of increasing crop yield and reducing the potential for denitrification losses. Thus, larger urea granules (up to 10 mm in diameter) commonly used in helicopter applications in replanted forest stands, and in agro-forestry plantations, could be used in broadcast applications for no-till cropping systems in the Northern Great Plains (NGP). The research noted above was largely done by hand application in small field research plots because existing spin-broadcast applicators could not achieve an even spread with larger urea granules. More recent pneumatic spreaders do have the capability to handle these larger granules. Past research has also investigated the addition of a nitrification inhibitor (dicyandiamide, DCD) with different-sized urea granules...although such treated granules were not commercially available at the time. Recent developments now allow the treatment of different-sized urea granules with both a urease and a nitrification inhibitor (i.e., Agrotain® and DCD).

This study investigates: two application timings (fall versus spring); two urea granule sizes (regular 3 mm and large 10 mm); four Inhibitors (regular untreated urea, urea+Agrotain®, and urea+Agrotain®+DCD, and Agrotain® plus N-Serve® (nitrapyrin); three incorporations (no incorporation, harrowing, and sweep chisel-plow tillage). The potential benefits to the agriculture industry are a low cost, low energy input method of applying N to no-till cropped fields in the NGP with reduced potential for ammonia volatilization losses. The fall 2009 treatments were applied as planned, and the spring applications will be done in late April 2010. Barley will be planted in early May 2010 and harvested in late August. *AB-27*

British Columbia

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

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Project Cooperators: Dick Puurveen, Guy Lafond, and Brian Hellegards

Unfortunately, this site experienced severe early growing season drought and no yield data were available for the phosphate experiment involving the Avail® polymer coating, and only a minimum amount of samples were available for the N experiment involving urea treated with Nutrisphere-N® (a polymer coating) and Super Urea (including both urease and nitrification inhibitors). However, Nutrisphere-N® did perform better than regular urea, while Super Urea generated intermediate results. Yields of canola were 2,866, 2,689, and 2,397 kg/ha for Nutrisphere-N®, Super Urea, and regular urea, respectively. This was the second year of a 3-year study plan. *BC-17F*

Manitoba

Impact of Traditional and Enhanced Efficiency Phosphorus Fertilizers on Canola Emergence, Yield, Maturity, and Quality

Project Leader: Dr. Cynthia Grant, Agriculture & Agri-Food Canada, AAFC Brandon Research Centre, PO Box 1000A, Brandon, MB R7A 5Y3, Canada. E-mail: cgrant@agr.gc.ca

Project Cooperators: Gerhard Rakow and Jo-Anne Relf-Eckstein

An adequate supply of P is needed in the first 2 to 6 weeks of growth to optimize canola yield. Due to recent experiences with relatively high prices for P fertilizer products, many producers reduced their rates of application for seed-placed monoammonium phosphate (MAP), which may reduce crop yield potential. If regular rates are maintained, farmers also run the risk of some seedling damage. A number of enhanced efficiency P products have been developed that may improve the effectiveness of seed-placed P fertilizer, by reducing the risk of seedling damage and/or maintaining P in an available form for a longer period to enhance crop uptake. These products include a polymer-coated MAP that releases the phosphate slowly into the soil, Polyon® (a polymer-coated product), and Avail® (stabilized phosphate). Ammonium polyphosphate liquid fertilizer may also show improved performance compared to MAP, particularly on calcareous soils. While these enhanced efficiency fertilizers may have an advantage over traditional MAP, they have a higher cost. Therefore, it is important to determine if any increases in crop yield, quality, fertilizer use efficiency, or simplification of field operations are large enough to justify their use.

Results in 2009 indicated that the enhanced efficiency P products had little effect on any of the growth parameters assessed. Differences that did occur were mainly due to poor performance of the Polyon® product, although the reasons for the poor performance were not apparent. The second part of the research assessed whether a new yellow-seeded cultivar of canola has a similar tolerance to seed-row P fertilizer compared to a conventional dark-seeded canola cultivar. Results found the yellow-seeded canola cultivar to have very poor emergence compared to a conventional dark-seeded canola, leading to lower yields and limited competitive ability with weeds and volunteer barley. *MB-22*

Comparison of Phosphorus-Based Starter Fertilizer Products, Forms, and Rates Affecting Crop Yields

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High P fertilizer prices during the spring of 2009 resulted in numerous questions regarding the utility and practicality of applying low rates of fertilizer with the seed. This lesson/demonstration was designed for the 2009 Crop Diagnostic School in Carman, Manitoba. It was presented to 358 extension and retail agronomists over a 2-week period in July. Three sources of P were compared, including granular orthophosphate (mono-ammonium phosphate 11-52-0 or MAP), liquid orthophosphate (6-22-2), and liquid ammonium polyphosphate (10-34-0). A research planter was equipped with a liquid fertilizer kit so that both dry granular and liquid starter products could be seed-row applied. The plots were used as a back-drop for discussion about the short-term and long-term efficacy of various starter P-based formulations and management strategies used in small grain and oilseed crops in Manitoba. In addition, a demonstration showed the distribution of starter liquid seed-row blend droplets compared to the distribution of MAP granules as the planter openers passed slightly above a plastic sheet.

It was interesting that the actual spread pattern comparing the dry granular and liquid formulations were not that much different. Some marketing information describes liquid starter blends as going down in a continuous stream along the bottom of the seed-row trench. However, it was shown that the liquid fertilizer actually falls down in droplets not that much closer than dry granules. The final yield samples from the four-replicate demonstration research project will be available in future project reporting. *MB-23*

Saskatchewan

Effects of Potassium and Chloride Nutrition on Seed Yield of Canaryseed

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Project Cooperators: Yantai Gan and Sukhdev Malhi

The objectives of this study are to determine the responsiveness of canaryseed seed yield to K and Cl^- and provide better recommendations to producers on the use of potassium chloride (KCl) in canaryseed production. In 2007, five locations were established in Saskatchewan at Melfort, Stewart Valley, Regina, and two locations near Indian Head on Vale Farms. In 2008, another location on the Indian Head Research Farm was added. Only the Vale farm sites showed strong yield responses in 2007 to Cl^-, but a moderate yield response to Cl^- occurred at Regina. The yield components most affected were seeds per square meter and seeds per head, which indicates that the addition of Cl^- may prevent seed abortion from occurring. Grain yield was not affected by Cl^- or K applications at Melfort or Stewart Valley in 2007. In 2008, only the Vale Farm sites had a Cl^- response. One important difference was that the yield response at the Vale farm site occurred when yield conditions were quite good (40 to 50 bu/A). These preliminary results indicate that canaryseed growers need to measure Cl^- when doing soil tests. The response to Cl^- occurred when the crop was either under stress or under high yielding conditions.

The work was repeated in 2009 with strong Cl^- response at the farm site near Indian Head, and varied response at Stewart Valley and Regina. This research confirms that canaryseed responds to Cl^- and that the positive effect is observed through improved seed fill and seed yield. There can be sites that respond to Cl^-, but not to K, and other sites can respond to both Cl^- and K. Both responses can be predicted quite well by testing soils for plant available Cl^- and K. The final project report will be completed in early 2010 after grain sample quality tests are complete. *SK-38F*

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

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

This project consists of three experiments comparing regular granular urea, urea treated with Nutrisphere-N® (a polymer coating) and Super Urea (including both urease and nitrification inhibitors) at 45, 90, and 135 kg N/ha. The experiments were conducted on spring wheat, barley, and canola. This study was initiated in April 2008, repeated in 2009, and will be conducted for a third year in 2010.

In 2009, growing conditions were excellent at the Indian Head Research Farm. A significant response to N was observed for all three crops. All three forms of N did equally well as no differences in yield were observed between N forms for all three respective crops. *SK-40F*

Field Evaluation of Urea Compared to Enhanced Urea Products

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Project Cooperator: Janelle MacDonald

A field experiment was conducted with canola near Kindersley, Saskatchewan, as part of an undergraduate research project of the University of Saskatchewan. Three different N fertilizer forms were evaluated, including Super Urea (including both urease and nitrification inhibitors), urea treated with Nutrisphere-N® (a polymer coating), and Environmentally Smart Nitrogen or ESN® (designed as a semi-permeable, polymer-coated urea source). The sources were compared to conventional urea applied at 44 kg N/ha, along with a zero-N control. All fertilizers were side-banded at the time of seeding. Canola was seeded in May, but due to drought conditions germination was delayed until rains arrived in mid-June. Mid-season plant samples were collected at the end of July, and canola reached maturity and was harvested at the end of September. Plant

materials were analyzed for N and P content and soil samples 0 to 30 cm and 30 to 60 cm were removed from the plots in October after harvest..

Both the conventional urea and coated forms (Nutrisphere-N® and ESN®) resulted in about 400 kg/ha more yield compared to the control. Nitrogen uptake was slightly higher in the ESN® and Nutrisphere-N® treatments compared to conventional urea, suggesting that they had slightly enhanced N recovery. However, the highest yield and N uptake was obtained with Super Urea. This may be attributed to the presence of the urease and nitrification inhibitors. Under the conditions of the experiment, the urease inhibitor could have helped reduce ammonia (NH_3) volatilization in the dry spring period and the nitrification inhibitor may have reduced potential denitrification losses after heavy rains were received in mid-June. A final undergraduate thesis report will be available in the spring of 2010. *SK-41*

Montana

A Micro-Meteorological Study to Quantify Ammonia Volatilization Losses from Surface Applied Urea in the Semi-Arid Northern Great Plains

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Ammonia (NH_3) losses from urea have ranged from 3 to 40% of the application rate (19.4% average) over eight gas sampling campaigns conducted to date in 2008 and 2009. In this semi-arid region, NH_3 losses are sometimes delayed by 2 weeks or more until sufficient precipitation falls to dissolve urea granules. Significant NH_3 losses may then occur over a three to six week period. Applying urea to frozen soils does not guarantee losses will be minimized. Surprisingly, some of the greatest NH_3 losses (e.g., 32, 36, and 40% of the application rate) occurred at three sites where urea was applied to moist surface soils near 0°C. Environmental conditions that result in prolonged damp conditions near the soil surface appear to promote volatilization losses. Ammonia fluxes as large as 22 kg N/ha/week have occurred under these conditions. Conversely, NH_3 losses from surface-applied urea are generally smaller (<16% of the application rate) if granules are applied to dry soils. Coating urea with an urease inhibitor like N-(n-butyl) thiophosphoric triamide (NBPT) at 4.2 ml/kg provides 2 weeks of protection against volatilization losses following fertilizer dissolution, and has reduced NH_3 losses by 62% over untreated urea.

Results from this study indicate that significant NH_3 volatilization losses can occur from cold soils when urea is surface-applied. This study will be continued for one more year. *MT-17*

North Dakota

Agronomic Evaluation of New Sulfur Sources for Canola

Project Leader: Dr. John Lukach, North Dakota State University, Langdon Research Extension Center, 9280 107th Ave NE, Langdon, ND 58249. Telephone: 701-256-2582. E-mail: jlukach@ndsuext.nodak.edu

Work on this project progressed well in 2009. Growing conditions were initially cool and moist, but with warmer growing conditions the crop yielded well and demand for S was high. The objective of this study is to evaluate the effectiveness of various commercially available and potentially available sources of S fertilizer for canola production in North Dakota. Research trials were carried out at two locations near Langdon. The S products included ammonium sulfate, elemental S, compound granules of N, P, and S, gypsum from coal power plant scrubbers, and a plant growth-promoting rhizobacteria (PGPR). All treatments were compared against a monoammonium phosphate check supplying N and P. Urea was added to certain treatments to balance N rates for all seed-row treatments.

Large canola yield responses to S were present at both sites. The 2009 data along with the previous 4 years will be combined, analyzed, and a final project report will be written with recommendations for S nutrition of canola in north-central North Dakota. *ND-14F*

Nitrogen Recommendation Recalibrations for Wheat in North Dakota

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The objective of this project was to review current N recommendations for wheat to determine profitable N recommendations for spring wheat and durum in North Dakota. Over 100 site-years of data were collected during this project from archived studies and recent N-rate studies. Soil test nitrate improved the relationship between available N and yield. The Return to N approach was used to establish relationships between

yield/protein response and economics of N application. This approach was modified for wheat by adding the criteria for the protein relationship. In the economic analysis, a 50% per point premium was provided between 14 to 15% protein, and a 50% per point dockage for any protein below 14%. The large number of sites made it possible to segregate different agri-climatic zones and determine whether the responses to available N were similar or different. The state was separated into the Langdon region, Eastern North Dakota, and Western North Dakota. When using the newly re-calibrated recommendations, a grower is asked to look exclusively at past field yield history and select productivity levels of low, medium, or high. The table values determined by region, productivity, wheat price and N cost are gross N requirements determined using return to N relationship equations. From this, the soil test nitrate will be subtracted. Other adjustments include previous crop N credits, additions due to short-term no-till adoption, credits due to long-term no-till adoption, and organic matter if greater than 5.9%.

The opening segment of the "North Dakota N Rate Calculator," is available on the web at this: www.soilsci.ndsu.nodak.edu/franzen/franzen.html. The final recommendation is usually plus/minus 30 lb N/A. Adjustments based on the common sense of the grower/consultant and their experience with the field area will dictate the final rate. Consideration due to protein property of the wheat variety, N application techniques that might not be 100% efficient, excessive previous year straw, and other considerations may play roles in defining the final rate. The recommendations were made available December 1, 2009, in both print form and as the web-based N calculator. *ND-15*

Nitrogen Recommendations for Dryland Corn in North Dakota

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All the 2010 research sites for this project were arranged, characterized, and prepared by taking soil samples. The research experiments will be planted during the growing seasons of 2010 and 2011. Experimental factors to be evaluated are N response curves from increasing rates of N along with a zero N treatment, as well as different responses of the selected corn hybrids grown. *ND-16*

Americas Group

North America

Western North America Region: Dr. Robert Mikkelsen

California

Evaluation of Improved Methods for Tissue Testing of Alfalfa

Project Leader: Mr. Steve Orloff, University of California, Cooperative Extension, 1655 S Main St., Yreka, CA 96097. Telephone: 530-842-2711. E-mail: sborloff@ucdavis.edu

Project Cooperator: Dan Putnam

Adequate nutrition is essential to achieving high alfalfa yields. The nutritional status of alfalfa fields is determined through soil analysis or plant tissue analysis. Despite the reliability of plant tissue tests, most alfalfa growers do not conduct tissue testing due to the complicated, time consuming, and tedious procedure currently recommended by the University of California. Current critical values are also based on alfalfa at one-tenth bloom growth stage. However, to produce highly digestible alfalfa, growers harvest alfalfa in the bud stage and many fields never reach one-tenth bloom.

Alfalfa tissue samples were collected from five different fields in Northern California. Tissue samples were collected at three different maturity stages. Whole plant samples (which simulate bale samples), top 6-in. samples, and fractionated plant samples were analyzed for various nutrients. Phosphorus concentration declined considerably with advancing maturity, which is in agreement with previous research. Potassium and S also declined with advancing maturity. Plant maturity must be considered when interpreting plant tissue test results. If the values are not adjusted for maturity, a sample collected at early bud stage may appear to have adequate P, but if the same plants were sampled at one-tenth bloom the tissue values may indicate they are deficient. It was believed that some sampling techniques may be less affected by advancing maturity and therefore the same critical values could be used regardless of the alfalfa stage of growth. However, it was found with all three sampling methods that P concentration decreased at a similar rate as the alfalfa matured from early bud to mid-bud to approximately 10% bloom.

The effect of maturity on nutrient concentrations observed in this study was used to adjust established deficient, marginal, adequate, and high plant analysis values for whole plant or cored bale samples. *CA-26F*

Soil-Specific Potassium Management in the Lodi Winegrape Region

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Project Cooperator: A.T. O'Geen, R.J. Southard, Paul Verdegaal, and Chuck A. Ingels

The importance of K for grapevine productivity and wine quality is well known, but the relationship between soil properties and K availability is not always clear. Potassium is the most abundant inorganic element in grapes, and the main cation in must (the grape juice before fermentation) and wine. Not only are K deficiencies a problem, but excesses are also a problem in relation to wine quality. A recent grower survey in the Lodi (California) district showed 85% of vineyards had received K fertilizer additions during the previous 3 years. About one-third of vineyard blocks in the survey reported K deficiency based on petiole samples, soil testing, or low yields. Only a few growers reported any problem with excessive K levels in fruit.

Soil studies were done in 36 Lodi district vineyards over the past 4 years, with the digging of more than 120 soil pits, and the collection of more than 700 soil samples. Soils in the region vary widely in K supplying capacity. Some clays have high K fixation capacity, where K is removed from solution and trapped within mineral layers. A portion of the K fixed in this manner can be a slow-release source for plants, but most will not be available fast enough during times of high demand.

Potassium fertilization trials were started in 2009 in two established commercial Syrah vineyard blocks with different soil properties. Potassium application rates of 0, 30, 60, or 90 lb/A were applied. After the first year, little response was observed to K additions, although some increase in petiole K concentrations was observed at veraison. Additional trial sites will be established in the coming year. *CA-28*

Washington

Root Responses to Fertilizer Placement and Source

Project Leader: Dr. William Pan, Washington State University, Department of Crop & Soil Science, 210 Johnson Hall, Pullman, WA 99164. Telephone: 509-335-3611. E-mail: wlpan@wsu.edu

A limiting factor in studying the response of root growth to various stresses has been the difficulty in making accurate observations and measurements. Various methods have been used, including rhizotrons, mini-rhizotrons, cameras, and low-resolution scanners. A new greenhouse technique has been developed that allows root growth and development to be measured without disturbance. The rhizosphere of plants growing in field soil are measured daily with high-resolution scanners and the images are quantified by assessing root length and root surface area.

With the equipment now properly working and calibrated, the response of roots to various environmental stresses will be observed and measured. These measurements may include response of different plant species to variably-placed nutrients and various forms of nutrients. Final products will include both photographs of root development over time and also quantitative understanding of how various nutrient management strategies impact root development. *WA-14F* ❖

Americas Group

North America

Northcentral Region: Dr. Scott Murrell

Indiana

Impact of Potassium and Phosphorus Nutrition Biomass Yield and Herbage Composition of Switchgrass Grown for Biofuels

Project Leader: Dr. Jeffrey Volenec, Purdue University, Department of Agronomy, 915 W State Street, West Lafayette, IN 47907-2054. Telephone: 765-494-8071. Fax: 765-496-2926. E-mail: jvolenec@purdue.edu

Project Cooperators: Sylvie Brouder, Keith Johnson, and Brad Joern

Current U.S. plans for energy security rely on the conversion of large acreages from food crop production to the production of cellulosic biomass in order to produce 86 billion gallons of biofuels, thereby reducing U.S. dependence on imported oil by 25% by 2025. Additionally, lands currently considered too marginal for intensive food production may be considered suitable for biofuel production, bringing highly erodible, nutrient-poor soils currently in conservation reserve programs back into intensive agriculture. In the U.S. Midwest, cropping systems may shift from the predominant corn-soybean base to a more varied array of species, including novel perennial grasses for which little agronomic and environmental impact data exist. Sustainable biofuels production with the concomitant protection and improvement of air, soil, and water resources requires a concerted effort by the scientific community to gain knowledge regarding the comparative production potentials and environmental impacts of candidate biofuel systems.

This multi-disciplinary team has initiated a study of the most promising biofuel crop species and management systems at Purdue University's Water Quality Field Station (WQFS) Project team expertise combined with the unique WQFS capabilities for quantifying agro-ecosystem carbon, N, and water balance are permitting a quantitative assessment of candidate system net energy balance. Our overall goal is to develop a cropping system-level analysis of the potential for miscanthus, switchgrass, maize-based, and native prairie production systems to provide renewable fuel while protecting natural resources. Our hypothesis is that biofuel cropping systems differ in total yield and yield of structural and non-structural carbohydrate pools relevant to system profitability. In addition, we hypothesize that tangible differences in the water, N, and C economies of candidate systems exist and these differences will drive changes in soil and water quality. *IN-25*

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

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Project Cooperators: Sylvie Brouder and Tony Vyn

A new model of research is desperately needed to meet the increased global demand for food, feed, and fuel. In 2009, IPNI assisted Purdue University in writing a proposal that was funded by the United States Department of Agriculture to plan Purdue's Long-Term Agroecology Program (LTAP). This project will address major research questions related to management impacts on interactions among soil N, carbon, water use efficiency, and the resultant ecosystem services from U.S. corn-based production. The overarching theme is ecological intensification. The program is multi-disciplinary and will include integration of research conducted at different locations with systematic data aggregation and curation, thereby permitting on-going data accessibility and re-purposing.

Existing resources provide the foundational elements of the field research. The resources being considered for inclusion are IPNI's Global Maize Centers and Purdue University's Water Quality Field Station, Long-Term Tillage Research Facility, Long-Term Drainage Research Facility, the Purdue Agricultural Centers, and the Crop Diagnostic Training and Research Center. *IPNI-27*

Iowa

Variability in Soil Test Potassium and Crop Yield in Iowa

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This project studied early growth, early K uptake, and corn grain yield response to in-furrow fluid starter K and broadcast K across the landscape using eight replicated strip trials and precision agriculture technologies. A low-salt liquid starter fertilizer (0-0-30) was applied at 15 to 22 lb K_2O/A alone and after broadcasting 120 lb K_2O/A (a common removal-based rate used by farmers for corn of corn-soybean rotations). Soils were sampled using a dense grid sampling approach and yield was harvested with yield monitors. Two trials were managed with no-till and the others used chisel-plow/disk tillage.

Mean field soil test K ranged from 102 (low) to 223 ppm (very high), but each field had values ranging from very low or low to high or very high. Averages from the entire length of the strips showed that K applied as either source: (1) did not affect early plant dry weight or K uptake consistently; (2) often increased early plant K concentration; and (3) increased grain yield at three sites. At two sites, broadcast K increased yield more than starter K and at one site both fertilizers increased yield similarly. Analyses of data for within-field areas with different soil series or with soil test K in different interpretation classes showed no consistent differences in response to starter or broadcast K. An interesting result was that a yield response to K sometimes was observed for soil test K levels higher than those for which K application is recommended in Iowa and neighboring states. The few instances with a early plant growth or K uptake response did not show a yield response. Starter K applied in addition to broadcast K never increased yield further.

Comparisons of these results with others using N-P or N-P-K starters indicate that application of in-furrow K has little or no true starter effect, which confirms previous Iowa research conducted with granulated fertilizer applied beside and below the seed row. However, the low liquid starter K rate applied often increased corn yield as much as the higher broadcast rate, which shows that farmers have management options concerning use of these K fertilizers sources for production of corn. *IA-09F*

Evaluation of Corn Response to Sulfur Fertilization in Iowa

Project Leader: Dr. John Sawyer, Iowa State University, Department of Agronomy, 2104 Ag Hall, Ames, IA 50011. Telephone: 515-294-7078. E-mail: jsawyer@iastate.edu

Project Cooperator: Brian Lang

In 2009, a series of on-farm strip trials was established to survey the frequency of corn response to S fertilization. At each field location, one rate of S was compared to no S applied. The S source was calcium sulfate (gypsum). Within-field replicates ranged from 3 to 9 across locations. Fifteen sites were established and 11 had useable data.

Seven different counties were represented and ranged from the middle of Iowa to the far northeastern part of the state. Sulfur rates across locations ranged from 15 to 40 lb S/A. A significant increase in corn yield to S fertilization occurred at 6 of the 11 sites, for a relative frequency of 55%. This frequency is similar to that of other recent small plot research conducted in northeast Iowa. Yield increases at the responsive sites ranged from 5 to 13 bu/A and were large enough to more than pay for S application. *IA-18F*

Evaluation of Sulfur Response by Corn

Project Leader: Dr. John Sawyer, Iowa State University, Department of Agronomy, 2104 Ag Hall, Ames, IA 50011. Telephone: 515-294-7078. E-mail: jsawyer@iastate.edu

Project Cooperator: Daniel Barker

The main objective of this study was to evaluate the 12-40-0-10S product (MicroEssentials MES10®), comprised of monoammonium phosphate (MAP) plus ammonium sulfate (AMS) and elemental S in equal proportions, as a S and P fertilizer source for corn production. A second objective was to provide additional data on the potential for corn response to S fertilization in Iowa. In addition, a second MicroEssentials product (MESZ® 12-40-0-10S-1Zn) was evaluated as a Zn fertilizer source. Sites were chosen in Mason City and Madrid, Iowa, based on their potential for soil S deficiency.

Results indicate a similar plant S uptake response to all S fertilizer products, but no yield response to S application at either site in 2009. A plant P uptake response was observed with all P fertilizer products, and a yield increase to applied P was found at the Madrid site and when analyzed across sites. A yield increase from P application was present for each product. However, for an unknown reason, the yield with the MES® product when applied at the 30 lb S/A rate resulted in no yield response at both sites compared to the control. This also occurred for the MAP product at the Madrid site. The products were surface-applied at both sites, with one difference being the Madrid site was tilled and the Mason City site was under no-tillage. However, other P and S applications (either as different products or at a lower rate of MES®) did not generate such low yields as all of these combinations produced a yield increase from P application.

Based on the results in 2009, no real difference was noted between the S or P fertilizer products. There was no yield increase with application of Zn as MESZ®. The MESZ® product also appeared to supply equivalent S and P compared to the AMS and MES® products. The MESZ® product did not have the yield issue noted with the high rate of MES®. This lends further evidence that the lower yield with the MES-30® and MAP-30 treatments was due to something besides product application, although that is unconfirmed. *IA-19F*

Global Maize Project in the United States: Ames, Iowa

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Project Cooperator: John Sawyer

Iowa has the largest area planted to maize of all corn producing states in the U.S. and it also has yields that are among the highest in the country. Iowa is within the Mississippi River Basin, which is an area of intense environmental scrutiny due to issues related to hypoxia in the Gulf of Mexico. Examining the gap between average and potential yields provides important information about future production growth in this state as well as other areas in the U.S. Midwest. Attaining greater production requires the identification of combinations of management practices that allow corn hybrids to fully express their genetic potential while limiting nutrient losses. These management practices are conceptualized by the term "ecological intensification (EI)." Field experiments are being planned for the 2010 cropping season that compare current farmer practices to what scientists at this center currently believe comprises EI practices. Within this study, N use efficiency will be measured to determine if EI practices can achieve both higher production levels as well as greater N use efficiency. *IPNI-26*

Americas Group

North America

Southeast Region: Dr. Steve Phillips

Alabama

Evaluation of Rates and Timings of Liquid Nitrogen Fertilizer to Optimize Alabama Wheat Yields with and without Fall Tillage

Project Leader: Dr. Charles Burmester, Auburn University, Agronomy and Soils Department, PO Box 158, Bella Mina, AL 35615. Telephone: 256-353-3978. Fax: 256-350-8746. E-mail: burnech@auburn.edu

Project Cooperator: Kip Balkcom

This project, started in 2008, is being conducted at four locations throughout Alabama. The objectives of the study are to: 1) determine the optimum N fertilizer rate for Alabama wheat production, 2) evaluate timings of N fertilizer application on wheat yield, 3) determine if fall tillage is necessary to optimize wheat yields, and 4) evaluate the usefulness of leaf N content in determining N fertilizer requirements.

All test sites responded positively to N fertilization. The optimum N rate on the heavier soils in northern Alabama, which generally produced the highest wheat yields and test weights, was 60 lb/A applied in the spring. Residual N in the soil was also much higher at this site than the other locations as indicated by the near doubling of N content of tillers collected at the Feekes 4 growth stage (F4). Yield was maximized at three Coastal Plain (CP) sites when 20 lb N/A was applied in the fall followed by 70 lb N/A at F4. Waiting until F6 in the spring to apply N fertilizer reduced wheat yields at the CP sites. Wheat N content was low at all CP sites at both F4 and F6, indicating that fall N fertilization rates may need to be increased above the 20 lb/A rate tested in this study and that spring top-dress treatments may need to be applied at F4 or sooner.

Residual soil N measurements are inconsistent on Alabama soils; thus, the N tissue data collected from these tests should be useful in developing critical wheat tiller N concentrations needed on Alabama soils. The fall tillage comparison had no significant effect on any measured variable at any of the trial locations. In northern Alabama, the comparison was chisel plowing versus no-till, and in the CP it was surface tillage compared to a sub-soiler leveler treatment similar to a para-plow *AL-19*

Ammonia Volatilization from Various Nitrogen Fertilizer Materials Following Application to a Bermudagrass Sod

Project Leader: Dr. Beth Guertal, Auburn University, Agronomy & Soils, Auburn, AL 36849.
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The loss of N fertilizer applied as ammonia (NH_3) is a concern for turfgrass managers, particularly if supplemental irrigation is not applied to move the fertilizer from the turf surface into the soil. Our previous volatilization research has shown that as much as 20% of applied N can be lost to NH_3 volatilization when N is applied as urea, without irrigation. The purpose of this research was to examine NH_3 volatilization as affected by N source, examining ammonium sulfate as one of those sources. Four laboratory studies were completed with N fertilizer applied to the top of hybrid bermudagrass *(Cynodon dactylon x C. transvaalensis)* or overseeded hybrid bermudagrass *(Lolium perenne)* turf. Two different experimental procedures were used, including: 1) plot fertilization in the field, with soil sample cores taken at 2-day intervals for 21 days of laboratory analysis; and 2) a single extraction of unfertilized soil sample cores that were fertilized in the lab and observed for the entire 21-day period.

Regardless of the method, NH_3 volatilization was always greatest from turfgrass that had been fertilized with urea. Turfgrass fertilized with ammonium sulfate or methylene urea consistently had lower levels of N loss as NH_3 through volatilization, usually close to zero. This experiment is on-going and will be repeated at several different temperatures, with and without irrigation. *AL-20*

Arkansas

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

Project Leader: Dr. Charles West, University of Arkansas, Crop, Soil and Environmental Sciences, 1366 W Alteimer Dr., Fayetteville, AR 72704. Telephone: 479-575-3982. E-mail: cwest@uark.edu

Two switchgrass field studies were established at the University of Arkansas in 2008. One describes growing-season biomass accumulation and NPK uptake curves and the other determines N response curves for biomass yield. The first study consisted of 12 harvest dates, ranging from May to February. Trends in cumulative growth and nutrient concentration were fitted to regression models as a function of day of year. The 2009 data showed that growth followed a typical S-shaped curve. Peak yield occurred at the August 28 sampling date. Yields were essentially constant from September 30 to October 27, and then gradually declined to February 17, 2010. Nitrogen removal increased throughout the season to 76 kg/ha on July 31. Data from later sampling dates are not yet available. Potassium uptake peaked on July 1 at 136 kg/ha and declined to 110 kg/ha by July 31. Phosphorus uptake increased gradually up to July 31 to a relatively low level of 15 kg/ha. Soil test P level was 30 to 35 ppm in the surface 10 cm, which is not considered deficient for switchgrass. Completing the 2009 sample analyses for N, P, and K will shed light on uptake patterns as affected by crop maturity and senescence.

The second study includes treatments of urea applied at 0, 35, 70, 105, and 140 kg N/ha. One biomass harvest was taken in early October. Linear regression analysis of biomass yield showed a slightly positive slope that was not significantly different from zero, and with a very low R^2. The lack of significant response to N fertilizer was unexpected; however, switchgrass and other native grasses are known to be efficient in their use of plant available N and do not always show a response. There was inconsistent response of switchgrass growth to N application within the four replications, which were blocked across the field area. There was also variation in plant population density. Switchgrass was seeded in 60 cm spaced rows in early July 2008, and not all rows achieved solid stands. Therefore, the first production year, 2009, consisted of fairly young plants, with some gaps between them. It is expected that in 2010 the plants will tiller out more and fill in the gaps more evenly, resulting in less yield variation within treatment. *AR-33*

Florida

Influence of Pre-plant Nitrogen and Sulfur Sources on Strawberry

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Project Cooperator: Henner Obregon

A field study was conducted to compare the effects of diverse pre-plant N and S fertilizer sources on early strawberry yields using the 'Strawberry Festival' variety. The fertilizer sources were ammonium sulfate (21% N, 24% S at 50 lb N/A and 57 lb S/A); ammonium nitrate (34% N at 50 lb N/A); polymer-coated ammonium sulfate (20% N, 23% S at 50 lb N/A and 57 lb S/A); ammonium sulfate nitrate (26% N, 14% S at 50 lb N/A and 27 lb S/A); and gypsum (18% S at 27 and 57 lb S/A). A non-treated control was also included. The fertilizers were applied one week before transplanting and broadcast and incorporated into the top 2 in. of the soil.

There were no differences among treatments for foliar N and S concentrations at 6 weeks after treatment, chlorophyll content (measured as leaf greenness) at 7 and 10 weeks after treatment, plant diameter at 6 and 14 weeks after treatment, and early fruit weight and number after the first 10 harvests. *FL-27F*

Georgia

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

Project Leader: Dr. E. David Dickens, University of Georgia, Warnell School of Forest Resources, PO Box 8112, Statesboro, GA 30460. Telephone: 912-681-5639. Fax: 912-681-0180. E-mail: ddickens@arches.uga.edu

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. The objectives of the study were to: 1) quantify the magnitude and duration of wood volume response to various fertilizer combinations,

2) determine changes in product class distribution, 3) determine the cash flow and rate of return for each fertilizer combination compared to unfertilized control plots, and 4) discern when fertilizers are to be re-applied to maintain wood volume gain. Fertilizer treatments examined NP, NPK, and NPKSCu in one trial and NP, NPCu, NPKCu, and NPKSCu in a second trial. The one-time fertilizer applications were applied in February 2005. Fertilizer levels applied per acre were 200 lb N, 50 lb P, 80 lb K, 60 lb S, and 5 lb Cu.

Data (4-year) were collected in January 2009. There were significant differences in 4-year growth increment for diameter as the control (0.883 in.) was significantly less than treatments supplying NP (1.02 in.), NPKCu (1.07 in.), and NPKSCu (0.963 in.). The volume per tree measurements were also significant with the control being significantly less than all fertilizer treatments. The NPKCu treatment had significantly greater volume per tree increment (4.1 cubic feet) than all other treatments except the NP treatment (4.0 cubic feet). There were no significant growth increment differences amongst treatments for trees per acre, diameter, height, live crown ratio, or volume per acre during the second measurement period (2007 to 2009). However, there were significant volume per tree differences for the 2007 to 2009 growth increment with the NPKCu treatment being significantly greater than the control and NPCu treatments. Pulpwood, superpulp, chip-n-saw, and sawtimber volumes will be estimated and tested for differences in early 2010. *GA-26F*

Louisiana

Effects of Potassium and Chloride with and without Manganese and Boron on Asian Soybean Rust in Louisiana

Project Leader: Dr. Raymond Schneider, Louisiana State University, Department of Plant Pathology & Crop Physiology, 302 LSB, Baton Rouge, LA 70803. Telephone: 225-578-4880. E-mail: rschnei@lsu.edu

Project Cooperator: Jim Wang

A comprehensive field experiment was conducted at the Ben Hur Research Station near Baton Rouge, Louisiana, in 2009. Main treatments included three rates of calcium chloride ($CaCl_2$) and potassium chloride (KCl) each, applied in a pre-plant operation. These six treatments were split three ways with foliar applications of Mn, B, and Mn+B. The control included micronutrient applications alone and a non-amended treatment. The trial was planted in July with a maturity group VI cultivar so that it would be in a susceptible stage in mid-September when soybean rust usually begins and progresses to high severity levels. Disease severity was measured at the mid-R6 stage and plots were harvested for yield determination.

Plots with intermediate and high levels of both $CaCl_2$ and KCl had very low levels of disease severity, while the lowest levels of application had relatively high disease severity. There were significant interactions between the Cl^- amendments and the micronutrient supplements. In particular, those treatments receiving B had significantly less disease except in the high KCl and high $CaCl_2$ treatments. However, plots receiving B alone had among the lowest disease severity scores of any treatment. Severity was measured at the mid-R6 stage and plots were harvested for yield determination.

In conclusion, Cl^- amendments, regardless of the accompanying cation, provided a moderate level of disease control, while the high level of disease control with B suggests that these mineral supplements have different modes of action. In all cases, disease severity eventually reached the same levels as the non-treated control, but this occurred at the late R6 and early R7 growth stages, which are generally considered to be beyond the point where foliar diseases would be expected to impact yield. As a practical matter, foliar applications of B would be a simple agronomic practice. *LA-22*

Precise Mid-Season Nitrogen Rate Determination for Use Efficiency and Yield Optimization of Rice

Project Leader: Dr. Dustin Harrell, Louisiana State University, Rice Research Station, 1373 Caffey Road, Rayne, LA 70578.

Project Cooperators: Brenda Tubana and Tim Walker

The development of a more profitable and environmentally-sound production system is essential to maintain a competitive rice industry in the Mid-South region of the United States. Nitrogen fertilizer is one of the major agricultural inputs in rice production. This project was conducted in 2009 to update a working algorithm of a sensor-based N decision tool for estimating the mid-season N requirement of rice. The components of the working algorithm include a yield potential predictive equation and an in-season estimate of responsiveness of rice to N fertilization. Sensor readings were collected from seven (variety x N) trials established in Crowley and Rayville, Louisiana, and in Stoneville, Mississippi, once a week for five consecutive weeks starting at panicle initiation. Prior to regression analysis, all data were grouped in two ways: 1) according to the number of days from seeding to sensing (DAS), and 2) according to cumulative growing degree days (GDD).

The highest association ($r^2 = 0.59$) between actual grain yield and the sensor-based yield estimate was obtained from the 1,701 to 1,900 GDD group. A rice grain yield potential predictive equation was developed using these data. A mid-season estimate of rice response to N was predicted using a second equation. Generally, the sensor-based N decision tool made mid-season N rate recommendations that resulted in total N inputs close to optimal N rates for each site. In most cases, variably applying mid-season N to rice based on sensor readings resulted in higher N use efficiency and net economic return compared with flat N rate application. Refinement of the working algorithm will focus on: 1) adjusting the mid-season estimate of rice response to N by accounting for the difference between pre-flood- and mid-season-applied N with respect to boosting rice grain yield, 2) determining the optimal sensing scheme orientation to minimize any water reflectance effect especially in low-biomass producing areas/plots, and 3) adding more data points to update the predictive models for yield potential and in-season estimates of rice response to N. *LA-23*

Mississippi

Precise Mid-Season Nitrogen Rate Determination for Use Efficiency and Yield Optimization of Rice

Project Leader: Dr. Timothy Walker, Mississippi State University, Delta Research and Extension Center, PO Box 197, Stoneville, MS 38776.

Project Cooperators: Dustin Harrell and Brenda Tubana

The development of a more profitable and environmentally-sound production system is essential to maintain a competitive rice industry in the Mid-South region of the United States. Nitrogen fertilizer is one of the major agricultural inputs in rice production. This project was conducted in 2009 to update a working algorithm of a sensor-based N decision tool for estimating the mid-season N requirement of rice. The components of the working algorithm include a yield potential predictive equation and an in-season estimate of responsiveness of rice to N fertilization. Sensor readings were collected from seven (variety x N) trials established in Crowley and Rayville, Louisiana, and in Stoneville, Mississippi, once a week for five consecutive weeks starting at panicle initiation. Prior to regression analysis, all data were grouped in two ways: 1) according to the number of days from seeding to sensing (DAS), and 2) according to cumulative growing degree days (GDD).

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Nitrogen Uptake, Residual Effects, and Nitrogen Translocation in Alamo Switchgrass

Project Leader: Dr. Rocky Lemus, Mississippi State University, Plant & Soil Science, Mississippi State, MS 39762. (Telephone: 662-325-7718. E-mail: rlemus@pss.msstate.edu)

Project Cooperator: Jack Varco

The main objectives of this study were to determine N translocation in switchgrass throughout the growing season as well as the best nutrient management practices by estimating N residual effects on biomass production, quality, and time of N fertilizer applications. Three N treatments (0, 56, and 112 kg N/ha) were applied to plots as ammonium nitrate. Double-labeled ammonium nitrate (^{15}N at 2.5% enrichment) was applied to a 1.5 x 1.5 m area in each plot. Plant shoot and root (crown + root) tissue and soil samples were collected on August 4 and November 11 of 2009 and on February 17, 2010. Shoot samples were collected using a 1 x 1 m area and stubble height of 8 cm. Root samples were collected using a 0.3 x 0.3 m area and a 15 cm depth. Ten soil core samples were collected within each plot to a 15 cm depth. Soil samples were weighed and air-dried to obtain soil bulk density data and soil water content at time of each sampling date. Soil samples were ground to pass a 2 mm mesh and saved for analysis. Roots samples were washed and separated into crown and root tissue. Yield data were collected on November 11 of 2009. Residual sampling will be continued in May, August, and November of 2010.

A linear increase in seasonal yields was observed, but mean separations were not statistically significant. Yields at 56 and 112 kg N/ha were 23% and 24% higher than the control, respectively. All collected samples are being analyzed for 15N, C, P, and K. *MS-17*

South Carolina

Incorporating Soil Electrical Conductivity in Developing Variable Nitrogen Application for Corn in the Southeastern U.S.

Project Leader: Dr. Pawel Wiatrak, Clemson University, Department of Entomology, Soils and Plant Sciences, 64 Research Rd., Blackville, SC 29817. Telephone: 803-284-3343x261, Fax: 803-284-3684. E-mail: pwiatra@clemson.edu

Project Cooperators: Ahmad Khalilian, David Wallace, and Ymene Fouli

The long-term goal of this project is to develop procedures for a site-specific, variable N application strategy for corn based on the spatial variability of soil texture and corn grain yield. The aim is to increase farm sustainability and develop environmentally sound corn production system. In 2009, studies were conducted at two Clemson University experiment stations and six grower fields throughout South Carolina.

Corn yields were generally reduced due to insufficient precipitation in June and July in 2009. Despite reduced yields, the results from the studies showed that optical sensing technology used in conjunction with soil management zones based on electrical conductivity (EC) can be successfully used to help growers improve profitability by optimizing N application rates. The sensors improve profitability by optimizing N application rates. The sensor-based system successfully showed that the grower fields used in this study did not need to apply any sidedress N in 2009 due to the reduced yield potential resulting from the drought. Nitrogen rate calibration strips in each field validated these recommendations. There is still a need to refine the existing algorithm by adding additional years (2008 was also extremely dry for optimal corn production). Therefore, the study on refining and evaluating the algorithm will continue in 2010. Soil zones based on EC influenced corn yields with the highest yields being observed in soil zones 2 and 3 (sandy loams and loamy sands in this experiment) due to relatively higher moisture and nutrient holding capacity (which are especially critical parameters affecting grain yield potential during drought stress) compared to soil zone 1 (mostly very sandy soils). Tillage system (tested only at one of the experiment stations) also affected grain yield with significantly higher corn yields being obtained following conventional tillage compared to no-till, but there was no difference between strip-till and no-till. Soil nitrate-N concentrations decreased with increased soil depth under conventional and strip-tillage, but didn't change under no-till for soil zones 2 and 3. However, soil nitrate-N increased with depth for soil zone 1 under all tillage systems. Therefore, variable N recommendations need to be used to improve N use efficiency for dryland corn and reduce water pollution. *SC-14* ❖

Americas Group

North America

Southern and Central Great Plains Region: Dr. Mike Stewart

Colorado

Spatial Management of Nutrients in Corn

Project Leader: Dr. Raj Khosla, Colorado State University, Department of Soil and Crop Sciences, C04 Plant Sciences Building, Fort Collins, CO 80523-1170. Telephone: 970-471-1920; Fax: 970-471-2758. E-mail: rkhosla@lamar.colo.edu

Project Cooperators: Dwayne Westfall, Kim Fleming, and Tim Shaver

Research at Colorado State University has for several years been evaluating the impact of precision nutrient strategies on irrigated corn production efficiency. Among these efforts has been an evaluation of the two most prominently used and accepted active NDVI (normalized difference vegetative index) remote sensors. On-going work has shown that both sensors perform equally well in the determination of N variability in irrigated corn in Colorado, and that the V12 to V14 growth stage range is best for the most accurate determination of N variability. The next logical step and current aim of the work is to develop an N recommendation algorithm for the two active crop canopy sensors.

Each sensor's NDVI N recommendation algorithm calculated unbiased N recommendations, suggesting that the means of algorithm development was valid, as was the estimate of required N at maize growth stage V12. The algorithm developed for each sensor calculated very similar N recommendations. The integration of ground-based sensors and the appropriate N application algorithms into an on-the-go fertilizer application system have the potential to increase the spatial accuracy of N application on fields with sufficient variability, assuming that the algorithms are shown to be stable over time and space. This work is ongoing, and was supported from in-kind soil and plant sample FAR contributions. Thus, support is on a year-to-year basis. *CO-12F*

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

Project Leader: Dr. Jessica Davis, Colorado State University, Department of Soil and Crop Sciences, C06 Plant Sciences Building, Fort Collins, CO 80523. Telephone: 970-491-1913. E-mail: jessica.davis@colostate.edu

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

Ammonia (NH_3) deposition has been identified as a concern from both human health and environmental protection standpoints and has recently been targeted by Colorado as a primary contributor to atmospheric and ecosystem changes in Rocky Mountain National Park (RMNP). Ecological ramifications, including increased forest and grassland productivity, eutrophication and acidification of fresh waters, hypoxia, and loss of biodiversity have been documented in terrestrial, freshwater, and coastal ecosystems. The Colorado Department of Public Health and Environment has estimated that 60% of the NH_3 deposition in 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 especially important if future regulations require that agriculture be held accountable for NH_3-related ecosystem damage. One promising way to track N to its original source is via N isotopic signatures (ä15N) since the ratio between the ^{14}N and ^{15}N isotopes is influenced by source. A major goal of this project is to assess the ability of isotopes as tracers, and in turn, to determine sources of NH_3 contributing to N deposition in RMNP. To ensure that agricultural producers are being treated fairly, this study seeks to 1) determine the major sources of NH_3 deposition in

RMNP based on N isotopic signatures of different NH_3 sources (i.e., agricultural, natural, and industrial), and 2). quantify the relative contribution of NH_3 to RMNP from animal feeding operations, synthetic fertilizers, and other sources.

The first year of this study was spent determining the best approach to isotope analysis. After laboratory methods were established, construction of appropriate equipment was initiated. Progress over the past year includes completion of laboratory apparatuses and preliminary field sampling. To enhance simultaneous site sampling capabilities, three stationary samplers are being assembled for future NH_3 studies with anticipated sampling to begin this winter. Once construction of the field samplers is completed, sampling in earnest is anticipated at sites involving fertilized soils, waste water remediation plants, vehicle emissions, etc. As with any novel and large-scale effort, considerable background work and evaluation is required. Support for this work is scheduled to terminate in 2010. *CO-13F*

Kansas

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

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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 P_2O_5/A, and 0 and 40 lb P_2O_5/A, respectively. The K treatments for grain sorghum were 0 and 40 lb K_2O/A.

The 2009 results of this project continue to demonstrate that fertilizer inputs are important to the production of irrigated corn and grain sorghum in western Kansas. Corn yield in the no fertilizer control was 85 bu/A in 2009. Nitrogen alone increased corn yield by as much as 70 bu/A, while co-application of N and P increased yield by over 150 bu/A. Averaged across the past 9 years, co-application of N and P increased irrigated corn yield by 139 bu/A. Application of 120 lb N/A (with P) was sufficient to produce >90% of maximum yield in 2009, which was similar to the 9-year average. Phosphorus fertilizer at the lowest P rate increased corn yield by over 85 bu/A with 120 lb N/A, and application of the highest P rate increased yield by an additional 13 bu/A. The no fertilizer treatment in the sorghum study produced 64 bu/A. Nitrogen fertilizer alone increased sorghum yield by as much as 51 bu/A, while N plus P increased yield by 75 bu/A. Application of 40 lb N/A (with P) was sufficient to produce about 85% of maximum yield in 2009, although yields continued to increase with higher N rates. Potassium fertilization had no effect on sorghum yield over the course of the study. This is one of the few continuous, long-term crop nutrition studies in the U.S. and support is planned to continue in 2010. *KS-23F*

Nitrogen Management for No-tillage Corn and Grain Sorghum Production

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No-tillage is being adopted by an increasing number of producers in the Great Plains. Its advantages include soil erosion reduction, increased water storage and efficiency, and improved soil quality. However, surface residue can create N fertilizer management challenges. Surface applications of urea containing fertilizer in these systems may be subject to volatilization losses, and leaching can also be an issue on coarse textured soils when N is applied in a single, preplant application. Several fertilizer technologies have the potential to address challenges in N management in no-till systems. For example, polymer-coated urea products have become increasingly available for agricultural use. The polymer coating allows the urea to be released at a slower rate than uncoated urea. Urease inhibitors and other additive technologies can be applied with urea-containing fertilizers to help reduce the potential for volatilization losses and improve performance. The objective of this study is to evaluate the effectiveness of specific enhanced efficiency fertilizer technologies for no-tillage irrigated corn production.

This 3-year irrigated corn study in north central Kansas compared urea, urea ammonium nitrate (UAN), Environmentally Smart Nitrogen or ESN® (a controlled-release polymer-coated urea), UAN treated with Agrotain® (a urease enzyme inhibitor), UAN treated with Agrotain Plus+® (including both urease and nitrification inhibitors), UAN treated with Nutrisphere®(a polymer coating), and ammonium nitrate at 80, 160, and 240 lb N/A. Nitrogen fertilizer was applied either broadcast or banded just prior to planting. A zero N check plot was also included. Corn was planted without tillage into residue from the previous year's corn crop.

Treated urea products out-yielded untreated urea, and were similar to ammonium nitrate. No significant differences in corn yield were found between N treated with ESN®, Agrotain®, or Nutrisphere-N®. UAN treated with Agrotain Plus+® or Nutrisphere-N® out-performed untreated UAN. A 2-year study was also conducted to compare banding and broadcasting of urea-containing fertilizers. With both urea and UAN, banding resulted in greater yields than surface broadcast application. The use of fertilizer additives resulted in yield increases even when banded. The results of this work show that if producers wish to apply urea-containing fertilizer on the soil surface in no-tillage production, banding is more effective than broadcasting. This research also confirms that several products are currently available to improve the performance of N fertilizer, whether broadcast or banded. This is the final year of this work. *KS-38F*

Improving Nitrogen Fertilization of Manured Fields in Kansas

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The appropriate application rate of inorganic N fertilizer for manure-amended fields is sometimes difficult to determine for several reasons. The goals of this study were to determine N response of winter wheat on manure-amended soil, evaluate N availability calculations recommended by Kansas State University (KSU), and examine application of optical sensors for making in-season N recommendations. Field experiments were conducted at three sites (Blaine, Manhattan, and Hays) during the 2008-2009 winter wheat growing season. Whole plot treatments were pre-plant N source (manure or fertilizer) and sub-plot treatments were in-season top-dress N rates (urea ammonium nitrate at 0 to 80 lb N/A). A reference treatment of 120 lb N/A was also applied at planting. A GreenSeeker RT 200 (Ntech Industries, Inc., Ukiah, California) was used to measure normalized difference vegetation index (NDVI) in winter wheat on whole-plot treatments.

At all three sites, there was no interaction between pre-plant N source and top-dress N rate, indicating that both manure and fertilizer treatments responded similarly to top-dressed N application. Results of the evaluation of in-season N recommendation tools showed that KSU recommendations performed well at the Blaine site and the Greenseeker performed well at the Manhattan site, but neither recommendation tool performed well at the Hays site. This suggests that both the KSU and GreenSeeker methods have the potential to produce appropriate recommendations on manure-amended fields, but more work is needed for further clarity. This project was supported with in-kind soil and plant analysis FAR contributions, and further support will be evaluated on a year-to-year basis. *KS-39F*

Nebraska

Ecological Intensification of Irrigated Corn and Soybean Cropping Systems

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An interdisciplinary research program on ecological intensification of irrigated maize-based cropping systems was established at the University of Nebraska in 1999 to: (i) improve understanding of the yield potential of corn and soybean and how it is affected by climate and management, (ii) develop approaches for managing continuous corn and corn-soybean systems at 80 to 95% of the yield potential, (iii) conduct an integrated assessment of productivity, profitability, input use efficiency, energy balance, and environmental consequences of intensified cropping, and (iv) develop scientific bases and decision support tools for extrapolation to other locations. Among the items this work has generated are the "Hybrid-Maize" growth simulation model, and several scholarly journal publications and *Better Crops with Plant Food* articles. The project is in its final stage with the development of a state-to-the-art, widely applicable tool for recommending N fertilizer rates for corn.

Instead of developing two separate models (systematic and generic) as was previously planned, it was decided that two models be combined into a single improved model (*Maize-N*) that relies on the robustness of a yield-based approach and mechanistic features of an uptake-based approach. The *Maize-N* model seeks to provide a means of analysis for the factors (biophysical, climatic, etc.) that govern N supply, N use efficiency, and N uptake in corn production systems. It is composed of three major modules: (i) a yield module for estimating corn yield potential and its variation under differing climatic regimes, (ii) a carbon (C) and N mineralization module for estimating soil indigenous N supply, and (iii) a yield response module for estimating the economically optimal N rate (EONR). The *Maize-N* tool has performed well in estimating

EONR as was indicated by its comparison against measured EONR in sites in the U.S., Asia, and Brazil. In the majority of site years (39 out of 46), the estimation of EONR was reasonably close to (≤ 22 lb/A) the observed or measured EONR. *Maize-N* was relatively robust in estimating EONR considering that the observed EONR and attainable yield both varied considerably...from 54 to 247 lb/A and 99 to 295 bu/A, respectively. The development of this model is in the final fine-tuning stages. This was the last year of support for this work. *NE-11F*

Texas

Nutrient Uptake and Removal Dynamics in Muskmelon Grown in South Texas

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Project Cooperator: Gene Lester

Fertilizer requirements for optimum yields may differ from the requirements for quality traits such as taste, flavor, texture, and shelf-life for certain high-value horticultural crops. Timing of fertilizer application, as well as soil and plant factors, are also critical in quality considerations. Currently, there are no nutrient management guidelines for optimizing produce quality even though certain nutrient elements such as K are known to influence quality development. Information on nutrient uptake and removal amounts may be useful in developing fertility recommendations for crops with different nutrient requirements and quality standards. The objective of this work is to evaluate nutrient removal and uptake dynamics of cantaloupe (muskmelon) in the Rio Grande Valley of Texas, and to ultimately improve the understanding and implementation of nutrient recommendations.

Leaf, stem, and fruit tissues of muskmelons were sampled from fields with different soil types and analyzed to calculate nutrient removal amounts. There were little differences in the concentration of major nutrients (N, P, K) in plant tissues during vegetative development. However, after fruit set the concentration of major nutrients was significantly reduced as developing fruits became sinks for these nutrient. Differences were also observed in tissue nutrient concentrations among the sampling sites and this was coincident with soil type -- tissues sampled from sites with heavy soils tended to have higher nutrient concentrations than those from sites with light textured soils. Estimates of nutrient removal amounts ranged from 18 to 38 lb N/A, 3 to 6 lb P/A, and 35 to 80 lb K/A and varied significantly among sites. Exceptionally dry weather during the 2009 growing season affected uptake and accumulation patterns of nutrients and fruit yields were lower than average. Data collected over multiple years under different weather conditions, soil types, and yield scenarios will be needed to establish realistic nutrient removal values that can be used to further develop fertilizer guidelines aimed at improving fruit quality. This work is planned to continue in 2010. *TX-52F*

Potassium Fertilizer Management in Irrigated Cotton in West Texas

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The majority of soils in the western part of Texas test high in extractable K, and this abundant soil K is often taken for granted. Over the last several years, cotton fields in some parts of this region have been exhibiting pre-mature leaf senescence, which may be linked to soil K supply issues. There is also some concern among growers and others that traditional soil K testing methods do not accurately reflect actual soil K availability to cotton. The typical practice of not applying K fertilizer, combined with higher cotton lint yields, leads to some degree of K mining in these soils. Fertilizer source and rate trials were initiated in two west Texas locations (Lubbock and Reeves counties) in 2009. Specific objectives were to: i) assess lint yield response to K fertilizer rates (0, 40, 80, 120, 160, 200 lb K_2O/A) in irrigated cotton production, ii) assess lint yield response to K fertilizer source (KCl and K thiosulfate), iii) assess soil test procedures for soil K availability, and iv) monitor leaf K between early bloom and first open boll as a function of K fertilizer rate. Both sites were irrigated...one with subsurface drip (Reeves) and the other with in-furrow flood irrigation (Lubbock). Both sites tested high in soil K by traditional measures. The soil test K procedures evaluated included traditional ammonium acetate extraction, water extraction, and a cation exchange resin method designed to measure dynamic K availability.

There was no response to K fertilizer nor were there source differences among the cotton parameters measured (lint and seed yield, plant biomass, leaf K concentration) at either site in 2009. However, the cation exchange resin test did show that there was net K fixation at the Reeves site and net release at the Lubbock

site. Early results also suggest that water soluble K bears further investigation as a useful K fertility tool in these environments. The questions and issues that brought about this work are not straight forward since the leaf drop problem is not consistent from year-to-year. Thus, the work warrants multiple years of effort. This was the first year of this study and support is planned to continue next year. *TX-54F* ❖

Americas Group

Brazil: Dr. Luís Ignácio Prochnow

Effect of Potassium and Magnesium Sources on Coffee Yield and Fruit Quality

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Coffee bean quality has become essential in today's markets, with only high standard coffee achieving good prices. Many factors contribute to final coffee quality, and K fertilization is one of the most important. Potassium chloride (KCl) is the most utilized source of K, and as such, a high amount of bioavailable Cl^- can be absorbed by plants. Recent research has shown that high contents of Cl^- in coffee beans can damage fruit quality. This is because Cl^- leads to higher water contents in beans which in turn may lead to the proliferation of microorganisms. Potassium magnesium sulfate or K-Mag® ($K_2SO_4 \cdot 2MgSO_4$ or 22% K_2O, 22% S, and 11% Mg) can be an alternative source of K. With this in mind, field experiments were carried out at two locations to compare yields and fruit quality under the two sources of K. The experimental design involves the two K sources applied at 0, 100, 200, and 400 kg K_2O/ha. Given the nutrient content of the two K sources, different amounts of S (0 to 400 kg/ha), Mg (0 to 200 kg/ha), and Cl^- (0 to 320 kg/ha) were supplied amongst treatments. Each experimental unit contained three rows of 12 plants each. Only the 10 central plants within the central row were harvested.

The use of K-Mag® increased plant S and Mg, and lowered Cl^- content, but there was no difference observed in terms of fruit quality after four harvests. Field operations are complete and yield data suggests a trend towards higher production with the use of K-Mag®, but a full statistical analysis is not yet available *Brazil-48*

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

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Continuous cultivation of lands under the same monocropping systems tends to promote soil degradation and increase 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 sustainable agriculture systems. Two experiments, one aiming at the production of fiber and the other at grain production, each containing seven different cropping systems, were initiated in 2008 and general results for the first year are now available.

Results initially suggest the production of dry matter yield in cover crops during the spring, before cotton, is sufficient to guarantee good soil protection and recycling of nutrients. Amounts of N, P, 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 crop intensification system of producing soybean and corn (second crop) in sequence resulted in higher amounts of nutrient export, which should be taken into consideration when

planning fertilizer recommendations. This is a long-term project and valuable and more conclusive results will be possible with time. *Brazil-55*

Sources and Rates of Phosphorus in a Cultivation System Integrating Crop and Pasture Production in Parana

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The integration of crop and pasture production within the same area 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 in bioavailable P. The main purpose of this project 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 soil at the site has been under no-till for 5 years. Treatments include 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 P_2O_5/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 P_2O_5/ha applied prior to seeding the spring-summer crop.

The experiment was started in April 2009 and only the results for the autumn-winter crop are available. There was a clear response to P in black oats for all P sources. The TSP source applied at 120 kg P_2O_5/ha generated the highest dry matter yield. No effect on soil carbon storage has been observed to date. The site is now under corn cultivation. *Brazil-55*

Global Maize Project in Brazil: Itiquira, Mato Grosso

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Project Cooperators: Eros A.B. Francisco (MT Research Foundation), Scott Murrell (IPNI USA), Aildson P. Duarte (Research IAC), and Adriel F. Fonseca (UEPG)

Cropping system intensification will be necessary to meet the future demands for corn. The established 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.

This experiment was initiated in November 2009 at Itiquira, Mato Grosso. This is an Oxisol site that has been under cultivation for 20 years. The experiment has a split-plot design with the main plots involving three types of cultivation systems and the sub plots being three levels of N input plus a control. The levels of cultivation are: (1) farmers' practice (FP) of soybean followed by corn, (2) FP + a forage crop *(Brachiaria decumbens)* in the winter, and (3) EI involving a 3-year complete crop rotation cycle of soybean, corn (second crop), forage, soybean, crotalaria, regular corn, and forage. The EI treatment will occur three times, alternating the initiation point of the crop rotation to permit the production of corn every summer. The levels of N input are 30, 60 and 90 kg N/ha plus a control with no N added. The results for the first year of cultivation will be available by mid 2010. 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 in Brazil: Ponta Grossa, Paraná

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Cropping system intensification will be necessary to meet the future demands for corn. The established 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.

This experiment is located in Ponta Grossa, Paraná. At experiment initiation in April/May 2010, all winter treatments will be established. The soil in the area is an Oxisol that has been under no-till cultivation for 6 years. The experiment has a split-plot design with the main plots involving three types of cultivation systems and the sub plots being three levels of N input plus a control. The levels of cultivation are: (1) farmers'

practice (FP) involving a 2-year complete crop rotation cycle of black oats, corn, wheat, and soybean, (2) FP + silage production, and (3) EI of black oats + forage peas, corn, black oats, and soybean. The EI treatment will occur twice, alternating the crop rotation initiation point to permit the production of corn every summer. The levels of N application are 60, 120, and 180 kg N/ha plus a control with no N added. This is a long-term project intended to influence current opinions on how to best manage cereal production in the region.
IPNI-19 ❖

Americas Group

Latin America–Southern Cone: Dr. Fernando García

Southern Chile

Potassium Run-off and Leaching Losses in Beef Cattle Production Systems of Southern Chile

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Livestock production in Chile is concentrated in the southern regions of the country and is largely based on a direct grazing system that has intensified over the last 10 years because of new commercial trade agreements signed by the country. This activity has increased application rates for N, P, and K fertilizer, stocking rates, and the intensity of rotational grazing. The objective of this study is to quantify K losses in surface run-off and leaching from permanent pastures grazed with different stocking rates. Previous studies have shown that over 95% of total K loss in these Andisols is through leaching. These losses are low when no K has been added as fertilizer. No information exists on how K losses are affected by autumn application of inorganic fertilizer. There is also no information on the effect of plant uptake on K extraction in cut areas, as this pathway can be more relevant for K fertilizer rate adjustments than K leaching losses. Thus, a second objective is to quantify K leaching losses after autumn K fertilizer applications under a typical cutting regime. Three treatments (0, 60, and 120 kg K_2O/ha), applied in March 2008, and in 2009, were compared to determine the relative amounts of K lost by leaching.

After 7 years of experimentation, grain yields in the continuous check treatment showed the effect of Pasture yields were increased by 10% with increasing K addition, in relation to the control treatment (11.8 t DM/ha/yr), but K plant concentration did not vary between treatments (average 3.6 ± 0.15%). Plant uptake was greater in the 120 kg K_2O/ha treatment, in response to the greater DM yield, varying between 495 (control) and 602 kg/ha (120 kg K_2O/ha). Potassium concentration in leachate samples varied between 2 and 3 mg K/L in 2008, with no differences between treatments, which resulted in 13 to 17 kg K/ha lost by leaching. Results of 2009 leachate samples are being processed.

High plant uptake during both seasons resulted in negative soil balances (-450 to -516 kg K/ha). This suggests that higher K additions are required in areas managed under cutting with no slurry or manure application. Also, field experiments should be complemented with laboratory soil K adsorption studies in order to improve our knowledge in relation to soil K dynamic in Andisols. *Chile-5*

Argentina

Global Maize Project in Argentina: Balcarce, Buenos Aires

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A long-term field experiment was established at Balcarce (Buenos Aires) in the 2009/10 growing season. The crop rotation was maize-wheat/doublecropped soybean, with both crop phases occurring each year. Soil samples were collected during site establishment to characterize initial conditions, especially soil carbon content in the whole soil profile. Treatments include current farmer practice (FP) and ecological intensification practice (EI). Treatments differed in either cultivar, planting date, pest and weed control, or nutrient management practices.

Wheat crops in the 2009/10 season developed under a lack of precipitation, which adversely affected crop development and tillering. Wheat yields at Balcarce were 4,129 kg/ha for FP and 4,497 kg/ha for EI, with significant differences between treatments. Maize was planted in October and November for the FP and EI treatments, respectively. Double cropped soybean was planted immediately after the wheat harvest in January. Emissions of nitrous oxide (N_2O) and CO_2, as well as nitrate (NO_3^-) leaching will be measured in the 2010/11 growing season. Ancillary field experiments were established to examine various factors of ecological intensification including: the interaction of N with maize plant population, N use efficiency for maize hybrids released in recent years, and an evaluation of cover crops as a source of carbon and N for a subsequent maize crop. *IPNI-24*

Global Maize Project in Argentina: Oro Verde, Entre Ríos

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

Wheat crops in the 2009/10 season developed under excellent climatic conditions at Oro Verde. Wheat yields were 4,613 kg/ha for FP and 4,456 kg/ha for EI and were not significantly different. Maize was planted in October and November for the FP and EI treatments, respectively. Doublecropped soybean was planted immediately after the wheat harvest in January. Emissions of nitrous oxide (N_2O) and CO_2, as well as nitrate (NO_3^-) leaching will be measured in the 2010/11 growing season. Ancillary field experiments were established to examine various factors of ecological intensification including: the interaction of N with maize plant population, N use efficiency for maize hybrids released in recent years, and an evaluation of cover crops as a source of carbon and N for a subsequent maize crop. *IPNI-25*

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

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The Regional Consortium of Agricultural Experimentation (CREA), a farmer 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; and 3) identifying the level of deficiency and potential response to nutrients other than N, P, and S. In 2008/09, two sites within a corn-wheat/soybean (C-W/S) rotation were planted to corn, and four sites within a corn-soybean-wheat/soybean (C-S-W/S) rotation were planted to wheat/soybean..

Climatic conditions at the two corn experiments were better than the whole Pampas region and did allow for high yields. Yield responses to NPS were significant at both sites, and responses to nutrients other than NPS were significant at one site. Considering the eight seasons and 34 sites under corn, significant relationships were established between grain yield and soil N supply as predicted by soil nitrate-N measured at sowing + fertilizer N rate. A critical level of 15 ppm Bray 1 P has been established below which corn P responses are highly probable. Wheat experiments were highly affected by severe drought. However, the relative responses to N, P, and S were similar to previous seasons as average responses to P and NP were 400 kg/ha (+25%) and 900 kg/ha (+57%). Considering the eight seasons and 31 sites under wheat, significant relationships were established between grain yield and soil N supply as predicted by soil nitrate-N measured at sowing + fertilizer N rate, N levels of 130 to 140 kg/ha allowed for grain yields of 4,000 kg/ha. A critical level of 15 to 20 ppm Bray 1 P has been established below which wheat P responses are highly probable. Double-cropped soybean yields were also affected by the severe drought and responses to N, P, and S averaged 168, 181, and 87 kg/ha. Considering the 35 sites under soybean during eight seasons, a critical level of 12 ppm Bray 1 P has been established below which soybean P responses are highly probable.

Sites will be planted to wheat/soybean in the C-W/S rotation and to corn in the C-S-W/S rotation during the 2009/10 season. *Argentina-12*

Long-term Nutrient Management Network for Southern Buenos Aires Province

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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 nutrients other than N, P, and S, such as K, Mg, B, Cl^-, Cu, and Zn.

Four sites were planted to barley at Olavarria, Pieres, Tandil, and Tres Arroyos during the 2008/09 growing season. Check yields varied from 2,970 to 3,730 kg/ha, and fertilized yields varied from 2,830 to 6,190 kg/ha. Responses to P were significant at three of the four sites (Olavarria, Pieres and Tres Arroyos), with average yield increases between 560 to 2,620 kg/ha. The Pieres site showed a significant response to NPS (+1,320 kg/ha). Phosphorus responses were related to low soil Bray 1 P levels, as all sites were below 16 mg/kg, and the dry conditions that prevailed during most of the 2008/09 growing season. Responses to N, S, and other nutrients were variable and not significant at any site. These sites will be planted to soybean during the 2009/10 season. *Argentina-27*

Exploration of Responses to Potassium in Western Uruguay

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Project Cooperator: Juan Diego Cano

This research is partly based on previous observations of K deficiency and responses in field crops grown within the northwestern Uruguay region. Field experiments in the first 2 years of this study (2006/07 and 2007/08) have also showed significant responses to K fertilization.

For the 2008/09 season, three field experiments under corn, wheat/soybeans, and barley/soybeans were established at a site with exchangeable soil K of 0.33 cmol/kg (129 ppm), which is a low to medium soil test level for the region. Despite reduced yields caused by drought, all four crops showed significant response to K application: +250 kg/ha in wheat and barley (+14 to 16%), +500 kg/ha in doublecropped soybean (+20%), and almost 1,000 kg/ha in corn (+18%). Potassium fertilizer increased the number of spikes per m2 in wheat and barley, as well as flag leaf K concentration in barley. At harvest, exchangeable soil K levels were increased by 0.28 to 0.32 ppm per kg of applied K.

Additional field study and a compilation of research results for this and other projects is planned for the 2009/10 season. *Uruguay-02*

Americas Group

Northern Latin America and Mexico:
Dr. José Espinosa and Dr. Raúl Jaramillo

Colombia

Nutrition and Crop Management Effect on Banana Yield and Quality

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As in 2008, the combination of two fertilizer placement alternatives (spread across whole-area versus localized in front of the daughter plant) and three weed control alternatives (spot control of aggressive weeds with glyphosate, whole-area mechanical control, and whole-area glyphosate control) provided the same six treatments to be evaluated at two locations in Colombia.

Compared with 2008, yields at the Cenibanano's Experimental Station were 20% higher, but no increases were apparent at the Navarra plantation. Yields at Cenibanano were 30% higher than at Navarra and because of this all values for extracted nutrients were also higher – an average increase of 40 kg (N and K) per ha per t of fresh fruit. Similar to 2008, no statistical differences were observed between weed control alternatives, despite the whole-area control providing a slightly better yield and extraction rate. As well, the placement of localized fertilizer did not have any benefit compared with the use of a whole-area spread distribution for fertilizers. This is not only similar to the 2008 results, but was also observed in related experiments in Ecuador.

The use of localized fertilizer is therefore a practice that has no effect on banana yield and actually could increase labor costs. The only potential advantage to its practice would be an improved ability to audit the use of fertilizer by plantation managers. *Colombia-13*

Costa Rica

Interaction of Phosphorus and Zinc Fertilization in Coffee Growing in Deficient Soils

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Project Cooperator: Dr. Kenneth Hilton, Mosaic

As in 2008, there was a clear yield response with the application of P and a negative response with the use of Zn alone. In 2009, the highest yield was observed with P alone (9.1 t coffee cherries/ha) followed by the harvest obtained with both P + Zn (6.8 t/ha). Application of Zn alone generated the smallest yield of 3 t/ha, which was actually below the control yield of 4.05 t/ha. Changes in order of the three treatments with P application is expected due to the cycle of coffee production, but improvements in yield can only be explained by the use of P. Contrary to initial expectations, no response of Zn application could be observed. Instead, a toxic effect was apparent in this case where the soil was P deficient, no P was added, and only ground Zn was applied.

Because the major objective was to test and record the response of Zn in coffee production, this study terminates after the last harvest is recorded in March of 2010. *Costa Rica-12*

Ecuador

Site-Specific Nutrient Management for Corn in Ecuador

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The study once again selected the same six locations used in 2008, although plantings occurred on neighboring fields in 2009. As in planting seasons of the 2 previous years, rainy (January to May 2009) and dry (June to October 2009) were evaluated. A site-specific recommendation was evaluated for each location in addition to the treatments tested in 2008.

In comparison to 2008, the rainy season harvest with complete fertilization increased at all locations by about 2 t/ha. This was due to very favorable weather, but can also be attributed to the use of a new high yielding hybrid. Moderate rainfall during the dry season also produced elevated yields, which were comparable to the average yield for the rainy period and up to 3 t/ha higher than the 2008 dry season under complete fertilization. This was in contrast to the large differences observed between cycles in 2008. As in 2008, the lowest yield was obtained within the N omission plot in both planting cycles. Overall, the observed agronomic efficiencies for N ranged from 18 kg grain increase/kg N (Quevedo, Dry) to 42 kg/kg (Salapi, Dry) for the grower standard practice and from 26 kg grain increase/kg N (Salapi, Rainy) to 50 kg/kg (Come Gallo, Rainy) for the site-specific recommendation. Across all locations, both the complete and site-specific recommendation increased yields from 1.2 t/ha (Salapi, dry) to 4.3 t/ha (La Chonta, dry) in comparison with traditional management.

As new high yields were obtained in 2009, the amounts of fertilizer N have been increased to 220 kg N/ha for both the SSNM and complete fertilization treatments. Another year of trials is in place to validate recommendations able to obtain the highest attainable yield. *Ecuador-08*

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

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During 2009, the planting densities of 60,000 and 50,000 plants/ha were tested in two planting arrangements at four locations in Bolivar Province located within the Ecuadorian Sierra. All four combinations were fertilized based on previous results. Thus, 140 or 120 kg N/ha were used for high or low densities, respectively, and both densities received 70, 20, 20, and 10 kg/ha of P, K, Mg, and S, respectively. The sites also tested - N and - P plots as well as the conventional crop management, which is based on a low planting density of 35,000 plants/ha and comparatively lower fertilizer use of 50, 35, 15, and 0 kg/ha N, P, K, Mg, and S, respectively.

Large differences in grain yield were recorded between locations. Recommended fertilization treatments generated yields between 3.5 and 7.6 t/ha, respectively. The absolute lowest value of 0.8 t/ha was recorded in a plot omitting N, which was the poorest performing treatment at all locations. On the contrary, the P omission plots showed only small reductions in grain yield (~10%) across all locations. Agronomic use efficiency for N ranged between 20 to 32 kg grain increase/kg N in comparison with 9 kg/kg under traditional farm management. Phosphorus efficiency was calculated at only 7 to 15 kg grain increase/kg P. These results together with the large yield decrease observed without N application confirms the need for higher N use to obtain high yields.

In 2010 the project's four locations will only test the 50,000 plants/ha planting density within two planting arrangements and two alternatives for split application of N. Also, besides the conventional farmer practice, we will add a treatment using increased planting density and traditional amounts of fertilizer. This last new treatment will measure the benefits of improved agronomic management alone. Based on results in 2010, we will likely extend the project for a last year in 2011 which will include training events for the farmers of Bolivar. *Ecuador-09*

Nutrition and Crop Management Effect on Banana Yield and Quality

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The production of banana at both locations in 2009 was 50% higher than 2008. This increase is partially attributed to the shortening of harvest cycles once plants developed from initial plantings. The larger plants have also developed more canopy cover and there is generally less pressure from weeds, which may also be reflected in the yield increase. Contrary to 2008, significant differences were observed between the use of

conventional fertilization and balanced (optimized) nutrition. In San José, a 10% yield increase was observed and at the less productive site at Patricia Pilar the increase was 20%. As in 2008, and also similar to results in Colombia, the placement of fertilizer either localized in front of daughter plant or spread over the whole area did not generate any significant differences. The use of glyphosate may be linked to slight yield declines at both locations; however, these responses have yet to be determined as statistically significant.

Overall, responses to balanced fertilization at both locations were large. The experiment is continuing for another year which will include the addition of nutrient omission plots at one location, excluding N and K, which will allow for the calculation of nutrient use efficiencies. *Ecuador-10*

Evaluation of Rice Response to Zinc

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Experiments were continued in 2009 at the same locations and cropping seasons as in 2008, although the actual field locations were changed to neighboring fields. Also, treatments once again compared NPK, NPKMgS, NPKMgS+2 kg Zn/ha, and NPKMgS+6 kg Zn/ha. Planting took place in January and May during the rainy and dry seasons, while the harvest took place correspondingly in May and at the end of September/early October.

Yields at both locations showed large differences between seasons, reflecting the change in available sunlight and low temperatures. The best average yield at Samborondon was 14 t/ha, recorded during the rainy season, while the highest yield for Babahoyo was 12 t/ha during the dry season. In all seasons and locations, the addition of Zn resulted in higher yields when compared with NPK alone, which ranged from an additional 30% (Samborondon, Rainy) up to 100% (San José, Rainy). Statistically significant differences were not always found between the treatments supplying Zn and NPKMgS alone, but trends of 10 to 20% more yield were observed as a result of Zn addition. Treatments with Zn also increased net absorption of Zn and P by rice, which in the case of Zn ranged from 207 to 480 g extracted Zn/ha in comparison with base NPK values that ranged between 120 to 230 g Zn/ha. The economic analysis, based on fertilizer and grain prices of December 2009, indicate that farmers will benefit from 30 to 40% increases in income due to the addition of 2 kg Zn/ha plus NPKMgS in comparison with NPK alone. In Ecuador, the market does not pay a premium for increased food grain quality.

This was the last year of the study. Technical summaries of our results and presentations will be prepared for the Soil Science Congresses in Ecuador and Colombia. These results have triggered the sale of Zn fertilizers in the areas of influence. *Ecuador-11*

Evaluation of New Corn Hybrids Response to Zinc in Ecuador

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This study continued at the same locations of Gualipe and Quevedo with experiments conducted during the rainy (January to May) and dry (May to September/October) cropping seasons. Corn varieties included DEKALB 7088 for the rainy period and INIAP 553 for the dry season. Treatments were identical to those used in 2008 and included the comparison of NPK, NPKMgS, and NPKMgS+2.8 kg Zn/ha. All Zn was applied as ground zinc oxide.

Grain yield in the rainy season ranged between 5.4 t/ha under the NPK treatment at Gualipe and 10.9 t/ha generated by the NPKMgS+Zn treatment at Quevedo. For both planting sites, the grain harvest was statistically higher with the inclusion of Zn compared to either NPK or NPKMgS. Yield was 30% lower overall during the dry (non-irrigated) season. The lowest yield of 3.8 t/ha was found at Gualipe and highest yield of 9.4 t/ha was recorded at Quevedo. In this case the addition of Zn proved to be more effective than NPK, but not NPKMgS. During the rainy season, the inclusion of Zn increased the accumulation of Zn in the grain by 200% and increased P accumulation by 100% when compared to either the NPK or NPKMgS treatments. During the dry season these increases in grain Zn and P content were less than 100%, except for the low yielding site at Gualipe, where the response was equal to results obtained during the rainy season.

Overall, similar tendencies were noted between 2008 and 2009. In terms of yield, the use of Zn is highly advisable, and could be most beneficial for areas with high yield potential. The use of NPK plus Zn, Mg, and S markedly increased the quality of harvested grain in all seasons and locations tested. This was the last year of the study. *Ecuador-12*

Best Crop and Fertilizer Management Effects on Yield of Oil Palm

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Project Cooperators: Dr. Gustavo Bernal (Research Leader, ANCUPA), Ing. Alain Durant (Plantation Manager, OLEPSA), and Ing. Jorge Troya (General Manager, OLEPSA)

This study maintained the same treatments tested in 2008, including: 1) farmer practice, 2) regular leaf pruning, 3) leaf pruning and weekly harvest, 4) treatment 3 plus balanced fertilization, and 5) all the previously listed best crop and fertilizer management plus chemical weed control within a close circle around each plant.

In 2009, a second experiment is planned for a plantation at Tarragona in the Quininde region which has The OLEPSA site suffered from an unfortunate attack of leaf borer pests throughout the entire block and results from 2009 may not properly reflect the impact of the treatments alone. At this site, the cumulative yield of fresh fruit for 2009 showed values comparable to standard practice (46 t/ha/yr) with the leaf pruning (47 t/ha/yr), and with pruning plus weekly harvest (44 t/ha/yr). We did not observe any increase in yield with the combination of these practices and the use of balanced fertilization (44 t/ha/yr). Yield was highest with treatment 5 using the list of best practices plus chemical weed control (48 t/ha/yr). The twin experiment located at the Tarragona plantation showed similar results to those measured at OLEPSA in 2008. This site showed a rather high yield increase with recommended practices in comparison with regular practices and little differences among the rest of treatments.

These changes in cumulative yearly harvest reflect, most of all, that the full time needed to express the results in fruit yield has not been reached (40 months according to the literature). These experiments will continue for at least 1 more year at OLEPSA and 2 more years in Tarragona. *Ecuador-13*

Guatemala

Site-Specific Nutrient Management for Soft Corn Varieties in the Highlands of Guatemala

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Five experimental sites were established at Alta Verapaz to initiate a site-specific management project in farm fields within the highlands of Guatemala. A simple experiment was designed to compare a balanced treatment based on local experience against plots with individual omission of N and P. All experimental plots were planted with a population of 62,000 plants/ha arranged in rows 0.8 m apart and hills 0.4 m apart. Every hill received two seeds. This is a major change in crop management introduced in the experiment to ensure a uniform population. Farmers normally plant 40,000 seeds with 4 to 5 seeds in each hill, which are unevenly distributed in the field. Competition within the hills leads to only one or two plants producing a good corn ear and this reduces yield potential. The exploratory balanced treatment was 146-90-74 kg N-P_2O_5-K_2O/ha + 26 kg MgO, 43 kg S, 1.1 kg Zn, and 2.4 kg B/ha. Results will determine attainable yield under this new crop and nutrition management and will be used to calculate rates needed to achieve a yield target for 2010.

Grain yield from the five sites ranged from 4.5 to 3.1 t/ha for the complete treatment, from 4.2 to 2.0 t/ha the P omission plot, and from 2.6 to 1.2 t/ha for the N omission plots. The high yield of 4.5 t/ha is a reasonable estimate of attainable yield for the soil and climatic conditions prevalent in Alta Verapaz and has becomes the target yield for 2010. This is an important improvement over yields normally obtained by the local farmers. A new rate of fertilizers will be calculated at each site which will be tested in 2010 besides a new set of omission plots.

This process will progressively fine-tune the fertilizer rates for the recommendation domain at Alta Verapaz. Improved crop and fertilizer management can lead to higher attainable yields, higher nutrient use efficiency, and a better economy for the local farmers. *Guatemala-06*

Honduras

Site-Specific Nutrient Management for Corn in Honduras

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Only one experimental site (Ayapa) was planted in 2009 due to logistic complications. During 2008, the complete fertilizer treatment produced 7.3 t/ha at Ayapa and farm practice produced 6.2 t/ha. Plots omitting N, P, K, and Mg produced 1.7, 7.3, 6.7, and 6.9 t/ha, respectively. The yield obtained with the complete treatment was used as a yield goal for the next cycle because it closely represented current yield potential for the region. A new site-specific nutrient management (SSNM) fertilizer recommendation was calculated by accounting for yields obtained in nutrient omission plots. The application rates for the 2009 complete treatment were: 200-90-120 kg N-P_2O_5-K_2O + 44 kg MgO, 50 kg S, and 3 kg Zn/ha. Rates for the SSNM plot were: 200-50-100 kg N-P_2O_5-K_2O/ha + 44 kg MgO, 50 kg S, and 3 kg Zn/ha.

The complete fertilizer treatment produced 8.2 t/ha and farm practice produced 7.5 t/ha. Plots omitting N, P, K, and Mg produced 3.6, 7.4, 7.4, and 6.8 t/ha, respectively. The SSNM plot produced 8.5 t/ha. Overall, yields were higher than in 2008 due mainly to a better population management at planting time. Average plant population at germination was 79,600 plants/ha and the final population at harvest was 75,500 plants/ha. Agronomic efficiency for N (AE-N) for the complete treatment was 23 kg grain increase per kg of N applied while AE-N for SSNM was 24.5 kg/kg.

Better management of split N applications can produce further increases in attainable yield and agronomic efficiency. A new SSNM rate will be calculated and tested during 2010, having a target AE-N of 30 kg grain increase per kg of N applied. *Honduras-01*

Mexico

Global Maize Project in Mexico: Celaya, Guanajuato

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Project Cooperator: Dr. Benjamin Zamudio

The corn producing areas of tropical Latin America provide a diverse set of climatic conditions that result in a wide range of yield potentials and thus nutrient requirements. In tropical areas, latitude and altitude have a profound effect on yield. For these reasons, it is necessary to determine yield potential and attainable yield under the best known management practices. It is also necessary to quantify the effect of such management on nutrient use efficiency, particularly N. The study was conducted at Celaya, Guanajuato State, with an altitude 1,830 meters above sea level. The experiment will be in the field for at least 10 years. Treatments in 2009 were: 1) best crop management including all needed nutrients and optimal plant population (with amounts adjusted each year according to past results achieved); 2) farm practice including all changes made by farmers during the study period; 3) treatment 1 without N application; and 4) treatment 1 with N application in 2 of 3 consecutive years.

Best crop management + N and a plant density of 125,000 plants/ha achieved a highest yield of 13.8 t/ha; best crop management - N and 125,000 plants/ha produced 5.8 t/ha; farm practice + N and 90,000 plants/ha produced 12.7 t/ha; and farm practice - N and 90,000 plants/ha produced 4.9 t/ha. Results were influenced by a long drought that affected Mexico throughout 2009. The yield potential using the “Hybrid-Maize” model and NASA weather data was 23 t/ha. *IPNI-28*

Global Maize Project in Mexico: Toluca, México

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The corn producing areas of tropical Latin America provide a diverse set of climatic conditions that result in a wide range of yield potentials and therefore nutrient requirements. In tropical areas, latitude and altitude have a profound effect on yield. For these reasons, it is necessary to determine yield potential and attainable yield under the best known management practices. It is also necessary to quantify the effect of

such management on nutrient use efficiency, particularly N. The study was conducted at Tocula, Mexico State, at an altitude of 2,370 meters above sea level. The experiment will be in the field for at least 10 years. Treatments in 2009 were: 1) best crop management including all needed nutrients and optimal plant population (with amounts adjusted each year according to past results achieved); 2) farm practice including all changes made by farmers during the study period; 3) treatment 1 without N application; and 4) treatment 1 with N application in 2 of 3 consecutive years.

Although drought affected this site, best crop management + N and 90,000 plants/ha produced the highest yield of 7.6 t/ha, while the same plant density under best crop management - N produced 5.2 t/ha. Farmer practice + N and 70,000 plants/ha produced 7.0 t/ha, while the same plant density under farm practice - N produced 4.8 t/ha. The yield potential using the *Hybrid Maize* model and NASA weather data was 13.7 t/ha. *IPNI-29*

Evaluation of New Corn Hybrids Response to Zinc in Chihuahua, Mexico

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New corn hybrids used extensively in Latin America frequently show Zn deficiency. Treatments in this study included NPK, NPKMgS, NPKMgSZn, and PKMgSZn, which were tested at four different locations in the Cuauhtemoc area near Chihuahua, Mexico. The N omission plot was included to understand N dynamics and efficiency in the cropping system used in the region. Data obtained in 2008 of this 3-year project showed slight differences among fertilizer treatments. The best location was Field 305 with yields being 13.3, 12.8, 13.9, and 5.0 t/ha for the above list of treatments. The highest yield obtained at Field 305 will be used as a yield goal for the next two cycles at all sites because it likely represents the yield potential for the region. Yields at Soto Maynez were 11.4, 11.8, 12.0, and 6.5 t/ha; yields were 10.1, 11.0, 12.2, and 8.0 t/ha at Field 114; and yields at Field 15 were 11.2, 11.4, 11.3, and 3.5 t/ha, for the above list of treatments.

The study continued in 2009 in only two locations, Field 305 and Field 15, due to logistic difficulties. Data for Field 305 once again only showed slight differences among treatments with the exception of the N omission treatment. Yields were 15.0, 15.2, 15.5, 7.5, and 15.1 t/ha for NPK, NPKMgS, NPKMgSZn, PKMgSZn, and farmer practice, respectively. The experiment at Field 105 had a severe attack of Hyalothyridium and yields were too low to report. Agronomic Use Efficiency for N (AE-N) was calculated for each site from the difference between the high yield and the yield obtained within the N omission plot. During the 2008 cycle, the AE-N for Field 305 was 36 kg grain increase/kg N applied (250 kg N/ha). In 2009, AE-N was 32 kg grain increase/kg N applied (250 kg N/ha), but yields were higher than in 2008. Farm practice obtained a AE-N of 19 kg grain increase/kg N applied (420 kg N/ha) showing that less N is required to obtain high yields under this combination of climate and soil. The simulated yield potential generated by the *Hybrid Maize* crop model and NASA weather data was 21 t/ha and more work is needed to reduce this yield gap. *Mexico-50*

Site-Specific Nutrient Management for Corn in Jalisco, Mexico

Experiments were repeated at the sites in Jalisco State, but only the Nogal site finished the cycle, due to drought at the other two sites. At Nogal, the complete fertilizer treatment produced 10 t/ha and farm practice produced 7.0 t/ha. Plots omitting N, P, K, Mg, and S produced 8.4, 5.7, 5.9, 9.1, and 5.6 t/ha, respectively. The yield obtained with the complete treatment was used as a yield goal for the next cycle because it represents the yield potential for the region. A new site-specific nutrient management (SSNM) recommendation was calculated considering the new yield goal and yields obtained by the omission plots. The complete treatment included 220-90-120 kg N-P_2O_5-K_2O/ha + 44 kg MgO, 50 kg S, and 3 kg Zn/ha. The SSNM plots received 160-120-150 kg N-P_2O_5-K_2O/ha + 44 kg MgO, 50 kg S, and 3 kg Zn/ha.

The complete fertilizer treatment produced 10.8 t/ha and farm practice produced 9.9 t/ha. Plots omitting N, P, K, and Mg produced 8.7, 9.8, 10.2, and 10.3 t/ha, respectively. The SSNM plot produced 10.7 t/ha. Agronomic efficiency for N (AE-N) for the complete treatment was 9.5 kg of grain increase per kg of N applied and AE-N for under SSNM was 13 kg/kg. These AE-N values are low and reflect the effect of drought on grain yield. The same SSNM rate will be used during 2010 in hopes of more typical climatic conditions.

Four new sites were also included to expand the study. However, only two sites (La Barca and Tlajomulco) finished the cycle due to the effects of drought. At La Barca, the complete fertilizer treatment produced 11.8 t/ha and farm practice produced 9.8 t/ha. Plots omitting N, P, K, Mg, and S produced 6.1, 11.2, 11.3, 10.9, and 9.3 t/ha, respectively. At Tlajomulco, the complete fertilizer treatment produced 8.8 t/ha and farm practice produced 7.2 t/ha. Plots omitting N, P, K, Mg, and S produced 1.7, 7.3, 8.1, 7.4, and 7.2 t/ha, respectively. A new SSNM rate will be calculated and tested during 2010 following the same procedure described for the Nogal site. *Mexico-51*

Identification of Corn Yield Gaps in Tropical Latin America

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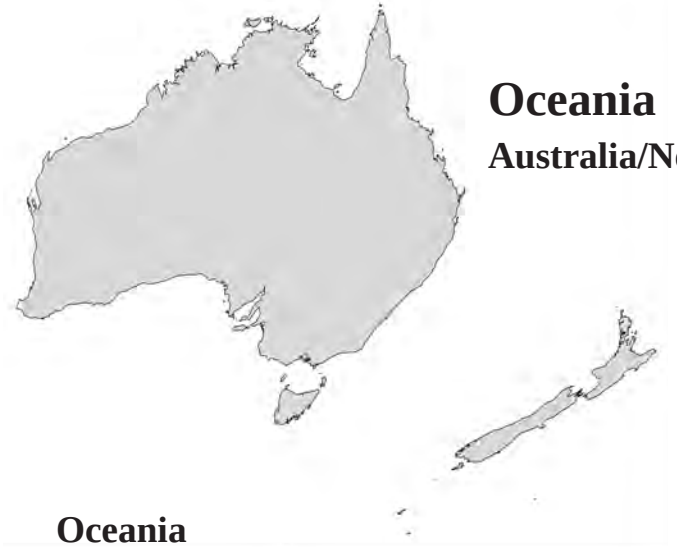
The corn producing areas of tropical Latin America provide a diverse set of climatic conditions that result in a wide range of yield potentials and consequently nutrient requirements. In tropical areas, latitude and altitude have a profound effect on yield. For these reasons, it's necessary to determine yield potential and attainable yield under the best known management practices. It's also necessary to quantify the effect of such management on nutrient use efficiency, particularly N. The study was conducted at two sites in Mexico: Celaya, Guanajuato State, altitude 1,830 meters above sea level and Tocula, Mexico State, altitude 2,370 meters above sea level. The experiment will be in the field for at least ten years. Treatments in 2009 were: 1) Best crop management including all needed nutrients and optimal plant population (with amounts adjusted each year according to past results achieved); 2) Farm practice including all changes made by farmers during the study period; 3) Treatment 1 without N application; and 4) Treatment 1 with N application in two of three consecutive years.

In Celaya, best crop management + N and a plant density of 125,000 plants/ha achieved a highest yield of 13.8 t/ha; best crop management - N and 125,000 plants/ha produced 5.8 t/ha; farm practice + N and 90,000 plants/ha produced 12.7 t/ha; and farm practice - N and 90,000 plants/ha produced 4.9 t/ha. Results were influenced by a long drought that affected Mexico throughout 2009. A simulated yield potential using the Hybrid Maize model and NASA weather data is suggested to be 23 t/ha. In Toluca, best crop management + N and 90,000 plants/ha produced the highest yield of 7.6 t/ha; best crop management - N and 90,000 plants/ha produced 5.2 t/ha; farm practice + N and 70,000 plants/ha produced 7.0 t/ha; farm practice - N and 70,000 plants/ha produced 4.8 t/ha. Drought also affected this site. The simulated yield potential for this site was 13.7 t/ha. *Mexico-52*



Oceania

Australia/New Zealand Region: Dr. Robert Norton

Oceania

Grain Mineral Contents in Southeastern Australia

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There is little recent data on grain P, Zn, and S contents from across Australia. This project is collecting two wheat varieties that have been grown in approximately 100 variety testing sites across Victoria, New South Wales, and South Australia. As of mid-January, approximately 30 samples have been received and once all are available, they will be sent for mineral analysis at Adelaide University. These data will be used to assess the spatial variability of grain mineral contents to assist with nutrient budgets as well as identifying areas where grain Zn and S levels are low.

Earlier research in Queensland indicated that grain P contents varied from 0.17 to 0.50% and such a range means there is a considerable error when nutrient budgets are used to guide fertilizer demand. To make a preliminary assessment of the grain levels, data from earlier experiments in Victoria were re-analyzed. These data were from nine sites across 2 years, but cultivars were different between the 2 years. These data show average grain P contents to be 2,592±443 mg/kg ... a CV of 17%. The levels of the other nutrients were S (1,656±197 mg/kg), K (3,931±527 mg/kg), Ca (365±81 mg/kg), Mg (967±141 mg/kg), Na (16±4 mg/kg), Cu (4±1 mg/kg), and Zn (16±4 mg/kg). Sodium and Zn were the most variable of the minerals assessed from that data set.

The data from 2009 will provide a larger sample using two consistent cultivars across a wide range of soil types, all of which have been soil tested. *ANZ-01*

Growth, Yield, and Water Use of Wheat under Elevated Carbon Dioxide

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While higher CO_2 is likely to stimulate plant growth, it seems that the interaction with changing water supply and rising temperatures will largely offset that "fertilizer" effect. To gain an understanding of these interactions, field experiments were conducted from June to December in 2008 at Horsham, Victoria, Australia on a vertisol used for a range of winter grain crops.

Atmospheric CO_2 was raised from ambient (380 ppm) to a target of 550 ppm using a FACE system, consisting of sixteen 12 m diameter experimental areas, with each area split for two irrigation treatments. Eight rings were sown on June 3 and the other eight on August 6. Within each half ring, the cultivars Yitpi or Janz were sown with no added N, and Yitpi was sown with added N.

Significant main plot effects were observed for sowing time and watering regime on biomass at Zadoks growth stage (GS) 30 (stem elongation), GS65 (mid flowering), and GS90 (ripening), as well as grain yield.

However, the results for growth, N concentration, and N uptake showed very few interactions between atmospheric CO_2 and sowing time, watering regime, or cultivar treatment. Across the three sampling times, the higher level of CO_2 increased aboveground biomass by 25%, 31%, and 32%. However, the plant N contents were significantly lower with higher CO_2 in all except the first sampling. This decline was also seen in leaf N concentration at GS65 where the leaf N declined from 3.78 to 3.54%, and at GS90 the grain protein content declined from 18.0 to 17.3%. We reported a similar decline in grain protein in 2007 and lower grain protein content under high CO_2 has been noted in other studies. It is likely that this effect is a consequence of lower N contents in the plant during growth, which leads to a lower labile N pool for N translocation during grain filling. In this experiment, the mean straw C:N ratio was 49.5±1.4 and it was not significantly affected by the carbon dioxide level. Even though this ratio was not affected, there was more stubble with elevated atmospheric CO_2 and this may lead to a larger demand for soil N to breakdown the stubbles. This research is on-going. *ANZ-02*

Ammonium Sulfate for Canola in Southeastern Australia

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This project is investigating the role ammonium sulfate (AS) can play as a fertilizer for cropping systems in southeast Australia. A pot experiment showed that after 42 days, compared to the control, AS gave a 104% growth response compared to urea/gypsum (61%) in canola. When a similar experiment was conducted using wheat as the test crop, AS and the urea/gypsum application produced similar responses. To test these effects, field trials were established at Pira and Nurrabiel, in western Victoria. Both sites were expected to respond to S and a range of fertilizers were compared. The control (no fertilizer) was compared to urea, gypsum, urea/gypsum together, and AS to supply 35 kg N/ha and/or 40 kg S/ha at sowing with 34 or 46 kg P_2O_5/ha.

The site at Pira showed a significant yield response to both applied S as gypsum with or without urea (+44%), but no significant response to urea alone. A large yield response was observed (+75%) when both N and S were supplied as AS. At Nurrabiel, neither urea nor gypsum alone, or in combination, gave a significant yield response, but when N and S were supplied together as AS, yields significantly increased by almost 30% (1.83 t/ha with urea/gypsum compared to 2.36 t/ha with AS). The urea/gypsum treatment was not significantly different from the control. None of the treatments had a significant effect on wheat grain yield at Nurrabiel. It seems that the S from gypsum was somewhat less available than the S from AS fertilizer at both these sites. There may also be synergy by placing N and S placed with AS, as similar effects have sometimes been noted with the co-placement of N and P fertilizers for cereals. The reasons for this could be a consequence of rhizosphere acidification, co-placement of N and S, or some other issue.

A clear understanding of why AS performed better than urea and gypsum will provide growers with guidelines about where this fertilizer can be reliably used. It is also possible that blending AS with other N sources could provide new types of mixed nutrient fertilizers for canola and other crops where N and S are in demand. *ANZ-03*

Nitrogen Dynamics under Elevated Carbon Dioxide

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Project Cooperators: Shukee Lam, Ph.D. student, The University of Melbourne and Dr. Roger Armstrong, Victorian Department of Primary Industry

The Australian Grains Free Air Carbon Dioxide Enrichment (AGFACE) facility was established to compare wheat growth, yield, and development under ambient atmospheric carbon dioxide (a[CO_2] ~380 ppm) and elevated atmospheric carbon dioxide (e[CO_2] ~550 ppm). Experiments on fertilizer N recovery, straw decomposition, and greenhouse gas production have been undertaken to estimate how e[CO_2] and a changing climate could affect crop production systems.

Elevated CO_2 increased crop biomass at the end of tillering, anthesis, and maturity. Although plant and grain N contents declined, crop N uptake was 24% higher with e[CO2]. Stubble C:N ratio was not affected by e[CO_2].

Wheat was grown with 15^N enriched urea in PVC microplots at 50 kg N/ha in the AGFACE facility. Harvest biomass increased by 23% and N uptake increased by 17% under e[CO_2]. Like the main experiment, C:N ratio of the stubble was not affected by e[CO_2] and it had no significant effect on the proportion of N

derived from fertilizer (%Ndff) for grain, stem, and root. There were no significant effects of e[CO_2] on 15^N recoveries in soil and total fertilizer N losses. The effects of e[CO_2] and irrigation on straw decomposition and soil respiration was also undertaken within the AGFACE experiment. Pure cotton cloth, wheat straw, and pea straw were decomposed using litter-bag method for 140 days. The mass remaining was the highest for cotton cloth (90%), then wheat (73%), and pea (50%). Total C content of wheat and pea straw and total N content of pea straw were reduced only under e[CO_2] and irrigated conditions. Soil CO_2 emissions were increased by e[CO_2] only under irrigation.

In these experiments, the C:N ratio and degradation of organic residues in the wheat crop is not affected by CO_2 levels, although large amounts of residue would enter soil nutrient cycles. These data indicate that e[CO_2] increases plant N demand, but does not increase the efficiency with which fertilizers are used nor the likely supply of N from residues. Further research is planned to investigate mineralization and N fixation under e[CO_2] and these data will be used to develop N strategies for future cropping systems. *ANZ-04*

Asia Group

China

Southwest Region: Dr. Shihua Tu

Nutrient Management Strategies for Lowland and Upland Cropping Systems in Chongqing

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Project Cooperator: Mr. Henglin Dai

This on-going monitored village site was established in 2001 to study the effects of different P and K treatments on crop yield. Results are being used to guide fertilizer application for the county, track changes in soil fertility, and predict sustainability under different nutrient input regimes.

In the lowlands, rice yield in the zero fertilizer check has continually declined over the past 7 years to 54% of the optimal (OPT) treatment. Compared to the OPT, rice yield was 2,362 kg/ha (38%) lower with P omission, and 1,325 kg/ha (17%) lower with K omission. Application of Zn did not improve rice yields. However, the use of calcium-magnesium phosphate instead of single superphosphate, which introduced Mg and raised soil pH, produced 575 kg/ha (8%) more than the OPT. In the uplands, all three crops showed better responses to P than K. Omission of P reduced yield by 41% for wheat, 37% for corn, and 23% for sweet potato; without K, yield was reduced by 26% for wheat, 28% for corn, and 30% for sweet potato. Maximal crop yields in 2009 were 2,115 kg/ha for wheat, 5,715 kg/ha for corn, and 5,050 kg/ha for sweet potato, which were obviously lower than those obtained in 2008, most likely a result of drought in spring season.

As in previous years, annual application of P and K was of great importance in maintaining high crop yields and soil fertility status. *Chongqing-NMS-05*

Effect of Potassium Fertilizer Source and Rate on Yield and Heavy Metal Contents of Chinese Cabbage in Chongqing

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This project is studying the effect of two sources of K fertilizer on yield and heavy metal content of Chinese cabbage planted in the suburban region of Chongqing City. Project results will guide K fertilizer application and nutrient management in this and similar areas under intensive vegetable cultivation. The two sources of K fertilizers were potassium chloride (KCl) and potassium sulfate (K_2SO_4). The rates were 0, 75, 225, and 450 kg K_2O/ha. All the treatments received 300 kg N/ha as urea and 150 kg P_2O_5/ha as single superphosphate. Both P and K fertilizers were applied as a single basal application, while N was split equally between the 4-leaf stage and leaf-ball formation.

Cabbage yield increased with increasing K rate regardless of source. Differences between two K sources were not statistically significant. At the lowest rate, both K sources significantly increased the content of amino acids compared to the check (CK), while all the other K treatments decreased amino acid content. Potassium sulfate applied at 75 kg/ha was the only treatment that enhanced vitamin C content. All rates of KCl produced lower sugar contents than K_2SO_4.

The effects of K source and rate on heavy metal uptake were not significant with the exception of KCl applied at 450 kg/ha, which significantly enhanced uptake of Pb (+20.4%) and Cd (+14.2%) compared to the CK. Mercury (Hg) uptake by cabbage was generally lower with larger rates of KCl, but increased under larger rates of K_2SO_4. Uptake of arsenic (As) was also positively related to increased rates of sulfate.

The study suggests that care must be taken to avoid excessive heavy metal uptake in vegetables grown on soil with risk of heavy metal pollution. The selection of the right source and rate of K fertilizer can prevent heavy metal uptake in these cases. *Chongqing-BFDP-09*

Nutritional Characteristics of Two Major Varieties of Litchi in Guangdong

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The objectives of this study were to understand the nutrient requirement and allocation in litchi as well as its rooting soil volume. To fulfill these objectives, two representative types of 15-year-old adult litchi trees (Guiwei and Feizhixiao) were dug out from two well-managed litchi plantations before harvest. Root length, weight, and spatial distribution in the soil were measured, and nutrient uptake and allocation within the plant were analyzed. Field experiments were also set up to test optimal fertilizer rates on litchi yield and quality. The results obtained from this experiment will be used to develop the best nutrient management options for litchi, including specific techniques for soil sampling.

To produce 100 kg of fruit, the Guiwei variety required the following applications per tree: 0.90, 0.92, 1.09, 0.91, 0.13, and 0.16 kg from a mature stand, each of N, P, K, Ca, Mg, and S as well as 17.10, 9.60, 0.56, 1.34, 1.39, and 0.0004 g of Fe, Mn, Cu, Zn, B, and Mo, respectively. The Feizixiao variety has a comparatively higher demand, as follows: 1.25, 0.37, 1.94, 1.36, 0.16, and 0.22 kg of N, P, K, Ca, Mg, and S plus 29.25, 3.24, 0.82, 3.01, 1.69, and 0.003 g of Fe, Mn, Cu, Zn, B and Mo, respectively. Nutrients removed by 100 kg of Guiwei fruits at harvest were 192, 30, 338, 40, 22, 22, 0.67, 0.65, 0.15, 0.35, 0.22, and 0.0003 g of N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, B, and Mo, respectively. For Feizixiao, all the nutrients were taken up in equivalent amounts with the exception of K, Mn, and Mo, which were twice the values observed for Guiwei. In terms of nutrient allocation in the plant, N, P, K and Cu were mainly accumulated in trunk, followed by the leaves and fruit; Ca was largely found in the trunk; Mg, S, Fe, Zn, and B in trunk and leaves; Mn in the leaves; and Mo was split between the fruit and leaves. The spatial rooting distribution was confined within a 6 m diameter and 0 to 70 cm or 0 to 50 cm depth for Guiwei and Feizixiao, respectively.

The information generated from this study greatly improves our in-depth understanding of the nutritional characteristics of two distinct litchi varieties and will lead to significant improvements in nutrient management within the province. *Guangdong-BFDP 09*

Effect of Balanced Fertilization on Pineapple Yield and Quality in Guangxi

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Project Cooperator: Mr. Liuqiang Zhou

This study continues to evaluate the effects of different fertilizer rates and combinations on fruit yield and quality of pineapple grown in Guangxi. Thirteen treatments tested four rates of N (0, 188, 375, and 562 kg/ha), four rates of P (0, 75, 150, and 225 kg P_2O_5/ha), four rates of K (0, 300, 450, and 600 kg K_2O/ha), Mg at 54 kg MgO/ha, B at 4.5 kg borax/ha, and Zn at 4.5 kg zinc sulfate. The optimum (OPT) treatment, based on soil testing and preliminary research, was set at 375-150-450-54 kg N-P_2O_5-K_2O-MgO/ha.

Pineapple yields responded to N, P, and K application and reached a peak yield of 35 t/ha under the OPT. Yields were reduced when application rates of N, P, and K were either below or above the OPT. Removing Mg from the OPT also resulted in a significant (-10%) yield reduction. Similar to the previous results, addition of Zn along with the OPT did not improve yield, whereas addition of B significantly reduced yield. Critical values for these micronutrients need to be adjusted since soil testing did indicate existing deficiencies. Agronomic efficiencies for the macronutrients were higher than in 2008 and ranged from 29 to 58 kg fruit increase/kg N applied, 26 to 44 kg fruit increase/kg P_2O_5, and 38 to 60 kg fruit increase/kg K_2O. The net income from the OPT treatment was US$6,035/ha, which was significantly above the other imbalanced fertilizer treatments. *Guangxi-BFDP-08*

Effect of Balanced Fertilization on Pineapple Production in Hainan

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Project Cooperator: Mr. Wen Zhang

This study continues to investigate the effect of fertilizer on yield and quality of pineapple on Hainan Island to develop fertilizer best management practices. The experiment consists of six treatments, including an optimal treatment (OPT) with 540-210-810 kg N-P_2O_5-K_2O/ha and a series of nutrient omission plots. This design was based on soil testing and results from a previous field study. The site has very high nutrient

leaching potential, with high rainfall, coarse-textured soil with poor structure, and extremely low nutrient adsorption capability. Thus, all fertilizers were split five times to minimize nutrient losses through runoff during the growing period.

Compared to the OPT, pineapple yield was significantly reduced under each individual nutrient omission treatment. The yield reduction was 16.4 t/ha (-29%) with N omission, 5.6 t/ha (-9%) with K omission, and 3.1 t/ha (-5%) with P omission. The K omission plots had slightly lower sugar contents in harvested fruit and the P omission plots had reduced contents of vitamin C compared to the OPT. Agronomic efficiency for the applied nutrients was measured at 30, 15, and 7 kg fruit increase per kg of N, P_2O_5, and K_2O applied. Similar to research data obtained in Guangxi, more than 90% of these nutrients remained in the stem and leaf and only a small proportion was transferred to the fruit at harvest. This suggests that recycling of crop residue would be of great value. *Hainan-08*

Nutrient Losses from Sloping Lands as Affected by Methods of Surface Mulching and Cultivation in Sichuan

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The objective of this project was to evaluate effects of different methods of surface mulching and cultivation on corn yield and nutrient losses from Sichuan's sloping farmlands during the summer rainy season. Three types of surface mulching included a check (no mulching), wheat straw, and plastic film. The three methods of cultivation included non-ridged or flat cultivation, down-slope cultivation (ridged), and contour cultivation (ridged). The NPK fertilizer rate was 225-150-150 kg N-P_2O_5-K_2O/ha according to soil test fertilizer recommendations.

Contour cultivation was best at enhancing corn yield, followed by flat cultivation. Plastic mulching was better than straw mulching, but all mulching treatments produced significantly higher corn yields compared to the check. The combination of plastic mulching + contour cultivation produced the highest corn yield. Any methods able to conserve more soil moisture could produce more corn yield on these rain-fed sloping lands. Treatments without mulching led to much more severe water losses and soil erosion compared to those with mulching. In this case, the down-slope treatment performed the worst, followed by the flat cultivation treatment. The amounts of soil eroded from the down-slope treatment (25.4 t/ha) and flat cultivation treatment (22.3 t/ha) were about 5 to 6 times that observed from the contour treatment (4.3 t/ha). Straw mulching reduced soil losses to only 0.1 t/ha under contour cultivation and 0.9 t/ha under down-slope cultivation. Though plastic mulching was superior to straw mulching in terms of corn yield response, it increased soil erosion by more than 10 times to 2.2 t/ha under contour cultivation and 10.8 t/ha under down-slope cultivation. Since the nutrient losses from these sloping lands were induced by water loss and soil erosion, the quantity of N, P, and K losses was closely related to these factors.

Contour cultivation + plastic mulching was very effective at increasing corn yields on these rain-fed sloping lands; however, contour cultivation + straw mulching was superior in terms of both corn yield response and preventing the loss of nutrients. *Sichuan-BFDP 09*

Nutrient Management Strategies for Wheat-Corn and Wheat-Rice Systems in Sichuan

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Project Cooperator: Mr. Yucheng Qin

Two on-going monitored village sites continued their study of nutrient management and crop responses in a wheat-corn system at Jianyang and a wheat-rice system at Chongzhou, both in Sichuan Province.

At Jianyang, crop responses to added nutrients were similar to previous years. Nitrogen was still the most limiting nutrient for both wheat and corn. Compared to the optimal (OPT) treatment, wheat yield reductions were the highest with N omission at 1.3 t/ha (-43%) and were similar under P omission (-19%) or K omission (-15%). Corn yields suffered most from K omission, losing 4.5 t/ha (-70%), followed by N omission at 3.0 t/ha (-47%). Meanwhile, P omission was least significant at 927 kg/ha (-15%). This is the fourth year that corn yields were impacted more by K than P. The impact of omitting Mg or Zn has grown with time. Omitting Mg or Zn from the OPT reduced corn yield by 380 kg/ha (-6%) and 758 kg/ha (-12%), respectively. At Chongzhou, N was still most limiting for wheat and rice. Wheat yields were most affected (-1.9 t/ha, or -39%) by N omission, then K (-700 kg/ha, or -14%), then P (-317 kg/ha, or -6%). The smaller response to P might be related to a warm winter in 2008, since crops become less responsive to P under elevated winter temperatures in the subtropical region. Rice yields were also most affected by N omission (-1.3 t/ha, or -32%) and were equally impacted by K or P omission (450 kg/ha, or -15%).

The results generated from these long-term experiments indicate that crop yields are most significantly affected by weather and nutrient management. Balanced fertilization is crucial to maintain high crop yield and nutrient use efficiency. *Sichuan-NMS-01*

Improving Topsoil Quality and Crop Productivity with Sloping Land Management Using Balanced Fertilization and Cash Crop Hedgerows in Yunnan

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Project Cooperator: Mr. Zhongwu Zhang

In its final year. this trial continues to monitor the effects of balanced fertilization, contour cultivation, and hedgerow crops as soil conservation measures for the sloping lands of Yunnan.

Soil erosion was highest in the farmers' practice (FP) plots, measured at 241 m^3/ha in water run-off and 5.3 t/ha in soil loss. The second and third most severe soil and water losses were observed with down slope + balanced fertilization (DC+BF) and BF, respectively. The BF + hedgerow crops (BF+H) and FP+H treatments had no run-off or soil erosion throughout the summer rainy season. The BF treatment produced the highest corn yield (12.4 t/ha), followed by BF+H (11.68 t/ha), DC+BF (9.94 t/ha), FP (8.64 t/ha), and FP+H (5.87 t/ha). The yield differences between treatments were large and highly significant, as treatments including FP led to corn yield reductions between 70 to more than 100%. The yield reduction attributed to the BF+H treatment versus the BF alone was attributed to hedgerow occupation of land and its competition for moisture and nutrients with corn. Nevertheless, the adverse effect of hedgerows on the in-field corn crop can be offset by the enhanced economic return generated from the hedgerow crops. The BF+H combination produced the highest net income (US$1,720/ha), followed by BF alone (US$1,164/ha). The lowest net income was from FP (US$567/ha) and FP+H (US$243/ha).

Good nutrient management combined with other agronomic practices can be the solution for high yields and incomes as well as environmental protection. *Yunnan-09*

Improved Nutrient Management to Reduce Run-off Losses from the Commercial Floral Production Surrounding Dianchi Lake in Yunnan

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Project Cooperator: Libo Fu

A huge commercial floral production base has developed around the Dianchi Lake over the past 10 years, and it has flourished due to good climate and geographic location. High profitability has stimulated the use of all crop inputs and has especially resulted in over-application of fertilizers. This is blamed, at least partially, for water eutrophication of the lake. This study investigated the effects of nine fertilizer treatments on growth and nutrient uptake of three rose cultivars (black, pink, and super) as well as nutrient loss through run-off. Treatments included a check (CK), farmers' practice (FP) using N and P only, and selected combinations of four N rates (0, 187.5, 281, and 375 kg N/ha), four P rates (0, 112.5, 169, and 225 kg P_2O_5/ha), and 315 kg K_2O/ha. All fertilizers were split three times between transplanting, floral initiation, and budding.

Rose flower numbers were significantly improved by reducing N and P rates, and with added K. The optimal treatment for all three rose cultivars was two-thirds of the current N and P rates used by farmers plus K (i.e., 187.5-112.5-375 kg/ha). This treatment increased black, pink, and super rose flower numbers by 5,780, 25,290, and 28,770/ha (8%, 19%, and 16%), respectively, when compared to FP. All the other treatments with reduced fertilizer rates had significantly fewer flower numbers. The total amount of nutrient uptake by the three roses followed the order of: super > black > pink for N; and super > pink > black for P. However, neither N nor P uptake by the three rose cultivars was closely correlated to fertilizer rate, which is a reflection of high initial soil N (available N >250 mg/kg) and P (available P >46 mg/kg) levels. Amounts of N or P detected in the effluent from the experiment fields were significantly increased under higher N or P rates. Furthermore, increased N rates also intensified P losses through leaching, but this did not hold true for the effect of increased P rates on N losses.

The results substantiated the hypothesis that floral fertilization in fields surrounding Dianchi Lake is excessive and should be rationalized to achieve better flower harvest, income, and environmental protection. *Yunnan-BFDP-09*

Effect of Controlled-Release Urea on Rice Yield and Nitrogen Use Efficiency in the Sichuan Basin

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Project Cooperators: Wenqiang Feng and Yusheng Qin

The objective of this study was to evaluate the effects of controlled-release urea (CRU) applied at rice transplanting and regular urea (RU) split between transplanting and the tillering stage. The study will assess treatment impact on crop yield, N uptake, residual soil N, and economic benefit. The experiment was conducted on a medium-to-high fertility soil with four N rates (0, 75, 112.5, and 150 kg N/ha). Each rate of N was tested with both CRU and RU. In addition, a RU treatment using a 40:60 split between a basal application at transplanting and a top-dressing at tillering was compared against a 40:60 split of RU:CRU applied as a single basal application at transplanting. All treatments received equal rates of P and K applied at transplanting.

When N was applied as a single basal application, CRU significantly increased yield compared to RU by properly controlling tillering and facilitating the formation of bigger ears. The optimal N rate of CRU appeared to be 112 kg N /ha. When RU was used in a 40:60 split between transplanting and tillering, yield improved by only 3% compared to the single basal application at transplanting. Mixing RU and CRU at a ratio of 40:60 and using a single basal application could reduce the time spent applying fertilizer, increase yield, and lower the costs associated with CRU. CRU was superior to RU in enhancing N recovery (up to 70%) and agronomic efficiency. Both N recovery and agronomic efficiency were increased as N rate decreased. The net income from CRU, at each N rate, was 2% to 8% higher than RU.

The results suggest that CRU is a promising candidate to replace RU as a single basal N application in single rice. A mixture of 40% RU and 60% CRU can be another option to reduce the cost associated with CRU while maintaining high rice yields. *Sichuan-BFDP-09* ❖

Asia Group

China

Southeast Region: Dr. Fang Chen

Effect of Fertilization on Yield and Quality of Medicinal Crops in Anhui

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Radix paeoniae and Rhizoma Atractylodis Macrocephalae are famous traditional Chinese medicinal herbs in Anhui. Cultivated area of these herbs covers 70,000 ha in Bozhou County. Based on past year's results, Anhui Agricultural University is continuing to conduct field fertilization trials for these two crops in 2009.

Results found the best NPK treatment in Radix paeoniae to be 300-150-75 kg N-P_2O_5-K_2O/ha, producing 65,224 kg/ha and and economic benefit of US$76,734/ha. This was 13.5% higher than results achieved with common practice. The average peony glucoside content in the product reached 3.45%, also a 13.5% improvement over common practice. Potassium had a significant effect on peony glucoside content.

Work with *Rhizoma Atractylodis Macrocephalae* found branches, root length, root diameter, yield, and economic benefit all increased with application of K fertilizer. The best NPK rate was 150-120-225 kg N-P_2O_5-K_2O/ha, which increased yield by 1,188 kg/ha (15.8%) and the benefit to farmers by US$3,494/ha (+13.4%) over the zero K treatment. Phosphorus application also increased branch number, root length, root diameter, yield, and economic benefit. Application of 120 kg P_2O_5/ha increased crop yield by 891 kg/ha (11.5%) over zero P application, a response valued at US$2,619/ha. *Anhui-17*

Nutrient Management and Balanced Fertilization Technology for Super-High-Yielding Wheat

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Anhui is one of the five largest winter wheat producing provinces in China. However, the average winter wheat yield is 3,195 kg/ha, which is 80% of the national average. Low yields are blamed on poor fertilization practices and this project is re-evaluating NPK fertilization throughout the province.

Field plots testing N, P, and K rates determined a common optimum (OPT) treatment of 180-75-90 kg N-P_2O_5-K_2O/ha. Paddy soil in the Jianghuai hilly region was more responsive to K than the calcareous black soil of the Huaibei plain region. Field experiments of winter wheat in Linquan and Feixi Counties showed large yield responses and economic benefits to balanced applications of N, P, and K. In Linquan, the optimum (OPT) treatment of 180-75-90 kg N-P_2O_5-K_2O/ha produced 6,836 kg/ha, which was 22.1%, 10.5%, 9.4%, and 25.0% over plots omitting N, P, K, and the farmers NPK fertilization, respectively. However, wheat yield under an OPT+15 kg Zn/ha treatment was 10% higher (7,532 kg/ha). *Anhui-18*

Balanced Fertilization Technology to Control Nitrogen and Phosphorus Loss in Intensive Vegetable Soil

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The management of nutrients in vegetable production areas is more often in excess of crop requirements, a response of growers to the high value of their production. A series of nutrient management trials in vegetables was carried out in Fujian Province, with the following results.

Rational application of K fertilizer promoted uptake of N and P in soybean grown at Longhai County and reduced the potential for environmental loss. The study used 180 kg N/ha and 90 kg P_2O_5/ha and 60, 120,

and 180 kg K_2O/ha. Soybean yield was 2,559 kg/ha with no K fertilization, and increased yield by 8, 12, and 14%, respectively, with increasing K rate. Nitrate-N (NO_3-N) concentration in soil column drainage water decreased from 146 to 86 mg/L under adequate K, while total P concentration in water samples decreased from 0.245 mg/L to 0.203 mg/L.

In a high fertility field in Pinghe County under kidney bean-cucumber-early rice cultivation, pre-study NO_3-N concentrations averaged 337 mg/L. At kidney bean harvest, NO_3-N concentrations for treatments supplying 60 to 240 kg N/ha ranged between 235 to 866 mg/L. In cucumber, rates between 105 to 420 kg N/ha produced post-harvest NO_3-N concentrations between 512 to 1,766 mg/L. Early rice yields reached 6,750 kg/ha with no fertilization, and post-harvest NO_3-N concentrations of water samples ranged between 303 to 426 mg/L. This range resembled the pre-study value. Pre-study P concentration for water samples was 0.437 mg/L. After three crop harvests, the average P concentration from check samples was 0.211 mg/L. Application of higher P rates to cucumber increased total P concentrations to 4.390 mg/L. In rice, P concentrations at mid or high P rates were about 25 to 50% lower than measurements taken after cucumber harvest and rice yields were 6,750 kg/ha.

In a carrot-rice rotation in Putian County, pre-study total P concentrations averaged 0.249 mg/L. In treatments providing 0 to 180 kg P_2O_5/ha to carrot, post-harvest P concentrations ranged between 0.201 to 0.485 mg/L. In the treatments providing 0 to 60 kg P_2O_5/ha to early rice, post-harvest P concentration ranged between 0.228 to 0.291 mg/L. *Fujian-09*

Nutrient Characteristics and Optimized Fertilization Techniques for Lotus Root

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A pot experiment studying the effects of N on lotus characteristics and a field trial of NPK fertilization was continued in 2009. Pot study treatments included a N omission check (CK) providing (PKBZn), an optimum (OPT) supplying NPKBZn, and an OPT with twice the N rate (2N) to simulate its over-application. Rates under the OPT were 45-15-45-0.5-0.5 g of N-P_2O_5-K_2O-Borax-$ZnSO_4 \cdot H_2O$ per 100 kg air-dried soil.

The main results found appropriate N application could obviously promote lotus to generate more standing-leaves and thus larger leaf area for photosynthesis. Ample N also slowed down the senescence of floating and standing leaves. Adequate N increased the SPAD value of standing leaves, which is correlated to a higher content of leaf chlorophyll. Both omission and over-application of N produced negative effects on growth and development of lotus. Nitrogen deficiency resulted in early leaf senescence, while its over-application led to both the delay of early lotus growth and accelerated leaf senescence in its later growth stage. Based on improved leaf photosynthesis, dry matter accumulation as well as healthy growth of lotus, adequate N application also improved the plant translocation from leaves to roots, and thus better root yields. Setting the relative yield of OPT at 100%, the CK and 2N treatments produced yields of 30% and 44%, respectively.

In the field, optimum nutrient application was 360-120-360 kg N-P_2O_5-K_2O/ha, producing a lotus yield of 26,546 kg/ha, which was 42, 17, and 20% greater than the treatments omitting N, P, and K, respectively. Net profit under the OPT was US$1,865, US$885, US$797/ha, greater than the N, P, and K omission treatments, respectively. At the OPT rate, the recommendation was to use 40% of N rate as basal dressing, 20% as a topdressing in early June, and the remainder topdressed at the end of June. Compared with local practice, the OPT produced broader, higher, more numerous lotus leaves, and thicker lotus stems. *Hubei-23*

Plant Nutrition and Balanced Fertilization Technology for High Yield and Quality Peanut Cultivation

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An investigation of farmers' peanut fertilization practices and soil fertility in Hubei Province was carried out in 2009 by the Oil Crop Research Institute of the Chinese Academy of Agricultural Science. Twenty counties were selected, 450 questionnaires were distributed, and 69 soil samples were tested.

Farmers' fertilization for N, P, and especially K were commonly lower than the peanut crop's need. Soil pH was acidic (3.9 to 5.3) in southeast Hubei and alkaline (7.4 to 8.3) in central and western Hubei. Soil organic matter and available N, K, and S were low, available P and B were moderate, and available Ca, Fe, Mn, Cu, and Zn were high. Peanut yields under an optimum (OPT) treatment of 120-135-135 kg N-P_2O_5-K_2O/ha

were 3,166 kg/ha and 3,016 kg/ha in Hong'an and Yicheng Counties, which were 37% and 32% higher than the check and 27% and 9% higher than common practice. The yields of OPT-N, OPT-P, and OPT-K were significantly lower than than OPT. *Hubei-28*

Controlling Nitrogen and Phosphorus Losses in Farmland of Hubei

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The Hubei Academy of Agricultural Science carried out this project on reducing N and P losses from fertilization in 2009. Average N loss from run-off was 10.7 kg/ha, with loss from the dry season (rapeseed, Oct-May) being 6.6 kg/ha (61%) and loss from wet season (rice, Jun-Sep) being 4.1 kg/ha (39%). Average P loss from run-off was 0.8 kg/ha, with dry season losses representing 0.5 kg/ha (60%) and wet season losses representing 0.3 kg/ha (40%). Rainfall significantly influenced run-off volume. Dry season rainfall accounted for 60% of the total and the run-off volume in the dry season was also 60% of the year's total. Losses of N and P in the check (CK) were 6.5 and 0.5 kg/ha; while N and P losses from the optimum (OPT) were 10.5 and 0.8 kg/ha. Thus, fertilization contributed to 38% and 33% of N and P losses, respectively. Relationship between yields and rates from N and P fertilization could be described by second polynomial equations. Annual maximum yield application rates were calculated as 545 kg/ha for N and 89 kg/ha for P; the economic optimum application rates were 473 kg/ha for N and 84 kg/ha for P. Annual optimum rates of fertilizer N and P application were 383 kg/ha and 83 kg/ha for rapeseed-rice cropping rotation in this region. Loss of N resulting from the OPT+manure treatment was higher than from the OPT. Organic N from manures is more susceptible to loss compared to the fertilizer N applied. Differences in P losses between the OPT and OPT+FYM were not as large due to the magnitude of the losses measured. Straw N content should also be considered within the total N input if it is returned to farmland. *Hubei-31*

Nutrient Management Technology for Chestnut

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Chestnut has a long history in Hubei Province and is widely planted today for its high economic value. In 2006, Hubei's area planted to chestnut reached 200,000 ha, which produced 94,490 t. Hubei is very suited for chestnut planting, but despite its history, many problems have been found in traditional chestnut management, particularly regarding its fertilization. The purpose of this project, implemented by Hubei Academy of Forestry Science in 2009, is to increase chestnut yield and improve nut quality and provide better nutrient management measures for local farmers.

Problems identified for chestnut fertilization include low K and P fertilizer use relative to N. Results from 112 soil samples found average soil pH to be 6.7, average soil organic matter content was 1.55%, and available N, P, and K contents were 109 mg/kg, 17 mg/kg, and 85 mg/kg. The response of chestnut trees to fertilization was not significant in this first year, but the response needs to monitored over a number of years to follow. *Hubei-32*

Soil Fertility Evaluation and Management Strategies for Garden Plants

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Increasing the diversity of ornamental species and promoting stability for the vegetative community of ornamental plants are primary tasks in this effort to build-up ecological gardens in the larger cities in Hubei Province. A bottle-neck in the effort of promoting the beneficial effects of garden landscapes is the discovery of suitable local species and use of standardized technologies to scale-up their use to city-wide levels. Current problems include unreasonable variety structures and planting densities, as well as poor culture and management in seedling nurseries, especially arbor nurseries. These problems result in the failure of species shortly after establishment. In addition, the economic efficiency of planting ornamental trees is directly influenced by species duration within nurseries. This project is aimed at: 1) conducting an investigation on garden plants in Hubei Province to assess the status of soil fertility and fertilization; 2) provide a better strategy for regional seedling industry development; and 3) develop better gardens in large and middle-sized cities in Hubei. This project will study the soil fertility of main garden tree species in different cities, study

adaptive relationships between the soil and tree species, and finally, develop improved strategies for soil nutrient management of local ornamental trees.

In 2009, over 300 soil samples were taken in 10 cities all over Hubei. Soil samples will be analyzed using the ASI approach in the IPNI Beijing lab and the complete results will be obtained by May 2010. To date, results indicate that since all of the garden plant soils in the 10 cities were primarily built with waste soil materials from urban development, they commonly had poor soil structure and thin surface layers. Plant species in these cities were not well selected based on local soil and climatic conditions. Most soil fertility improvement efforts have also been ignored and this has resulted in the majority of plants growing weaker with time. *Hubei-33*

Effect of Soil Fertility Evolution on the Weed Succession Process

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The process of ecological adaptation of plants involves a mutual interaction between plants and their environment. In an agro-ecosystem, the changes caused by long-term fertilization can bring new selection pressures, particularly for weeds. These pressures affect the frequency of weed occurrence, weed community structure and diversity, and the soil weed seed bank. An agro-ecosystem is an artificial ecosystem under the effect of intensive human disturbances. The weed community, as an important component of the agro-ecosystem, will exhibit a variety of traits in its natural succession process and pattern under soil fertility evolution. These traits will also illuminate rehabilitation measures for the natural ecosystem as well as management strategies for farmland weeds. Three experimental sites were established in 2008, including: Honghu County, Hubei; Yichang County, Hubei; and Minhou County, Fujian. The project's initial objective is to disclose the grass community succession process and patterns under accelerated soil fertility evolution through long-term fertilization. The project hopes to provide scientific foundations for comprehensive management of weeds in farmland and rehabilitation of degraded natural ecological systems.

A biodiversity survey of grass communities was conducted in April and July of 2009 at each site including grass species, species coverage, and modular traits of some species. Results found the respective dominant species in Honghu, Yichang, and Minhou to be 49 species in 18 families, 45 species in 20 families, and 54 species in 25 families. In Honghu, the dominant species were Humulus scandens, Setaria faberii, Glycine soja, Artemisia annua,and Artemisia princeps. In Yichang, the dominant species were *Cynodon dactylon, Erigeron annuus, Lindernia ciliate, Setaria faberii,* and *Bidens pilosa*. In Minhou, the dominant species were *Biden pilosa, Erigeron annuus, Imperata cylindrical,* and *Rublaceae cordifolia*. Most of the soil and plant analysis results will be ready in 2010. *Hubei-34*

Soil Nutrient Index and Fertilizer Recommendations for Winter Rapeseed

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This investigation of nutrient management was carried out in Hubei Province involving 398 farmers planting rapeseed, in locations distributed throughout 20 counties.

All farmers applied chemical fertilizer, but only 20% applied organic fertilizer. Problems in rapeseed nutrient management included: low and imbalanced P and K rates, a low reliance on organic sources, and too high a proportion of N fertilizer being applied as a basal dressing. The average NPK application rate was 173-61-49 kg N-P_2O_5-K_2O/ha and chemical fertilizers represented 96%, 92%, and 79% of the total N, P, and K. The average rapeseed yield was 1,967 kg/ha. Direct-seeding represented about 58% of the area and 42% of rapeseed was transplanted. About 76% of the N fertilizer was applied as a basal dressing. The average yield within a selected optimum (OPT) treatment supplying 180-90-120 kg N-P_2O_5-K_2O/ha + 15 kg borax/ha) was 2,089 kg/ha, which was 1,119, 944, 418, 144, 211, and 148 kg/ha higher than the CK, OPT-N, OPT-P, OPT-K, OPT-B, and farmer's practice, respectively.

Compared with the complete treatment, 60%, 75%, 90%, and 95% relative yield levels obtained from the P and K omission plots were selected to establish abundancy/deficiency indices for available soil P and K. The critical soil B value was where relative yield reached the 90% of the complete. Extreme deficiency, deficiency, slight deficiency, optimum, and abundance indices of available P for the "routine" soil analysis method were <6, 6 to 13, 13 to 25, 25 to 35, and >35 mg P/kg. For the ASI method they were: <6, 6 to 12, 12 to 25, 25 to 30, and > 30 mg P/L. The respective deficiency, slight deficiency, optimum, and abundance

critical values for available K were: <50, 50 to 125, 125 to 175, and >180 mg K/kg for the routine method; and <35, 35 to 80, 80 to 100, and >100 mg K/L for the ASI approach. The critical values for available B were 0.6 mg B/kg for the routine method and 1.0 mg B/L for the ASI method. Nutrients required by rapeseed for producing each 100 kg seed under the OPT were 4.9 kg N, 1.9 kg P_2O_5, 6.8 kg K_2O, 6.4 kg CaO, 1.4 kg MgO, 1.9 kg S, 19.1 g Fe, 8.3 g Mn, 0.7 g Cu, 5.1 g Zn, and 5.4 g B. *Hubei-35*

Long-term Potassium Fertilization Effects on Rice and Potassium-Supplying Capacity of Paddy Soil

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Soil K content of arable land located within the middle reaches of the Yangtze River is under a steady decline, resulting in K deficiency. A long-term field experiment was initiated in 1981 at the Key Field Monitoring Experimental Station for Reddish Paddy Soil Eco-environment, in Wangcheng County of Hunan Province. The cropping pattern used in the study was early rice-late rice-fallow (winter). The field treatments included a control (CK, no fertilizer), NP, NPK, NP+RS (NP plus rice straw), and NPK+RS.

Results show that K application increased grain yields of early rice and late rice. Over the past 27 years, average yields of early rice under the NPK and NPK+RS treatments were 15.2% and 10.9% above the NP and NP+RS treatments, respectively. In late rice, yields under the NPK and NPK+RS treatments were 17.2% and 9.1% higher than the NP and NP+RS treatments. Yields followed a negative trend over time in the CK and NP treatments, while the opposite was true for the NPK, NP+RS, and NPK+RS treatments. Contents of total soil K, slowly-available K, and immediately available K in the different soil layers under the NPK and NPK+RS treatments were higher than those under the NP and NP+RS treatments. Rice straw also had a significant impact on rice yield. The average yield under 27 years of returning rice straw (NP+RS and NPK+RS) was 12.2% and 6.7% above the NP and NPK treatments, respectively. Rice straw should substitute for a portion of K fertilizer recommendations. The annual average yield with NPK, NK+PM, NP+RS, and NPK+RS were 16.2%, 11.0%, 12.4%, and 23.6% above the zero K fertilization treatment (9.44 t/ha), respectively. *Hunan-14*

Mechanisms of Soil Acidification Induced by Different Agricultural Management Practices for Paddy Soil in the Red Soil Region

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The contents of water-soluble and exchangeable elements such as Cd and Pb will increase with soil acidification, especially in low pH soils. Biological activities are sharply enhanced and bring greater risk to grain crop production. Soil acidification also results in base cation (K, Na, Ca, and Mg) loss. This project is studying soil acidification mechanisms, chemical degradation, and prevention techniques induced by different agricultural management practices applied within the seriously acidified region in Hunan Province. It is expected that the results will contribute to higher, more stable rice production. A long-term field experiment with double rice and winter fallow crops was conducted at the Key Field Monitoring Experimental Station for Reddish Paddy Soil Eco-environment in Wangcheng County. Treatments included a check (no fertilizer), plots omitting N, P, and K, and a complete NPK, NPK+Ca (lime), NK+PM (pig manure), NP+RS (rice straw), and NPK+RS.

Results showed declining pH values over time in all treatments. The effect of fertilizer application on soil pH decreased with soil depth. Lime application slowed the soil pH decline. Farmyard manure application (pig manure+rice straw) caused a more rapid decline in soil pH compared to strict fertilizer application. The check is also showing a small, but detectable, pH decline over time. After 28 years, total soil Cd, Cr, Cu, Ni, Pb, and Zn contents have increased. Total soil As increased in four treatments and total Co increased in six treatments. However, with the exception of Cd, the potentially toxic elements were largely in residual forms. The Cd contents in all treatments exceeded the National Environmental Quality Standards for Soils. Total soil Ni in the NK treatment and total Cu in the NK+PM treatment also exceeded this standard. *Hunan-15*

Efficient Nutrient Use and Regulation of Soil Nutrient Dynamics for High Yield Rice

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Fertility characteristics of highly productive paddy soils were studied as part of a science-based approach to sustainable utilization of paddy soils. Organic matter fractions (total and labile) and nutrient contents (total and available) and their relationships with rice yield were investigated within double-rice cropping systems located in eight important rice production counties in Hunan.

Highly productive paddy soil under double-rice had organic matter contents of 47.7±11.59 g/kg, total N of 2.70±0.72 g/kg, and available P of 39.8±14.21 g/kg. Contents of organic matter, total N, and available P in moderately productive paddy soils were not significantly different compared to these highly productive soils. The less productive soils did have significantly lower values for all soil properties listed compared to both high and mid-productivity soils. Fertilizer P in the high productivity soil was more mobile and could be easily moved to water bodies, and thus become a source of eutrophication. Available soil K contents in high productivity soils were in the mid-range (108.8±22.8 mg/kg). The contents of soil organic matter, total N, and available P were very high in high productivity soil because of long-term rice cultivation and its fertilization. Both the organic matter and P pools were in surplus status. The texture of high productivity soils were generally loamy to sandy clay loam dominated by kaolinite with a weak K retention capacity. Attention should be paid to the rational application of K fertilizer and rice straw recycling to maintain or improve the soil K balance in high productivity soils. For most mid-productivity soils, due to their relatively high contents of organic matter, total N, and available P, rice yields equal to those obtained in high productivity soils could only be achieved with good field management practices. The physical properties and nutrient status in low productivity soils are limiting yields and rational application of manure and inorganic fertilizers are required to remove the yield barriers in these soils. *Hunan-16*

Balanced Fertilization Techniques for Gingko

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Taixin County of Jiangsu Province is one of the two most famous gingko production counties in China. The region has over 2,000 years of gingko planting history. Traditional fertilization for gingko trees in this region relies mainly on farm manure and N fertilizer, some P fertilizer, but almost no K fertilizer. This strategy is resulting in declining gingko yields and quality in Taixin. A better nutrient management strategy for this gingko planting region is needed. From 2007 to 2009, a balanced fertilization field trial was conducted by the Jiangsu Academy of Agricultural Science.

Results found the optimum (OPT) treatment of 185-75-150 kg N-P_2O_5-K_2O/ha could produce a highest gingko nut yield of 5,021 kg/ha. Compared with treatments omitting N, K, and Zn, the OPT produced 903, 448, 21 kg/ha more, while returning an additional US$1,270/ha, US$143/ha, US$27/ha, respectively. Soil N and K deficiency were the most yield-limiting nutrients for gingko production in Taixin. *Jiangsu-09*

Soil Fertility and Nutrient Management for Intensively Managed Farmland in Jiangsu

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Soil fertility in intensively managed farmland in Jiangsu Province has declined over the last 20 years. The main problems include unbalanced nutrient application (which emphasizes N and P, but neglects K and secondary nutrients and micronutrients), soil acidification, and spatial variability in soil nutrients. The Jiangsu Academy of Agricultural Science implemented this project to provide a better understanding of suitable management strategies for the region.

A total of 355 soil samples, collected from 12 counties, were selected for determination of their basic properties by ASI soil analysis methods. Results found the main factors affecting soil fertility status to be low soil organic matter (OM) content and low micronutrient status including Zn. The OM content in the coastal region, hilly area, and northern area of Jiangsu were less than 1.0 g/kg, while the Taihu Lake region had an OM value of 1.0 g/kg. Sulfur deficiency in the silt soil of northern Jiangsu and soil acidification in the hilly

area are also significant problems. Regardless of salinity status or the alluvial nature of soils of the coastal region, long-term rice planting significantly increased soil fertility indexes such as OM content, and available N, P, K, and Mg. Thus, rice planting effectively improved soil fertility in the coastal region. *Jiangsu-10*

Balanced Fertilization for High Yielding Evodia Rutaecarpa

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In 2009, Jiangxi Agricultural University continued this project on balanced fertilization (BF) techniques for Evodia (a high value medicinal fruit crop) grown in Zhangshu and Ruichang counties.

Soil test-based balanced fertilization (BF) promoted plant growth and product yield. The average plant diameter of plants with the OPT treatment of 75-60-100 kg N-P_2O_5-K_2O/ha was 2.4 cm, while plant diameter in the CK treatment was only 0.7 cm. The OPT treatment obtained an average fruit yield of 3.71 kg/plant, which was 38.4%, 33.5%, and 154% higher than the - P, - K, and CK treatments, respectively. Results also found that BF can improve soil physical properties. Compared with the check (CK) treatment supplying zero fertilizer, soil under the OPT treatment had 37% higher water content (increased from 19.4% to 26.5%) within the top 20 cm of soil profile, while soil porosity increased by 42% (from 40.8% to 58%) and soil bulk density decreased by 21% (from 1.51 to 1.19 g/cm^3). *Jiangxi-25*

Fertilization Technology for Reduced Agricultural Area Sourced Pollution in Jiangxi

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This project was implemented in 2008 by the Jiangxi Academy of Agricultural Science. A rice field trial was carried out in Nanchang County to study agricultural production technology required to optimize fertilizer use and reduce pollution related to agricultural activity.

The field trial indicated that N loss from run-off was not directly related to N application rate, but rather, unbalanced fertilization generated more run-off N than did balanced fertilization. The manure treatment produced the highest run-off loss (4.8 kg N/ha) in early rice. In late rice, the treatment with 25% less N and 50% less P than the selected optimum (OPT) generated the highest losses (4.2 kg/ha). The high losses under the manure treatment were likely due to increased soil microbial activity and accelerated release of mineral N. The loss of P through run-off was also unrelated to P application rate and the rate of loss was very low. In early rice, the highest loss was found in the NPK treatment (0.339 kg P/ha). For late rice, the highest loss (0.25 kg P/ha) was found in the treatment with 25% less N and 50% less P than the OPT. *Jiangxi-26*

Effect of Forage Grass Nutrition on Domestic Herbivore Product Quality

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Forage-based livestock production is a means of lowering production costs, while using less grain; and it can potentially have less environmental impacts. Over 1 million ha of winter fallow lands exist in Jiangxi, which represents a great resource for livestock. The Jiangxi Academy of Agricultural Science implemented this project in 2008 to improve forage grass quality and in turn, meat quality of fed livestock, through better nutrient management practices.

A selected optimum (OPT) treatment containing NPK, Ca, Mg, Zn, and Se resulted in the highest yield (177 t/ha) of Mexican maize forage grass. Grass receiving this OPT was more palatable to milk cows; thus, use of this forage produced 71% and 53% more milk compared to the NPK and CK, respectively.

An OPT treatment supplying NPK+Zn+Se obtained the highest ryegrass yield (70,542 kg/ha), which was 3.6% above the NPK treatment and 190% above the check (CK). With geese as the livestock, growth was affected by fertilizer treatment in ryegrass forage. However, the different fertilization treatments had no impact on the slaughter weight of geese. Ryegrass receiving NPK+Zn+Se improved goose meat quality through increased amino acid components (16.5%), and contents of Zn (11.3%), Se (60.0%), and P (7.7%).

Use of ryegrass from the P omission plot reduced meat P and Zn contents, but increased its fat and Mg content. The K omission plot significantly decreased K content in goose meat, but had no other effect. The N omission plot had almost no influence on the nutrient content of goose meat. Addition of Zn and Se markedly increased the amino acid content of goose meat. *Jiangxi-27*

Balanced Fertilization and Better Cultivation Practices for Eucalyptus

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Balanced fertilization (BF) effectively improved the productivity of Eucalyptus. The productivity under the soil test based optimum (OPT) treatment of 100-170-120 kg N-P_2O_5-K_2O/ha was 1.04 to 2.25 times (one-year-old trees) and 1.5 to 4.4 times (five-year-old trees) than that observed in the zero fertilizer check (CK) treatment. Balanced fertilization improved soil fertility under Eucalyptus by improving soil bulk density, total soil porosity, soil permeability, soil organic matter, available N, P, and K contents, and reducing soil acidity. The biological diversity of the Eucalyptus understory shrub layer was stable in the high-intensity management treatment compared to the mid- and less intensive, and check (CK) treatments. The Simpson diversity indexes (used to quantify the biodiversity of a habitat, where smaller values represent higher diversity) for the understory shrub layers of the above list of treatments were 0.82, 0.72, 0.83, and 0.71, respectively. *Jiangxi-28*

Soil Potassium Status and Nutrient Management of Oil-Tea Fields

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Oil-tea (Camellia oleifera Abel) is a woody oil-bearing plant with high economic, social, and ecological benefits in south China. Its planted area has expanded quickly in recent years, with total area now covering 400 million ha. Jiangxi is one of the main oil-tea producing provinces with more than 100 million ha.

In 2009, a field fertilization experiment showed that balanced fertilization significantly increased oil-tea yield and its economic benefit to farmers. Fresh fruit yield under the optimum (OPT) treatment of 190-47-192 kg N-P_2O_5-K_2O/ha was 25,418 kg/ha and the corresponding oil yield was 2,033 kg/ha. This was 2.2 times the yields obtained under common farm practice and this response generated an additional US$4,881/ha. Fresh fruit yields under the OPT-P and OPT-K treatments were 18,583 kg/ha and 15,780 kg/ha, respectively. These yields were 26.9% and 37.9% less than the OPT, and as a result returned US$3,401 and US$2,412/ha less than the OPT. Both N and K are especially important nutrients for oil-tea crops grown in this area. *Jiangxi-29*

Influence of Different Fertilization Patterns on the Availability of Environmental Pollutants

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The soil environment can be changed with the application of fertilizers, which can also affect the transformation or availability of pesticides or heavy metals. This research examines the influence of various forms of N or K fertilizers on the bio-availability of lead (Pb) or cadmium (Cd) to rapeseed, pakchoi, and rice, growing in Pb or Cd-contaminated soil.

After incubating under waterlogged conditions, or 60% field moisture capacity (FMC) conditions for 60 days (d), the lowest pH and nitrate-N (NO_3-N) content, the highest ammonium (NH_4-N) content, and the highest available Pb or Cd contents were observed in the Pb or Cd-contaminated soil treated with ammonia-based (NH_3) fertilizers. The highest pH and NH_4-N content, lowest NO_3-N content, and lowest available Pb or Cd contents were observed with urea application. A significant or very significant negative correlation was found between soil pH and available Pb or Cd contents of contaminated soils incubated at different moisture conditions. Available Pb content could be reduced by K fertilization, but a difference between K fertilizer forms was not detected, when contaminated soil was incubated at 60% FMC. Available Cd content could be increased by the application of potassium chloride (KCl), and was not affected by the application of potassium nitrate (KNO_3) or potassium sulfate (K_2SO_4). For rapeseed or pakchoi grown in uplands, the bio-availability of Pb or Cd in the Pb or Cd-contaminated soil was lower with application of calcium nitrate

$Ca(NO_3)_2$ or urea than with two ammonia-based fertilizers. Better growth and lower contents of Pb or Cd in rice were observed in soil receiving urea-N. The change of potash fertilizer form had no influence on the growth and Pb uptake of rapeseed, pakchoi, and rice, or the available Pb content. The KNO_3 source produced better growth in rapeseed or pakchoi in the Cd-contaminated soil. For rice grown in soil contaminated by Cd, the application of K_2SO_4 was not only better for growth, but also promoted the accumulation of Cd.

For field soils that are heavily contaminated with Pb or Cd, the application of the right variety of N or K fertilizer would be beneficial to decrease the accumulation of Pb or Cd in crops tissue, and reduce the effects of environmental pollution. *Nanjing-10*

Nutrient Uptake and Loss from Farmland in Shanghai

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There are 110,000 ha of rice and 100,000 ha of vegetable and fruit in Shanghai. Over-application of N and P has caused environmental problems and has resulted in deficiencies in K and other nutrients. In 2009, the Shanghai Academy of Agricultural Science conducted this project to monitor the loss of soil N and P nutrients in GuoYuan village.

The percentage of individual nutrient loss in relation to the total amount applied (percent loss coefficient) was calculated as [(Nutrient loss from fertilized treatment - Nutrient loss from nutrient omission treatment)/ Total rate of nutrient applied] x 100%. Nutrient loss coefficients under vegetables ranged between 0.43 to 7.31% for N and 0.1 to 1.58% for P. Coefficients for rice were lower at 2.26 to 8.01% for N and 0.01 to 0.89% for P. Results from a rice fertilization trial found the optimum (OPT) treatment of 270-75-112 kg N-P_2O_5-K_2O/ha could obtained 9,176 kg/ha, which was 28%, 9.7%, 13%, and 35% more than the - N, - P, - K, and zero fertilizer check, respectively. *Shanghai-08*

Balanced Fertilization and Its Environmental Effects in Vegetable-Rice Rotation Systems

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A field experiment studying nutrient use within an eggplant-rice rotation found the highest eggplant yield (67,375 kg/ha) and economic benefit (US$21,624/ha) under the optimum (OPT) treatment of 600-300-375 kg N-P_2O_5-K_2O/ha. In rice, the OPT of 150-60-90 kg N-P_2O_5-K_2O/ha produced 7,167 kg/ha and generated US$1,417/ha. An attempt to reduce the N rate by one-fourth in eggplant and increase N input in the subsequent rice season (188-60-90 kg N-P_2O_5-K_2O/ha) did not generate a significant grain yield benefit.

Surface water nitrate (NO_3-N) concentrations reached peak values 2 days after soil flooding during the conversion from eggplant to rice. These nitrate levels were between 4.8 to 81.7 mg/kg 6 days after soil flooding, and were obviously higher than ammonium (NH_4-N) concentrations (0.31 to 1.92 mg/kg). After rice, topsoil NO_3-N was obviously lower than that measured in mulched dryland crop cultivation. Subsoil NO_3-N (40 to 60 cm) content under mulched eggplant cultivation was lower than in other mulched dryland crop cultivation. This implies that long-term rice-dryland crop rotations could inhibit soil nutrient leaching and pollution of groundwater. *Zhejiang-24*

Mechanisms of Environmental Factors Affecting Uptake and Utilization of Nitrogen and Phosphorus by Vegetables

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Project Cooperators: Yong-song Zhang and Qichun Zhang

The results from 2009 showed that contents of ammonium (NH_4^+-N), nitrate (NO_3^--N), and total inorganic N increased first and then decreased in the incubation soils amended with manure and urea. Temperature and moisture regime had a significant effect on N mineralization rate and nitrification rate of the soils. Soil inorganic N content at 30 ºC was 20% higher than at 5 ºC in non-fertilized soil, and soil inorganic N content under dry-rewetting (DW) was 28% higher than under continuously wet conditions (CWC) in urea-amended soil. The average amounts of N mineralization and nitrification in urea-amended soils were 157 and 165 mg/kg, which were 10 and 8 times those in non-fertilized soils. Meanwhile, the average amounts of soil N mineralization and nitrification in manure-amended soils were 37 and 46 mg/kg, which was 2.3 and 2.1 times

those in non-fertilized soils. Soil urease activity at 30 ºC was 22% higher than that observed at 5 ºC, while the urease activity under DW was 10% higher than under CWC.

A hydroponic experiment studied the effects of elevated atmospheric carbon dioxide (CO_2) concentrations from 350 to 800 μL/L on root exudation of organic C and organic acids, and their activation of insoluble P in the rhizosphere of tomato grown in nutrient solutions with sufficient (2 mmol/L) and deficient (2 μmol/L) P supply. Results showed that elevated CO_2 concentration decreased P concentrations, but increased the P contents in roots and shoots of tomato plants. The total C secretion from plants under elevated CO_2 treatment was 0.16 mg C/h, which was 2 times that observed under 350 μL/L CO_2.

Two hydroponic experiments studied the effects of N levels and forms on biomass and photosynthesis on Chinese cabbage grown with different light (full light, 30% full light) and moisture conditions. Nitrogen was supplied at five levels in Experiment 1, and Experiment 2 used four ratios of NH_4^+ to NO_3^- at a total N rate of 15 mM. Results found insignificant changes in biomass and photosynthetic rate when N level decreased from 15 to 12 mM, and 9 mM in the nutrient solution, whereas NO_3 accumulation was decreased by 38% and 40%. Under conditions of low light and water stress, increased pigment contents, photosynthetic rate, chlorophyll fluorescence parameters, and biomass were found when N form was supplied at a 5/10 (NH_4^+/NO_3^-) ratio. *Zheijiang-25* ❖

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Nutrient Management and Balanced Fertilization in Gansu

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Crop yields in Gansu are mainly limited by water supply, so nutrient management practices must consider the available water regime. Research on nutrient responses and efficiencies to N, P, and K fertilizers were investigated in spring maize, potato, wheat, and soybean in 2009. Plastic mulching is an effective water conservation technique, but in covered crops like wheat and corn, the use of plastic mulch only allows for for recommended rates of P and K to be applied in the first season while subsequent crops under the same mulch must rely on residual fertility. Thus, cooperators want to investigate how to appropriately apply nutrients during the first season so that adequate residual P and K fertility can support two or three seasons of crop production under established plastic mulch.

At Dingxi City, spring maize grown with the aid of water conserving plastic mulch and a recommended optimum (OPT) treatment of 225-120-90 kg N-P_2O_5-K_2O/ha produced a high yield of 9 t/ha. This represents a 10.5% increase, valued at US$99/ha, over the mulched version of common farmer practice (FP) of applying 150-105-0 kg N-P_2O_5-K_2O/ha. A similar trial in Zhenyuan County found the OPT to be 225-90-60 kg N-P_2O_5-K_2O/ha. For potato grown at Dingxi City, also under plastic mulch, the OPT of 225-105-90 kg N-P_2O_5-K_2O/ha generated 22% more tuber yield compared to the FP of applying 180-105-0 kg N-P_2O_5-K_2O/ha. The OPT with plastic mulch produced 133% more income (US$611/ha) over the OPT without mulch. A mulched wheat experiment in Dingxi City found the recommended OPT of 150-120-84 kg N-P_2O_5-K_2O/ha could produce 21% more grain than FP using 150-105-0 kg N-P_2O_5-K_2O/ha. The OPT without mulch did not generate a significant grain yield response when compared with each nutrient omission plot or FP. Wheat yield under the OPT with plastic mulch was 42% higher than that of OPT without plastic mulch. In watermelon grown at Xhengyuan County, the OPT of 180-120-90 kg N-P_2O_5-K_2O/ha produced 46% more yield, and US$2,147/ha, compared to the FP of applying 180-90-0 kg N-P_2O_5-K_2O/ha. Soybean grown in Zhenyuan County has shown no response to N, but P and K application have increased yields by 21% and 13%, respectively. *Gansu-NMBF*

Nutrient Management and Balanced Fertilization in Inner Mongolia

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Field experiments were conducted on rainfed and irrigated potato, oil sunflower, and rapeseed to document nutrient accumulation and yield response.

In flood-irrigated potato at Wuchuan County, application of 210-90-165 kg N-P_2O_5-K_2O/ha produced 19.1%, 11.6%, and 4.0% more tuber yield over N, P, and K omission plots, respectively. A similar potato trial in Chayouzhong Qi was more responsive and produced 32.9%, 37.4%, and 35.1% more yield over omission plots when 210-150-150 kg N-P_2O_5-K_2O/ha was applied. Similarly, sprinkler-irrigated potato in Chayouzhong Qi receiving 300-150-225 kg N-P_2O_5-K_2O/ha obtained 28.7%, 34.7%, and 32.7% more yield over N, P, and K omission plots. Yields under flood-irrigated potato were similar (36 t/ha) in Wuchuan and Chayouzhong Qi. Yield under the sprinkler-irrigated sites reached 60 t/ha. Nutrient use efficiency under sprinkler irrigation was 30% higher than under flood irrigation. Experiments on sunflower for oil demonstrated high seed yields under the selected optimum (OPT) of 210-75-150 (Hangjinhouqi), 240-105-105 (Wuyuan), and 285-120-150 kg

N-P_2O_5-K_2O/ha (Daqi). Across these sites, the average agronomic efficiency (kg seed increase per kg added nutrient) for these OPTs was 4.0 (N), 3.5 (P_2O_5), and 6.5 (K_2O). Average recovery efficiency for applied N, P, and K was 47%, 22%, and 45%. About 6.1 kg N, 2.2 kg P_2O_5, and 4.1 kg K_2O was required to produce 100 kg sunflower seed. Experiments in oilseed rape have been conducted in Wuchuan County for 7 years. Average agronomic efficiency for an average OPT (90-43-45 kg N-P_2O_5-K_2O/ha) was 4.1 (N), 6.8 (P_2O_5), and 5.1 (K_2O). Recovery efficiency for applied N, P, and K was 30%, 15%, and 49%. About 6.1 kg N, 1.9 kg P_2O_5, and 4.6 kg K_2O was required to produce 100 kg rapeseed. *Inner Mongolia-NMBF*

Nutrient Management and Balanced Fertilization in Ningxia

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Experiments in 2009 were conducted on wheat, rice, vegetables, and sunflower to discover the best nutrient management practices for conditions in Ningxia Province.

Trials testing N rates on spring wheat grown in Wuzhong City found the highest average yield of 5,280 kg/ha with 240 kg N/ha plus 120 kg P_2O_5/ha and 90 kg K_2O/ha. Protein content increased from 6.8% to 7.3% as N rate increased from 120 to 360 kg N/ha. Wheat quality indicators such as wet gluten, sediment value, and water absorption also improved at higher N rates. Nitrogen recovery efficiency decreased and apparent N loss increased under the higher rates of N. In rice grown at Lingwu City, the recommended OPT of 225-90-135 kg N-P_2O_5-K_2O/ha produced 11 t/ha yield, which was 21% more than farmer practice (FP) of applying 270-105-0 kg N-P_2O_5-K_2O/ha. The agronomic efficiencies of N, P, and K for this OPT were 30 kg grain increase/kg N, 25 kg grain increase/kg P_2O_5, and 15 kg grain increase/kg K_2O. Recovery efficiencies for N, P and K were 26%, 14%, and 34%. The OPT resulted in US$412/ha more income than FP. A similar trial at Lingwu found 225 kg N/ha and 135 kg K_2O/ha to be appropriate rates. In Chinese cabbage grown at Lingwu City, N was the first yield-limiting factor followed by P and then K. The recommended NPK rate of 300-180-150 kg N-P_2O_5-K_2O/ha produced 7.5 t/ha, or 11% more yield, than FP of applying 120-180-0 kg N-P_2O_5-K_2O/ha. A trial on carrot, also at Lingwu City, found the recommended NPK rate of 300-180-150 kg N-P_2O_5-K_2O/ha could produce 8.8 t/ha, or 10% more yield, than the FP of applying 120-180-0 kg N-P_2O_5-K_2O/ha. In sunflower, application of 45 kg K_2O/ha along with 75 kg N/ha and 45 kg P_2O_5/ha increased seed yield by 1,565 kg/ha, or 17%, compared with the K omission plot. *Ningxia-NMBF*

Nutrient Management and Balanced Fertilization in Qinghai

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In 2009, experiments in Qinghai were mainly focused on finding the yield-limiting nutrient factors for spring wheat, rapeseed, rainfed potato, and forage grass in Xi'ning City, Huzhu County, and Chengduo County.

In spring wheat grown at Xining, N was the main nutrient limitation. Application of 150 kg N/ha produced 38% more grain yield compared to the N omission plot supplied with 90 kg P_2O_5/ha and 135 kg K_2O/ha. Omission plots in rapeseed grown at Huzhu County also found N to be a larger yield-limiting factor compared to P. However, the balanced OPT of 125-75-135 kg N-P_2O_5-K_2O/ha only produced 4% more yield than the farmer practice (FP) of applying 140-86-90 kg N-P_2O_5-K_2O/ha. Agronomic efficiencies (AE) under this OPT were 6.3 kg seed increase/kg N and 3.8 kg seed increase/kg P_2O_5. In rainfed potato grown at Huzhu County the recommended NPK treatment of 214-86-193 kg N-P_2O_5-K_2O/ha and the corresponding set of nutrient omission plots determined N to be most limiting followed by K, then P. The recommended treatment produced a 10% higher tuber yield compared to the farmer practice (FP) of applying 343-74-0 kg N-P_2O_5-K_2O/ha. The AE values calculated under this recommendation were 38 kg tuber increase/kg N, 20 kg tuber increase/kg P_2O_5 and 28 kg tuber increase/kg K_2O. Balanced use of NPK (450-210-120) in natural grassland in Chengduo County resulted in 359%, 246%, 9% more dry matter yield than the N, P, and K omission plots, respectively, and also generated an additional US$644/ha compared to the FP of zero fertilization. Data of dry matter accumulation and nutrient uptake at different crops stages were also investigated in this study. *Qinghai-NMBF*

Nutrient Management and Balanced Fertilization for Major Crops in Shaanxi

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Experiments were conducted in three counties within Shaanxi Province studying the effects of nutrient management on yield and quality of apple and kiwi, biomass and nutrient uptake by grape, as well as yield and nutrient uptake by potato.

The recommended rates for a 10-year old apple orchard at Heyang County were determined to be 0.6-0.24-0.3 kg N-P_2O_5-K_2O/tree (1,667 trees/ha). Two-thirds of this N rate was applied basally and the remainder was top-dressed. Yield was most impacted by N omission followed by K and then P. The recommended NPK treatment produced 3.8 t/ha (+8%) more than farm practice (0.64-0.46-0 kg/tree). Spraying 0.5% of $CaCl_2$, $FeSO_4$ and $ZnSO_4$ solutions significantly increased apple yield by 63%, 59%, and 44%, respectively, and increased vitamin C (Vc) content, compared with the check receiving a pure water solution. Research in kiwi in Yangling County recommended 0.35-0.17-0.17 kg N-P_2O_5-K_2O/tree (2,000 trees/ha). This produced 38.5 t/ha of kiwi fruit, or 22.6%, 5.5%, and 21.5% over the N, P, and K omission plots, respectively. These treatments increased Vc content by 18, 12, and 23 mg/100 g, respectively. Application of farmyard manure in addition to the recommended NPK rate produced the highest Vc content. In a 7-year-old grape orchard in Fufeng County, total biomass accumulation from March 30 to November 30, not including the fruits, ranged between 5,391 to 17,760 kg dry weight (DW)/ha. The average increase was 12,369 kg DW/ha. Year-round accumulation of N, P_2O_5, and K_2O was 97, 33, and 141 kg/ha, respectively. The recommended NPK rate for grape was determined to be 130-55-187 kg N-P_2O_5-K_2O/ha. Nutrient requirements for producing 1,000 kg grapes was 4.1 kg N, 1.8 kg P_2O_5, and 7.8 kg K_2O. In plastic-covered potato in Huaxian County, no tuber yield response to N application was demonstrated, but application of P and K increased yields by 10.5% and 15.3%, respectively, with yields of 33.4 t/ha. *Shaanxi-NMBF*

Nutrient Management and Balanced Fertilization in Xinjiang

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About 90% of agriculture in Xinjiang is irrigated and drip irrigation continues to be most popular in crops such as cotton and processing tomato. This study investigated nutrient responses and management for improved nutrient use efficiency in the region's main crops in 2009.

In drip-irrigated cotton grown at Bozhou City, the recommended NPK rate of 225-150-30 kg N-P_2O_5-K_2O/ha and its corresponding omission plots found N to be most limiting followed by P and then K. Agronomic efficiencies (AE) under the recommendation were 1.6 kg lint increase/kg N, 1.5 kg lint increase/kg P_2O_5, and 5.1 kg lint increase/kg K_2O; while recovery efficiencies (RE) were 34%, 25%, and 75% for N, P, and K, respectively. Phosphorus fertilizer increased lint yield by 8 to 16% and 150 kg P_2O_5/ha was considered most appropriate. Basal application of half this P rate before planting and the remainder applied through drip irrigation produced 5% and 12% more lint yield than either 100% basal application or 100% drip irrigation, and also improved P use efficiency. In drip-irrigated maize grown at Bozhou City, the recommended NPK rate of 225-105-45 kg N-P_2O_5-K_2O/ha produced 15.5 t/ha grain yield. The AE values under this recommendation were 22 kg grain increase/kg N, 16 kg grain increase/kg P_2O_5, and 17 kg grain increase/kg K_2O. Use of this NPK recommendation plus 30 t/ha farmyard manure produced the highest grain yield of 19.0 t/ha while generating US$378/ha more income than NPK alone and US$396/ha more than the farmers' practice (FP) of applying 308-135-0 kg N-P_2O_5-K_2O/ha.

Polymer coated urea (PCU) applied to cotton in Ma'nasi County at either 126 or 180 kg/ha respectively produced 11% and 31% more lint yield (responses valued at US$278/ha and US$882/ha) compared to the same rate of regular urea (RU). Nitrogen use efficiency (NUE) was also improved with use of PCU. A melon experiment also demonstrated yield and NUE benefits for PCU over RU. A balanced treatment of 360-150-105 kg N-P_2O_5-K_2O/ha applied to processing tomato in Ma'nasi County produced 17% more yield, or US$530/ha more income, over the FP of applying 272-195-45 kg N-P_2O_5-K_2O/ha. Balanced fertilization with 240-90-75 kg N-P_2O_5-K_2O/ha + 30-15 kg Fe-Mn/ha on cotton in Ma'nasi County also resulted in 9% more lint yield, or US$375/ha, over the FP of applying 183-100-20 kg N-P_2O_5-K_2O/ha. *Xinjiang-NMBF* ❖

Asia Group

China

Northeast Region: Dr. Ji-yun Jin

Nutrient Limiting Factors for Maize, Soybean, and Rice Production in Heilongjiang

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Project Cooperator: Mr. Shuangquan Liu

Field experiments were conducted to study yield limiting nutrients within main production centers for maize (four sites), soybean (five sites), and rice (three sites) in the province. Optimum (OPT) treatments providing nutrients adjusted to levels guided by soil testing were compared against site-specific sets of nutrient omission plots.

In maize, the best yields, ranging between 8.5 to 12.6 t/ha, were produced under the OPT treatments. Yields were most affected by N omission but were also significantly lower without P or K. Specifically, N omission produced yield losses between 20 to 42% which is a range valued between US$232 to US$768/ha. Yields under P omission dropped by 10 to 27% (US$105 to US$525/ha) and K omission caused a 11 to 19% yield loss valued between US$122 to US$372/ha. At Yi-an, which is located in western Heilongjiang, Zn deficiency was also identified. Omitting Zn from the OPT reduced maize yield by 38% which represents a value loss of US$639/ha. In soybean, the OPT produced the best yields, which ranged between 1.6 to 3.2 t/ha. Omission of P reduced soybean yield by 10 to 26%, valued between US$289 to US$500/ha, and omission of K caused a 7 to 38% yield loss valued between US$219 to US$588/ha. In rice, again the OPT produced the best yields, ranging between 6.6 to 8.5 t/ha. Rice was impacted the most by N omission which caused yield losses between 26 to 48%, valued at US$628 to US$1,270/ha. Omitting P from the OPT lowered yield potential by 20 to 28% (US$207 to US$688/ha) and K omission caused a 13 to 26% yield loss valued between US$163 to US$601/ha. *Heilongjiang-NMBF*

A Macronutrient Rate Study for Maize Production in Liaoning

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Project Cooperator: Dr. Yuehua Xing

Field experiments were conducted within the main maize production regions in Liaoning Province in 2009 to determine the range of appropriate rates of N, P, and K required to support maximum economic yields.

Field trial sites used for N rate study supported maximum yields of 10.3 t/ha at Gaizhou using 320 kg N/ha and 9.4 t/ha at Shenyang using 290 kg N/ha. However, maximum economic yields at these sites were 10.1 and 9.4 t/ha, respectively, with corresponding rates of 159 and 260 kg N/ha. Over all N rates, maize yields increased by 5 to 75%, with net benefits between US$21 to US$766/ha. The P rate study supported maximum yields of 8.9 t/ha at Shenyang using 32 kg P_2O_5/ha, 9.7 t/ha at Gaizhou using 76 kg P_2O_5/ha, and 9.9 t/ha at Fuxin using 110 kg P_2O_5/ha. Maximum economic yield at each site was 8.8, 9.7, and 9.8 t/ha, with corresponding rates of 30, 58, and 64 kg P_2O_5/ha. Maize yield responses to P application ranged between 2 to 8%, with net benefits between US$24 to US$136/ha. The Gaizhou field site used to evaluate K rate responses produced a highest yield of 10.2 t/ha using 126 kg K_2O/ha. However, the maximum economic rate of 102 kg K_2O/ha also resulted in a 10 t/ha yield. Maize yield responses to K application ranged between 3 to 20%, with net benefits between US$35 to US$307/ha. *Liaoning-NMBF*

A Macronutrient Rate Study for Maize Production in Jilin

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Project Cooperators: Dr. Jiagui Xie and Ms. Xiufang Wang

A total of 18 field experiments were designed for 2009 to determine the proper rates for N, P, and K fertilizers for high yield maize production in selected locations within the "spring maize belt" in Jilin Province.

Results indicated that N rates for maximum economic yield ranged between 63 to 188 kg N/ha, appropriate P rates ranged between 51 to 62 kg P_2O_5/ha, and K rates ranged between 23 to 72 kg K_2O/ha. Yields ranged between 6.2 to 12.4 t/ha. Application of N, P, and K fertilizer increased yields by 3 to 60%, 3 to 19%, and 2 to 8%, respectively. Agronomic efficiency for N ranged between 22.5 to 3.8 kg grain increase/kg N. The net benefit from fertilizer application ranged from US$7 to US$726/ha for N, US$46 to US$240/ha for P, and US$14 to US$114/ha for K.

The wide range of proper rates of N, P, and K for maximum yield maize production is indicative of great variation in soil fertility and supports the importance of soil testing to guide fertilizer recommendation programs. It is also important to develop suitable site-specific nutrient management programs to maximize yields and profits within this maize belt of China. *Jilin-NMBF*

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

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Project Cooperators: Dr. Jiagui Xie and Ms. Xiufang Wang

A long-term field experiment was initiated at Liufangzi, Gongzhuling City, in Jilin to investigate the ability of ecological intensification (EI) practices to improve yields over time, compared to farmer practices (FP), while minimizing adverse environmental impacts. In this first year, a split-plot design with four replicates was used. The maize plots consisted of two treatments: EI (180-75-90-20-5 kg N-P_2O_5-K_2O-S-Zn/ha) and FP (251-145-100 kg N-P_2O_5-K_2O/ha). The three split plots were: 1) N applied in all years; 2) N applied in 2 of 3 years; and 3) no N applied any year. The site represents the typical mono-cropping system of spring maize. Spring maize was planted on May 4 and harvested on September 29.

Results indicated that an average grain yield of 8.5 t/ha was obtained in the EI treatment, which was 14.2% greater than FP. Agronomic efficiency (kg grain yield increase per kg N applied) was 20.5 kg grain/kg N in the EI treatment and 9.4 kg grain/kg N in the FP treatment. Partial factor productivity (kg grain yield per kg N applied) was 47.3 kg grain/kg N with EI and 29.7 kg grain/kg N with FP. The apparent recovery efficiency of N (increase in kg N uptake per kg N applied) was 28.3% for EI and 20.9% for FP. Compared to FP, the EI treatment increased P and K uptake, but not N uptake. *IPNI-20* ❖

Asia Group

China

Northcentral Region: Dr. Ping He

Optimized Nitrogen Nutrient Management for Vegetables in Beijing

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Over-fertilization is of great concern for the vegetable production area immediately surrounding Beijing. Field trials and demonstrations were conducted in 2009 to determine optimal N rates for important vegetables grown within the region. Different N application rates, including 0, 90, 180, 270, 360, and 450 kg N/ha were applied on greenhouse tomatoes located in Dasunge Village of Shunyi. Farmers typically apply 450 kg N/ha, but no yield differences were apparent as N rates decreased to 270 kg N/ha. Additionally, use of 270 to 360 kg N/ha reduced surface (0 to 20 cm) soil nitrate concentrations by 31.7 to 69.3% and nitrate accumulation in the top 100 cm depth could be reduced by 28 to 49%. A separate open field experiment was conducted on Chinese cabbage in Xiaofengying Village of Yanqing County. Results showed that yield was not significantly affected as N application rate fell from 450 kg/ha (farmers' rate) to 315 kg/ha. Nitrate concentration was also reduced with N rate.

This initial data suggest that farmers could rely on lower N rates without suffering yield losses, and the potential risk to the environment could also be decreased. Results from the first year of experimentation, both under greenhouse and open field study, indicate that vegetable yields were not affected as N rate was reduced by 30 to 40%. *Beijing-NMBF*

Soil Nutrient Availability and Nutrient Uptake in Northeast China as Influenced by Different Fertilization Patterns

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Project Cooperators: Dr. Liping Yang and Dr. Mingfang Cheng

The lack of synchrony between soil nutrient supply and plant uptake is one of the most important factors contributing to low fertilizer use efficiency. Information is lacking on temporal variability of nutrients during the crop growth period from the viewpoint of a soil-crop system. In 2009, Yushu City, Jilin, was the site selected to study the effect of different fertilization patterns on soil nutrient availability and nutrient uptake in spring maize to provide a scientific basis for synchronizing nutrient supply with crop requirements. The field experiment consisted of treatments designed to compare a zero fertilizer control against: 1) a 1/3: 2/3 split (basal: top-dressing) of 225 kg N/ha, 2) 1/4: 3/4 split, 3) 1/4: 3/4W split (W stands for bed-irrigation sowing using 60 m3 water/ha), 4) 1/4: 3/4M split (M stands for manure applied at 10 t fresh pig manure with respective contents of water, N, P_2O_5 and K_2O of 39.7%, 0.96%, 1.96%, and 1.84%), 5) 1/4: 3/4MW split, 6) 1/4: 1/2: 1/4 split (basal: top-dressing: top-dressing), 7) 1/3: 1/3: 1/3 split, 8) CRU (Controlled-release urea applied at 180 kg N/ha), and 9) FP (farmers' practice of 225 kg N/ha all applied basally). Rates of P_2O_5 and K_2O application were 90 and 120 kg/ha, respectively.

Soil nitrate (NO_3-N) and ammonium (NH_4-N) contents were comparatively higher at the seeding stage, reached a low level at jointing stage, increased to a relatively high level at the flare opening stage, then decreased slowly as the maize crop developed further. Accumulation rates for N, P, and K were much lower at seedling stage, highest from jointing stage to flare opening stage, and decreased to a much lower level from tasseling stage to ripening. The practice of using two top-dressed applications of N, manure application, and CRU significantly increased soil NO_3-N and NH_4-N contents within the 0 to 40 cm depth, the accumulation rates of N, P, and K, and therefore N use efficiency and yield of maize were improved. Compared with a single top-dressing of N, yield increases were 5.1 to 17.0% for N top-dressed twice, 2.8 to 18.0% for manure application, 9.6 to 23.1% for CRU, and 13.1 to 20.4% for the combined use of manure and bed-irrigation sowing. *CAAS-NMBF*

Nutrient Management and Balanced Fertilization on Wheat and Maize in Henan

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Project Cooperator: Mr. Bingqi Li

This project's goals are to determine the optimal (OPT) rates of N, P, and K fertilizers and provide scientific recommendations for fertilizer application in a winter wheat-summer maize rotation located within the black soil region of southern Henan Province. For winter wheat, treatments included an OPT of 180-105-105 kg N-P_2O_5-K_2O/ha, three nutrient omission plots, farmers' practice (FP) of 195-75-75 kg N-P_2O_5-K_2O/ha, and an unfertilized check (CK). A separate site for summer maize used the above structure of treatments as well; however, the OPT for summer maize was 180-60-150 kg N-P_2O_5-K_2O/ha and FP included 240-0-0 kg N-P_2O_5-K_2O/ha.

The OPT produced best yields for both winter wheat (7.6 t/ha) and summer maize (7.4 t/ha). All nutrient omission plots had significantly lower wheat and maize yields compared to the OPT. Nitrogen was most limiting in both crops, while P was more significant than K in wheat and the opposite held true for maize. Yields in the FP treatment were only 5.3% (wheat) and 9.3% (maize) lower than the OPT. Thus, the higher N rates used in the FP could not generate any yield advantages even if the soil fertility was low. The OPT was also able to increase agronomic efficiency (AE) for N. Values for AE in winter wheat were 12.1 kg grain increase/kg N for the OPT and 9.1 kg grain increase/kg N for FP. The AE values for summer maize where 13.2 kg grain increase/kg N in the OPT and 7.0 kg grain increase/kg N in the FP.

The selected OPT treatments were more balanced and could enhance yield and N use efficiency for both winter wheat and summer maize. *Henan-NMBF*

Nutrient Management and Balanced Fertilization on Wheat and Maize in Shandong

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Project Cooperators: Mr. Guo Yang and Mr. Jianlin Wei

The experiment was initiated in 2009 in Qingzhou, Shandong Province, to determine the optimal rates of N, P, and K fertilizers for winter wheat and summer maize and provide scientific recommendations for fertilizer use in the region. In winter wheat, treatments included an optimal (OPT) treatment of 240-75-90 kg N-P_2O_5-K_2O/ha, a set of nutrient omission plots, and a farmers' practice (FP) of 160-80-80 kg N-P_2O_5-K_2O/ha. A separate site for summer maize included the same treatment structure although the OPT was 180-75-90 kg N-P_2O_5-K_2O/ha and the FP treatment was 240-45-45 kg N-P_2O_5-K_2O/ha.

The OPT produced the best yields for both winter wheat (6.9 t/ha) and summer maize (8.5 t/ha). The N omission plots had significantly lower wheat and maize yields compared to the OPT, while the P and K omission pots produced marginal yield gaps for both crops. No significant differences in both wheat or maize yield existed between the OPT and FP.

It is apparent that N was over-applied for the selected OPT treatment for winter wheat and therefore requires further adjustment. In summer maize, N was over-applied for the FP treatment, and optimization of fertilizer application has the potential to reduce N fertilizer application in maize by at least 30%. *Shandong-NMBF*

Nutrient Management for Summer Maize in Shanxi

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Project Cooperator: Mr. Bin Wang

Intensification of agricultural production with poor nutrient management practices has decreased N use efficiency and increased environmental pollution in Northcentral China. Work in 2009 optimized nutrient management in summer maize for increased yield and fertilizer use efficiency in Shanxi. A field experiment conducted in Linfen tested five treatments including: a balanced 'optimum' (OPT) nutrient application of 210-90-60 kg N-P_2O_5-K_2O/ha based on soil testing and a target yield, farmers' practice (FP) of 276-0-0 kg N-P_2O_5-K_2O/ha, and an OPT-N, OPT-P, and OPT-K.

The OPT was only able to produce 3.7% more grain yield than the FP. The N, P, and K omission plots produced 17.3%, 8.1%, and 4.2% less than the OPT, respectively, indicating that N was the first nutrient limiting factor for yield. The OPT did have better N use efficiency than the FP. Recovery efficiencies were

42.7% vs. 35.9% (OPT vs. FP), agronomic efficiencies were (10.1 vs. 6.4 kg grain increase/kg N), and partial factor productivities were 47.1 vs. 34.6 kg grain yield/kg N.

Since the OPT tested in this study generated only marginal yield increases, there remains considerable potential to improve N use efficiency further for summer maize. *Shanxi-NMBF*

Optimized Nutrient Management on Vegetables in Tianjin

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Project Cooperators: Ms Jinghua Zhu and Mr. Mingrui Li

Over-fertilization is a great limitation to improved nutrient use efficiency. This not only lowers yield potential, but can also spawn higher environmental risks. The aim of this study is to assess the extent to which fertilization rates can be lowered without incurring significant yield or profit losses.

In Houyou Village of Tianjin, the optimal (OPT) treatment of 450-225-675 kg N-P_2O_5-K_2O/ha failed to generate a yield advantage in cucumber over the farmers' practice (FP) of applying 750-825-900 kg N-P_2O_5-K_2O/ha. However, the OPT did generate 8.3% more profit than FP. Agronomic efficiency (AE) for N, P, and K applied within the OPT was 9.6 kg yield increase/kg N, 231 kg/kg P, and 110 kg/kg K. Meanwhile, AE values for the FP were 12.5 kg/kg N, 41.8 kg/kg P, and 69.9 kg/kg K. In terms of partial factor productivity (PFP or total yield per kg nutrient), a single kg N, P_2O_5, and K_2O produced 19.4, 38.7, and 12.9 kg cucumber within the OPT, while the corresponding PFP values were 11.2, 10.2, and 9.4 kg cucumber under FP. Other vegetable field demonstrations collectively indicated that balanced fertilization could increase yields over those commonly obtained for tomato (+11.7%), cucumber (+11.5%), cowpea (+18.8%), respectively. Extra profits generated through adoption of balanced fertilization in these respective crops amounted to US$1,996, US$3,343, and US$1,639/ha.

These results indicated that the OPT maintained good cucumber yields, increased profitability, and improved nutrient use efficiency through more balanced fertilizer input. Tianjin-NMBF

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

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Project Cooperator: Mr. Chunjie Li

A long-term field experiment was initiated at Dahe Experimental Station in Hebei Province to investigate the ability of ecological intensification (EI) practices to improve yields over time, compared to farmer practices (FP), while minimizing adverse environmental impacts. In this first year, a split-plot design with four replicates was used. Main plots consisted of EI (240-60-90 kg N-P_2O_5-K_2O/ha) and FP (140-138-0 kg N-P_2O_5-K_2O/ha). Subplots were: 1) N applied in all 3 years; 2) N applied in 2 of every 3 years; and 3) no N applied. The site represents the typical rotation system of summer maize and winter wheat. Summer maize was planted on June 15 and harvested on September 30, while winter wheat was planted in the same plot after the summer maize harvest.

A grain yield of 8.1 t/ha was obtained by the EI treatment, which was 6.4% more than FP. Agronomic efficiency (kg grain yield increase per kg N applied) was 4.0 kg grain/kg N in the EI treatment and 4.9 kg grain/kg N in the FP treatment. Partial factor productivity (kg grain yield per kg N applied) was 33.7 kg grain/kg N with EI and 54.3 kg grain/kg N with FP. The apparent recovery efficiency of N (increase in kg N uptake per kg N applied) was 19.1% for EI and 15.8% for FP, respectively. Compared with FP, the EI treatment increased N and K uptake, but not P uptake. *IPNI-21* ❖

Asia Group

South Asia

West India Region: Dr. Harmandeep Singh

Inventory of Available Potassium Status and Modeling its Relationships with Potassium Content, Yield, and Quality of Sugarcane for Site-Specific Nutrient Management in Maharashtra

Earlier work done on the inventory of available K status in Maharashtra revealed that out of 25 districts of the state, 12 districts were medium and 13 districts were high in available K. Among the sugarcane growing districts, Kolhapur, Sangli, Satara, Nashik, Jalgaon, and Wardha districts had medium K, while Pune, Solapur Ahmednagar, Nanded, Parbhani, and Osmanabad districts had high levels of available K in soil. However, the referred assessment was done long ago and needs reassessment because of the introduction of several new high-yielding varieties and the related change in farmer practices, especially with regard to fertilizer K use. Moreover, there is limited information on the relationships between available soil K and plant K, available soil K and cane yield, and available soil K and juice quality. These relationships are important to developing extension tools/decision support systems for site-specific and efficient fertilizer K use by farmers.

The importance of applying secondary nutrients and micronutrients with macronutrients in improving sugarcane production is well known. Our experience with site-specific nutrient management (SSNM) from 2003-04 through 2005-06 revealed that cane yield and quality were highest with the integral application of N, P, K, S, Zn, Fe, and Mn nutrients. But no such SSNM package has yet been developed for a newly released variety of sugarcane in Maharashtra (Co 9805) that yields about 20% higher than the existing and commonly used varieties, and also has shown to respond to B application. Keeping in mind the above considerations, we propose to conduct this study with the following objectives: 1) to assess available K status of soils and of sugarcane leaf blades from nine sugarcane-growing districts in Maharashtra; 2) to model the relationships between soil K, plant K, yield, and quality of sugarcane for different regions of Maharashtra; 3) to evaluate the effect of major and secondary nutrients and also micronutrients on yield and quality of sugarcane variety Co 9805; and 4) to determine the economics of growing sugarcane variety Co 9805 in Maharashtra.
SA-02 ❖

Asia Group

South Asia

North & East India Regions and Bangladesh:

Dr. Kaushik Majumdar

Site-Specific Nutrient Management for Rice-Maize Cropping Systems in Bangladesh

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This project was initiated to develop principles for optimizing N, P, and K management for rice and maize, with particular emphasis on the rice-potato-maize (R-P-M) cropping system. The project aims to consolidate research results on maize and rice and develop system-level fertilizer best management practices (BMPs). Data sets arising from field experimentation will enable accelerated development, refinement, field evaluation, and release of nutrient decision support tools for implementing improved nutrient management for rice and maize.

Activities were initiated in three districts (Comilla, Rajshahi, and Rangpur) from January 2010 with nutrient management trials in boro (dry season) rice. Two different treatment designs are currently being followed, namely: 1) omission plot trials involving N, P, K, S, and Zn; and 2) Nutrient Manager (NM) for Rice evaluation trials with five treatments (farm practice; Bangladesh Rice Research Institute (BRRI) recommended NPKSZn; NM-based NPK plus BRRI-based S and Zn; NM-based NPK but no S and Zn; and NM-based NPK plus BRRI-based S, but no Zn. Experiments have been established in the three districts on fields differing in landscape position, soil type, as well as past fertilizer and residue management. Surface soil samples have been collected from all fields for determination of the physico-chemical properties. Irrigation water samples will be collected from each district to measure pH and to estimate the contribution of Ca, Mg, and K in the irrigation water. In both trials, fertilizer (N, P, and K) rates were determined based on a yield goal approach. In omission plots, N, P, and K fertilizers were applied at rates sufficient to eliminate all nutrient deficiencies except for the specific nutrient omitted. In the NM evaluation trials, treatments with lower K fertilizer rates are being explored to study drawdown rates for native K in these soils. Grain yields and other data will be used to develop various relationships with site characteristics, develop new scientific principles in SSNM, and to further refine the NM for Rice in Bangladesh. *Bangladesh-09*

Maximizing Productivity, Farmer Profit, and Nutrient Use Efficiency in Rice-Based Cropping Systems of the Terai Agro-ecological Region of West Bengal

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This study was initiated in the Terai agro-ecological region of West Bengal to assess the importance of soil test-based fertilizer application in improving yields and profitability of rice-lentil-jute and rice-potato-cowpea cropping systems. Previous results showed that yield was significantly improved by the soil test-based recommendation in the component crops. Omission of nutrients from the optimum treatment caused variable yield losses depending on the nutrient concerned. Significant yield losses were observed when secondary and micronutrients were omitted from the soil test-based treatment. These soils were found to be most limited by Zn, B, and P. Yield loss of rice and cowpea due to omission of Zn from the optimum was about 30%. Omission of B from the optimum reduced yield by 19% and 34% in cowpea and rice, respectively. This suggests the growing importance of secondary and micronutrients as major yield limiting factors in these production systems.

The average uptake of nutrients by the component crops were significantly correlated with yield, which highlights the importance of the soil test and yield target-based nutrient application followed in this study. Such significant correlations between uptake and yield was also observed in the farmers' fields in the third year of the study when the best treatment of the on-station trial was validated against general recommendation and existing farmers' practice. Comparative economics of production, calculated between the best treatment from the on-station trial, the general recommendation, and farmers' practice, showed a significant advantage to following the soil test-based recommendation. The benefit of using the optimized treatment, as compared to the other two treatments, varied from Rs.4,456/ha (US$97) in rice, Rs.8,145/ha (US$177) in cowpea, Rs.13,789/ha (US$300) in potato, Rs.17,778/ha (US$386) in lentil, and Rs.25,245/ha (US$549) in jute.

Results from this study corroborate that soil test and yield target-based site-specific nutrient management is necessary for improved yield and farm profit in the Terai region. *EZ India-41*

Importance of Soil Test-based Nutrient Application through Farmers' Participatory Approach in Red and Lateritic Soils of West Bengal

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The applicability of soil test-based fertilizer application is severely curtailed in developing countries due to a lack of infrastructure and high cost of implementation. This is particularly true in India where the size of holdings is typically low. The current study was initiated to assess the use of Geographic Information System (GIS)-based fertility maps for fertilizer decision making in fragmented land holding systems.

The results showed that physiochemical soil parameters of farmers' fields predicted from the GIS maps closely match actual soil analysis. The comparative assessment of soil pH and nutrient content from farm fields, after actual analysis or predicted from the GIS, had only minor variations in available N content and practically no variation in available P content under the two methods of evaluation. However, a larger difference was observed in available K content, which was attributed to high variability in K fertility with samples well distributed between low, medium, and high fertility groups. This was not well predicted through the GIS maps. Fertilizer recommendations based on GIS maps and actual soil tests did not produce significant yield difference in a rice-potato-sesame cropping sequence. It is likely that small variations in the nutrient availability under these two systems of assessment were minimized when the values were categorized and recommendations were generated. To substantiate this, a comparison was made between the mean fertilizer (NPK) doses under the soil test and GIS-based treatments for each crop. Results showed that N and P application rates to be identical, but K rates varied slightly, which again was attributed to comparatively higher variations in available soil K.

To arrive at a cost effective grid size of sampling, actual soil analysis values of pH, organic C, and available P and K contents of random samples from the study area were compared with the predicted values from maps using 50, 100, and 250 m grid sampling. A 250 m grid was found to be adequate to address variability in a red and lateritic soil and predictability of soil parameters did not differ significantly between 50, 100, and 250 m grid-based maps. This methodology provides a cost-effective option of implementing improved nutrient management in large areas of the small-scale farming system in Eastern India. *EZ India-43*

Global Maize Project in India: Ranchi, Jharkhand

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

This project was initiated to optimize nutrient management for improved productivity within the maize-wheat cropping system. The working objective includes a quantitative estimation of the attainable yield potential of maize and wheat from a system perspective, estimation of the indigenous nutrient supplying capacity of soils, and using such information to develop a strategy of nutrient management to maximize system productivity. Different N management strategies for timing and rate are being assessed in the cropping system to provide additional input for developing a scientific approach for nutrient management in Jharkhand. The strategies developed will be evaluated for both agronomic and economic performance and will help assess short-term and long-term effects of intensive maize-wheat production systems from a nutrient management perspective.

The experimental design for maize and wheat incorporates three sub-experiments that run simultaneously for: Experiment A) long-term system evaluation of an ecologically intensified (EI) system and farmers' practice (FP) in maize-wheat; Experiment B) studying the effect of N rate and timing and real-time N

management on productivity of maize-wheat; and Experiment C) estimation of indigenous nutrient supplying capacity of soils to evaluate an alternate approach of plant-based, site-specific nutrient management. The results from experiment B and C will be utilized to continuously improve the EI treatment in experiment A for the development of guidelines of best management practices.

Significant yield differences were observed between treatments in the first season of maize. However, yield levels were lower than expected due to an in-season hailstorm and subsequent yield loss. The yield under FP was found to be 1.4 t/ha lower than the current EI treatment. In all experiments, N was found to be most limiting, leading to a yield loss of 3 to 3.5 t/ha when N was omitted from the fertilization schedule. The yield loss due to omission of P and K, as compared to the optimum treatment, was in the range of 0.7 to 0.9 t/ha at an optimum yield level of 4.6 t/ha. One season of field data from the maize experiment showed that 160 kg N/ha split between three applications (basal, crown root initiation, and panicle initiation stages) produced the highest yields. Treatment-wise soil and plant samples are currently being analyzed to assess nutrient uptake in maize and residual soil fertility. *IPNI-22*

Management of Multi-Nutrient Deficiencies through Site-Specific Nutrient Management

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Project Cooperators: Dr. Dhyan Singh, Dr. Anand Swarup and Dr. K.S. Yadav

This research was initiated to assess the nature and extent of multi-nutrient deficiencies in soils of different agro-ecological sub regions (AESRs) and evaluate site-specific nutrient management (SSNM) options to enhance yields, net returns, and soil fertility. Fourteen on-farm experiments were conducted using pearlmillet-wheat and pearlmillet-mustard cropping systems near the village of Lohtaki in Gurgaon District (AESR 4.1). Seven treatments were assessed including: SSNM, NPK applied according to soil test/crop response fertilizer adjustment equations (TY), TY + secondary and micronutrients (TY+Micro), state ad-hoc recommendations (SR), SR + K, farmers' fertilizer practice (FFP) + K, and FFP.

Simultaneous deficiencies of N, P, K, S, Zn, and B were frequently observed in the village. SSNM out-yielded the other fertilization options and yield gains over FFP were as high as 80% for pearlmillet and over 60% in wheat and mustard. Inclusion of K in the FFP increased pearlmillet yield by 0.25 to 0.41 t/ha. The benefit of K was greater (0.54 to 0.62 t/ha) when SR was supplemented with fertilizer K. Subsequent winter crops also responded to K fertilization, indicating that the recommendations from the State are not adequate to achieve the high yield potential of modern cultivars. The carryover effects of S and micronutrients were greater in wheat and mustard compared to their direct effect in pearlmillet. Analysis of post-harvest soil samples (0 to 15 cm) showed a marked increase in available P and K content under the SSNM and TY treatments when compared with the other options. The annual net returns were highest under SSNM in both cropping systems.

Two years of on-farm experimentation clearly established the superiority of SSNM over other fertilization options in enhancing annual productivity, profits, and soil fertility restoration under these intensive cropping systems. *NWZ India-72*

Evaluating Production Systems to Approach Attainable Yields and Profits in the Upper Gangetic Plains Region

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Project Cooperator: Dr. Arvind Kumar Shukla, ICAR

A lack of information on site-specific nutrient management (SSNM) and inadequate nutrient application rates are the main reasons for stagnating productivity of crops in the Indo-Gangetic plains region. This work explores several nutrient management strategies to increase system productivity of important cropping systems of the area. Field experiments were conducted in 2008-09 to evaluate the performance of five nutrient management options: farmer practice (FP), the state recommendation (SR), an improved SR (ISR) using 25% more N and 50% more P and K, the state soil testing laboratory recommendation (STLR), and the IPNI soil test-based, SSNM treatment in major cropping systems.

The maximum gains in productivity for SSNM over FP were 35%, 38%, 54%, 31%, 29%, and 51%, respectively, for rice, maize, pigeon pea, sesame, groundnut, and sorghum fodder. Averaged over cropping systems, the grain yield of wheat was highest under SSNM, followed by ISR, and was lowest under FP. The enhancement in wheat yield under the SSNM and ISR options was attributed to larger ear size, more grains per ear, and higher numbers of effective tillers/m^2. Highest system productivity in terms of wheat equivalent yield (WEY) was recorded under SSNM (12.5 t/ha) within the rice-wheat system, followed by maize-wheat (10.8 t/ha), groundnut-wheat (8.86 t/ha), pigeon pea-wheat (8.83 t/ha), sesame-wheat (7.69 t/ha), and sorghum

(dry fodder)-wheat (5.99 t/ha). System wheat equivalent yield (SWEY) were 33% and 23% higher in SSNM and ISR respectively over FP. The productivity of the six rice-based cropping systems varied considerably and was 40.4 t/ha in rice-garlic, 17.5 t/ha in rice-potato, 13.7 t/ha in rice-wheat, 12.5 t/ha in rice-berseem, 12.0 t/ha in rice-chickpea, and 11.6 t/ha in rice-mustard systems. The cumulative annual productivity in terms of systems rice equivalent yield (SREY) was maximized with SSNM (20.7 t/ha) followed by ISR (18.9 t/ha), STLR (18.0 t/ha), SR (17.6 t/ha), and FP (14.5 t/ha).

Together, these results suggest that SSNM recommendations based on indigenous nutrients supplying capacity of soil and targeted yields can help attain high yields in many crops and cropping systems in the region. *NWZ India-73*

Fertility Mapping and Balanced Fertilization for Sustaining Higher Productivity of Wheat in Agra District

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The project evaluates a plant-based approach to site-specific nutrient management (SSNM) to manage farm nutrient variability. This approach uses a crop-based estimate of indigenous nutrient supply to determine the yield supported by the soil in absence of a limiting nutrient when all other nutrients are adequate. On-farm testing aims to quantify the variation in soil nutrient supply in wheat areas in Western Uttar Pradesh to develop a SSNM approach that improves on common farm practice (FP)

Twenty omission plot trials have been started in winter wheat in four villages. The study compared five treatments including omission plots for N, P, K, S, and the complete treatment of 180-90-100-35 kg N-P_2O_5-K_2O-S/ha that also provided a blanket dose of micronutrients. The mid-season evaluation of the standing crop showed marked variability in nutrient supplying capacity of the soils as evidenced by severity of nutrient deficiency symptoms across sites.

Concurrently, intensive geo-referenced soil sampling was done in a selected village at a predetermined grid size. Soil samples are being analyzed for several parameters, including nutrients. Surface maps for different nutrients will be developed from latitude/longitude coordinates and analyzed parameters of samples. These maps will be utilized for making fertilizer recommendations for the subsequent crop. *NWZ India-74*

Site-Specific Nutrient Management for Rice-Wheat in Punjab

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Project Cooperator: Naveen Gupta

Punjab, with only 1.5% of the geographical area of India, contributes about 11% of rice production and 20% of wheat production in the country. This rice-wheat system is practiced in more than 60% of the cultivable area in the state. Current assessment of yield gaps showed that average yield of rice and wheat are 43% and 17% lower, respectively, than the maximum attainable yields observed in field experiments. Lack of site specificity and inadequacy of nutrient application is one of the main reasons for such yield gaps. Presently, wheat establishment under no-till is gaining popularity in the state. However, nutrient management strategies under such no-till systems are not well defined. The current work was initiated under the Cereal Systems Initiative in South Asia (CSISA) project to develop and implement site-specific nutrient management (SSNM) in this rice-wheat system with reference to both conventional and no-till establishment systems.

Farmer participatory trials (29) were initiated in wheat under conventional and no-till. Three different sets of trials are currently in progress in the state, including: 1) a nutrient omission trial to identify N, P, K supplying capacity of soils under different establishment practices, 2) a nutrient omission trial to estimate P and K draw down potential of soils under conventional system, and 3) a validation trial for the first version of a rice-wheat Nutrient Manager software system. This Nutrient Manager software is a fertilizer recommendation tool that is based on existing knowledge of SSNM. It is being developed to help extension workers implement SSNM in cereal crops in farmers' fields even under situations where soil testing facilities are not available. The farmers' field validation of the initial version of software will be helpful to understand the limitations of the current version, while inputs from the two types of omission plot trials are expected to help modify and improve its efficacy under different tillage practices. *NWZ India-75*

Site-Specific Nutrient Management for Rice-Wheat in Haryana

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Project Cooperator: Anil Bana

The intensive rice-wheat cropping system in Haryana is a major contributor to foodgrain production in India. However, a comparison between average yields and those obtained in yield maximization trials under best management practices show a yield gap of 60% in rice and 14% in wheat. Implementation of site-specific nutrient management (SSNM) principles in rice and wheat is necessary to bridge such yield gaps. The present study was initiated under the Cereal Systems Initiative in South Asia (CSISA) to develop and evaluate a cropping system focused decision support tool for wide-scale implementation and adoption of SSNM principles in farmers' fields.

Farmer participatory trials (58) were initiated in wheat under conventional and no-till systems across several districts of Haryana. Three different sets of trials are currently in progress, including: 1) a nutrient omission trial to identify N, P, K supplying capacity of soils under different establishment practices, 2) a nutrient omission trial to estimate P and K draw down potential of soils under conventional cultivation, and 3) a validation trial for the first version of a rice-wheat "Nutrient Manager" software. The effect of different residue management practices under zero-till systems such as full residue retention, partial residue retention, complete residue removal, or partial burning are also being studied in the omission plot trials to help understand the dynamics of N, P, and K under differing residue management scenarios. A first version of the Nutrient Manager software for rice-wheat system has been developed for Haryana. This software is based on existing knowledge of SSNM in cereals and is capable of providing SSNM recommendation for individual farm fields.

The current study will help modify and improve the limitations of the current version while inputs from the two types of omission plot trials in Haryana will improve the efficacy of "Nutrient Manager" under existing crop and tillage management practices. *NWZ India-76* ❖

Asia Group

South Asia

South India Region and Sri Lanka: Dr. T. Satyanarayana

Site-Specific Nutrient Management for Maize-Wheat in Northern Karnataka

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Project Cooperator: Dr. Y.R. Aladakatti

The rice-wheat cropping system is the most predominant cereal production system in India. However, during the recent past, the area and production of maize is gaining importance due to growing demand for feed destined for the poultry sector ... presently accounting for over 50% of maize production. Since maize has less demands for water, there is a tremendous opportunity for the area under maize-wheat to grow, and increases the importance of developing nutrient management guidelines for this emerging cropping system. This project aims to understand the yield potential of the maize-wheat cropping system through different nutrient management strategies. Developing a scientific approach to site-specific nutrient management (SSNM), evaluating its agronomic and economic performance, and assessing the short and long-term effects of intensive maize production are the objectives of this study. The expected outcome is to develop and disseminate SSNM recommendations to maize farmers within Northern Karnataka.

Field experiments were laid out during June 2009 at agricultural research station near Dharwar. The highest maize yield within an ecological intensification study was 3,357 kg/ha under the complete treatment of 180-90-100 kg N-P_2O_5-K_2O/ha. A study examining real-time N management applied either 160 or 240 kg N/ha through split applications occurring at the basal, V4 to V6 stages, and V10 stage (guided by leaf color charts) and achieved yields of 4,942 and 4,620 kg/ha, respectively. A third study estimating indigenous nutrient supplying capacity through nutrient omission plots found that ample NPK could produce 4,743 kg/ha, whereas omitting N, P, and K resulted in yields of 2,615, 3,961, and 4,325 kg/ha, respectively.

Nutrient uptake studies for maize are under progress. This project continues to June 2012. SZ *INDIA-51*.

Investigations on Balanced Fertilization for Breaking Maize Yield Barriers in Tamil Nadu

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Field verification trials were conducted during 2009 to determine optimum nutrient recommendations for high yielding maize. With significant responses of maize to higher rates of N application in earlier trials within the study, two higher rates were evaluated, including 125% and 150% of the recommended optimum dose of N.

Results revealed that irrespective of soil series, the enhanced level of N at 125% of the optimum with optimum P, K, and Zn recorded higher grain yields. Maize yields ranged from 6,717 kg/ha in the Irugur soil series to 11,628 kg/ha in Palaviduthi soil series with the average being 9,132 kg/ha. Enhanced N application at the 150% optimum dose (300 kg N/ha) did not show any marked increase in grain yield and illustrated the polynomial response to increasing N application rates. Based on these findings, the maximum N rate for higher maize yields in Tamil Nadu was 250 kg/ha. On-farm trials were also conducted in four different locations of Tamil Nadu to demonstrate the best nutrient recommendations to farmers. The results from these trials are yet to be compiled; however, researchers are confident that the optimum nutrient recommendations evolved so far would certainly help achieve higher yields over the state recommendation and farmer practice. *SZ India-47*

Site-Specific Nutrient Management for Maximization of Crop Productivity in Southern Karnataka

Project Leader: Dr. M.A. Shankar, University of Agricultural Sciences, Bangalore, All India Coordinated Research Project on Dry Land Agriculture, GKVK, Bangalore, Karnataka 560065

Based on the results obtained from the field experiments pooled over 2 years, it was revealed that yields of both sorghum and sunflower were significantly influenced by site-specific nutrient management (SSNM). Sorghum grain yield obtained under soil test based SSNM (target yield of 4,000 kg/ha) was 3,609 kg/ha, which was significantly higher than that obtained with common farmer practice (2,545 kg/ha). However, the yields obtained with the state recommendation (SR) and the 150% SR were 3,360 and 3,469 kg/ha. In case of sunflower, grain yield with SSNM for a targeted yield of 2,500 kg/ha was 1,715 kg/ha. Meanwhile, yields obtained with the SR and 150% SR were 1,546 and 1,627 kg/ha. The yield obtained with farmer practice was 1,431 kg/ha, which was 16% less than that obtained with SSNM.

Interpretation of data pertaining to nutrient balance sheets, enzymatic and microbial changes with different fertility levels, and developing fertilizer schedules based on soil test values is in progress. The project was started in July 2007 and is expected to be completed in 2010. *SZ India-49*

Site-Specific Nutrient Management for Maximum Economic Yield and Quality of Transgenic Cotton in Northern Karnataka

Field experiments were conducted during June 2008 on the response of transgenic cotton to planting geometry and yield target-based nutrient application. Seed cotton yield did not differ significantly with respect to planting geometry at both the Dharwad and Siruguppa locations, but the levels of nutrients applied had significant effect on the kapas yield at both sites. The interaction effects between planting geometry and nutrient application were also not significant. Among the three planting geometries tried, 90 x 30 cm proved economical under both rainfed (Dharwar) and irrigated (Sirugappa) conditions ... with corresponding seed cotton yields of 1,678 and 2,457 kg/ha and benefit-to-cost ratios of 1.39 and 2.79. Nutrient application for a yield target of 4,000 kg/ha resulted in a seed cotton yield of 1,992 and 2,680 kg/ha, thus the target yields were not attained at either location. The researchers attribute this gap to late sowing of cotton at both locations due to a late onset of monsoon rains at Dharwad and a late release of canal water at Siruguppa. Therefore, the researchers felt that the same study should be repeated.

Field experiments were laid out during June 2009, repeating the same set of experiments and treatments. Based on visual observations and from the data collected from the first picking, the results seem to be promising and do not fall in line with first year's observations. This project was started in mid 2008 and is planned to continue for 3 years until mid-2011. *S India-50*

Global Maize Project in India: Dharwad, Karnataka

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Project Cooperator: Mr. Y.R. Aladakatti

This project was initiated to optimize nutrient management for improved productivity within the maize-wheat cropping system of this region. The working objective includes a quantitative estimation of the attainable yield potential of maize and wheat from a system perspective, estimation of the indigenous nutrient supplying capacity of soils, and using such information to develop a strategy of nutrient management to maximize system productivity. Different N management strategies for timing and rate are being assessed in the cropping system to provide additional input for developing a scientific approach for nutrient management in Karnataka. The strategies developed will be evaluated for both agronomic and economic performance and will help assess short-term and long-term effects of intensive maize-wheat production systems from a nutrient management perspective.

The experimental design for maize and wheat incorporates three sub-experiments that run simultaneously for: Experiment A) long-term system evaluation of an ecologically intensified (EI) system and farmers' practice (FP) in maize-wheat; Experiment B) studying the effect of N rate and timing and real-time N management on productivity of maize-wheat; and Experiment C) estimation of indigenous nutrient supplying capacity of soils to evaluate an alternate approach of plant-based, site-specific nutrient management. The results from experiment B and C will be utilized to continuously improve the EI treatment in experiment A for the development of guidelines of best management practices.

Data have been collected from the experiments and are currently being analyzed. *IPNI-23* ❖

Asia Group

Southeast Asia: Dr. Thomas Oberthür

Indonesia

The Oil Palm Management Program (OMP)

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Project Cooperator: Ian Rankine (Director, Agrisoft-Systems Australia Pty Ltd)

The Oil Palm Management Program (OMP) is an Agricultural Management Information System for agronomy and field data management in oil palm plantations developed by Agrisoft Systems Indonesia (www.agrisoft-systems.com). As a long-term supporter and discussion partner in the development, IPNI endorses the software and currently uses it to manage the data of its yield intensification program using the best management practice (BMP) concept.

During the last year, OMP was further developed with a set of new user-defined categories and extended productivity parameters, sustainability indicators, analytical reports, and advanced spatial mapping concepts to support the specific requirements for precision agriculture in oil palm. The OMP-AMIS (Agronomic Management Information System) is now commercially used for plantation management in Indonesia, Papua New Guinea (PNG), Malaysia, and Guatemala, where it helps to address some of the core issues of the industry (such as low productivity, long-term sustainability, and environmental acceptance). OMP tools are used for site-specific management to assess and react to in-field variability with a set of fine-tuned best management actions and optimized inputs, on-time, and at the right location. The database is designed for long-term data management and can support two crop cycles. It produces 'proof of action' reports and 'change over time' views and analyses from a wide set of parameters, which can be used directly for Round Table for Sustainable Palm Oil (RSPO) auditing and ISO certification.

During 2010, OMP will be further developed with a focus on a specific OMP-AMIS version for smallholder and outgrower operations, which are major producers in Indonesia and PNG, on advanced mapping and special data analysis methods (grid maps), on environmental aspects (RSPO dashboard report), and on the development of user or task-specific solutions, like the CLA crop loss auditing program, which can be used to monitor harvesting standards. *Indonesia-23*

Site-Specific Nutrient Management for Maize in Indonesia

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In 2004, the IPNI Southeast Asia Program and the Indonesian Agency for Agricultural Research & Development (IAARD) launched a broad nationwide initiative to develop and evaluate a new site-specific nutrient management (SSNM) approach for favorable environments. Under the leadership of the Center for Food Crops Research and Development (ICFORD), strong institutional support is provided by six Indonesian Centers and Research Institutes and five provincial Assessment Institutes for Agricultural Technology (AIAT). On-farm trials were conducted in the five key maize producing provinces of North Sumatra, Central Java, East Java, Lampung, and South Sulawesi with one or two hybrid maize crops per year in 2004 to 2007. Using participatory approaches, the new nutrient management strategies were evaluated with a larger group of farmers at all project sites in 2007 and 2008. Also in 2008, a national Technical Working Group with multi-institutional partnerships was formed to facilitate the wider-scale dissemination of plant-based SSNM for maize in Indonesia.

In 2009, partners worked towards finalizing project results obtained in 2004-2008 for special publication in an Indonesian journal. Major emphasis in 2009 was given towards the development of tools and promotional materials related to the newly developed SSNM approach, including the Nutrient Expert for Hybrid Maize software released in December 2009 and a training video on best management practices for maize. As a further step towards dissemination of SSNM, Quick Guides with management options for a given region will be developed and evaluated for each of the project sites in 2010. These Quick Guides are complemented by videos on general crop and nutrient management strategies for maize and will form a package of tools to aid in introducing new recommendations to farmers in wide-scale extension campaigns.

This project is closely linked with similar activities in Vietnam and the Philippines, forming a regional initiative in the development of technologies for small-holders growing maize in favorable tropical environments. *Indonesia–26*

Philippines

Site-Specific Nutrient Management for Maize in the Philippines

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In 2005, the IPNI Southeast Asia Program in partnership with the University of Los Baños and the Department of Agriculture-Bureau of Agricultural Research (DA-BAR) launched a new national research initiative to increase the productivity and profitability of maize farming through site-specific, integrated crop and nutrient management. On-farm trials were conducted at three key maize production sites in the provinces of Isabela, Bukidnon, and Nueva Ecija/Tarlac with one or two hybrid maize crops grown per year in 2005 to 2007. Project results were used to develop, evaluate, and refine a new plant based site-specific nutrient management (SSNM) approach for irrigated and favorable rainfed maize in the Philippines.

Data from field trials showed that the SSNM concept has significant agronomic and economic potential to enhance the productivity and profitability of maize farming in the Philippines. Attainable yield in irrigated and favorable rainfed environments was estimated at 8 to 10 t/ha. With SSNM, grain yield increased on average by 1.0 t/ha (+12%) and net benefit by 5,170 PhP/ha (US$125/ha; +7%) compared to farmer practice across all sites and seasons. With sufficient evidence and promising results collected from researcher managed on-farm trials, SSNM has proven a reliable technology ready for wider-scale, participatory evaluation in partnership with government and non-government units, extension, the private sector, and farmers.

Activities towards wider-scale evaluation and delivery of SSNM in the country were fully implemented in 2008 after the official launch by the Department of Agriculture of the new national initiative on SSNM for Maize in the Philippines, as well as the creation of a National Management Team that will provide guidance and assistance on the technical aspects of SSNM. A series of on-farm activities in key maize-growing provinces in 16 regions started during the 2008-09 dry season and will continue for three more seasons until 2010. First results from these on-farm trials were promising, confirming earlier studies that there are significant opportunities to increase maize production in the Philippines through improved crop and nutrient management. *Philippines–04*

Southeast Asia

Enhancing Profitability in Rice Farming in Asia through Improved Nutrient and Crop Management

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The focus of this project has been on transforming the knowledge intensity and scientific complexities of site-specific nutrient management (SSNM) into easy-to-use decision tools and videos for extension workers, crop advisors, and farmers. Nutrient management decision support software entitled Nutrient Manager for Rice in the Philippines and Pemupukan Padi Sawah Spesifik Lokasi (Location Specific Rice Fertilization) in Indonesia were distributed on CD in local language with training throughout each country. Each consists of 10 to 15 questions easily answered by an extension worker and farmer. Based on responses to the questions, a field-specific guideline with amounts of fertilizer required by crop growth stage is provided to enable farmers to increase their profit by applying the right amount of fertilizer at the right time to their field.

In the Philippines, Nutrient Manager for Rice was also released as a web version (www.irri.org/nmrice). The decision tool was used in the Philippines to develop province-specific quick guides on fertilizing rice, which were released and promoted by the Department of Agriculture in 75 provinces (www.pinoyrkb.com/resources). A video for farmers entitled Proper Nutrition Makes Healthy Rice Plants was developed and distributed in the Philippines via CD and the internet (www.pinoyrkb.com/resources). Another video was developed in Bahasa Indonesia and distributed via CD and the internet in Indonesia.

Experiences from the Philippines and Indonesia with decision tools, videos, and quick guides for accelerating the uptake of nutrient best management serve as a model for replication with rice, maize, and wheat across Asia. Initial versions of six new decision support software tools were developed in response to requests from national and international organizations. As of December 2009, decision tools for providing field-specific best nutrient management were under field testing and verification for wheat in India, maize in Bangladesh, and rice in Bangladesh, China, India, Sri Lanka, and West Africa. Multi-institutional partnerships within the Cereal Systems Initiative for South Asia (CSISA), the Irrigated Rice Research Consortium (IRRC), and the IRRI-CIMMYT rice-maize project in Bangladesh, together with emerging public-private sector partnerships across Asia, provide opportunities for accelerating the development, verification, dissemination, and uptake of locally adapted best nutrient management for cereals across Asia. *Southeast Asia-01*

Best Management Practice for Maximum Economic Yield in Oil Palm

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The best management practice (BMP) concept for yield intensification in existing mature oil palm plantings has been developed and refined by IPNI and its partners over a period of 8 years. In this approach, a set of site-specific BMPs are identified and implemented in a representative number of full-size management blocks in each estate to achieve crop management objectives related to productivity, profitability, sustainability, and the environment. Through this process, estates identify better ways to implement BMPs for yield intensification, and decisions on larger investments in BMPs are based on practical, commercial-scale evidence.

In 2009, IPNI continued its project on yield intensification in partnership with six collaborating plantations in Sumatra (North, South) and Kalimantan (West, Central, and East), Indonesia. By late 2009, BMP implementation at the six project sites ranged from 25 to 35 months. Yield advantages with BMPs were significant at all projects except Site 1 where current yield is already close to the site's achievable yield potential. Based on all data from all six sites, annual fruit yield with BMPs was 3.2 t/ha or 14% greater compared to the standard practice. Yield advantages with BMPs ranged from 2.1 to 6.0 t/ha with the exception of Site 1, where the average BMP yield was only 0.4 t/ha higher than the 29.9 t/ha average of the reference blocks. These encouraging yield improvements achieved through the implementation of BMPs at sites broadly representative of the oil palm industry underline the general applicability of the BMP concept. Clearly, a short harvesting interval (HI) and improved crop recovery are the key prerequisites for closing current yield gaps at project sites. Effects of other agronomic BMPs not directly related to crop recovery are yet to be observed. Achieving consistently short HI will be the greatest challenge in yield intensification over a wider area. The approach will be specific to sites in relation to the local cropping trend in particular the difference between peak and trough crop levels.

In 2009, the first training course for estate managers – on using the BMP approach to intensify yield in mature plantations – was conducted in South Sumatra for Sampoerna Agro group. A key priority for 2010 in the on-going project will be determination of oil and kernel contents so that recorded fruit yield can be expressed as oil and kernels. *Southeast Asia-03*

Vietnam

Site-Specific Nutrient Management for Maize in Vietnam

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In 2005, the IPNI Southeast Asia Program in partnership with five research institutes and universities in Vietnam launched a national research initiative to develop and evaluate a new plant based site-specific

nutrient management (SSNM) approach for favorable environments in Vietnam. On-farm trials were conducted at 13 key production sites in nine provinces of South, Central, and North Vietnam with one or two hybrid maize crops per year in 2005 to 2007.

Results indicate significant opportunities to increase productivity and profitability of maize farming in the country. Across all sites and seasons, yield with SSNM was 0.8 t/ha or 12% greater compared to farmer practice (7.3 t/ha vs. 6.5 t/ha). Adjustments in fertilizer N, P, and K rates and better timing of fertilizer N applications were the key to achieving greater yield with SSNM. However, the full benefit of improved nutrient management was only achieved once other constraints to yield (primarily low planting density) were removed. With improved crop and nutrient management, average yield reached 8.2 t/ha, an increase of +1.7 t/ha or 26% compared to the farmer practice.

Major emphasis in 2008 was given to the refinement of plant-based SSNM recommendations through participatory evaluation. In 2009, partners worked towards finalizing project results obtained in 2004-2008 and the acceptance of SSNM for maize as a national technology in Vietnam. *Vietnam-09*

Nutrient Imbalances in Degraded Soils of North Vietnam

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This project aims at developing strategies for dealing with the spatial variability of soil nutrient imbalances when developing site-specific nutrient management (SSNM) options for small-scale farmers in North Vietnam. Past research on degraded soil and the rice-rice-maize rotation indicated that yield responses to the application of fertilizer N, P, and K are limited by imbalances of soil Ca, K, and Mg. However, a detailed analysis on the magnitude and spatial distribution of these imbalances was lacking. The study area covers more than 100,000 ha of rice-based cropping area within Vinh Phuc, Bac Giang, and Hanoi Provinces, representing 78% of the total area with degraded soils in the Red River Delta. A multi-scale soil sampling strategy with more than 1,000 soil samples taken in late 2005 was used in combination with geo-statistical interpolation to produce detailed thematic maps of key soil properties. These maps were used to refine existing SSNM recommendations for evaluation in the 2007-08 winter maize cropping season. Existing SSNM recommendations were evaluated in three areas with degraded soil of different pH: very low (pH < 4.5), low (pH 4.5 to 5.0), and moderate (pH > 5.3). For sites with very low and low pH, addition plots with application of Mg, lime, and Mg+lime were embedded in the standard SSNM practice. A second Mg+lime treatment with additional K fertilizer (+30 kg K_2O/ha) compared to the SSNM recommendation (90 kg K_2O/ha) was included to test whether more K is needed when problems related to pH and Mg supply are corrected. For farms with moderate pH, only the effect of Mg and Mg plus increased K dose were evaluated in two separate addition plots embedded in the standard SSNM plot.

First results indicate significant yield constraints in maize due to nutrient imbalances. Compared to the standard SSNM, at low soil pH, the application of lime, Mg, and additional K increased yield by 0.8 to 1.4 t/ha. Average yield increases were < 0.5 t/ha when pH or Mg deficiency was corrected separately. When simultaneously corrected, yield increased by 0.7 t/ha, while a further 0.6 t/ha yield improvement was achieved with additional K. The same trial was repeated during the 2009-10 winter maize season and will continue during the 2010 spring rice and summer rice seasons. Results of the winter maize season are currently undergoing analysis. *Vietnam-10* ■

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