BETTER CROPS
WITH PLANT FOOD

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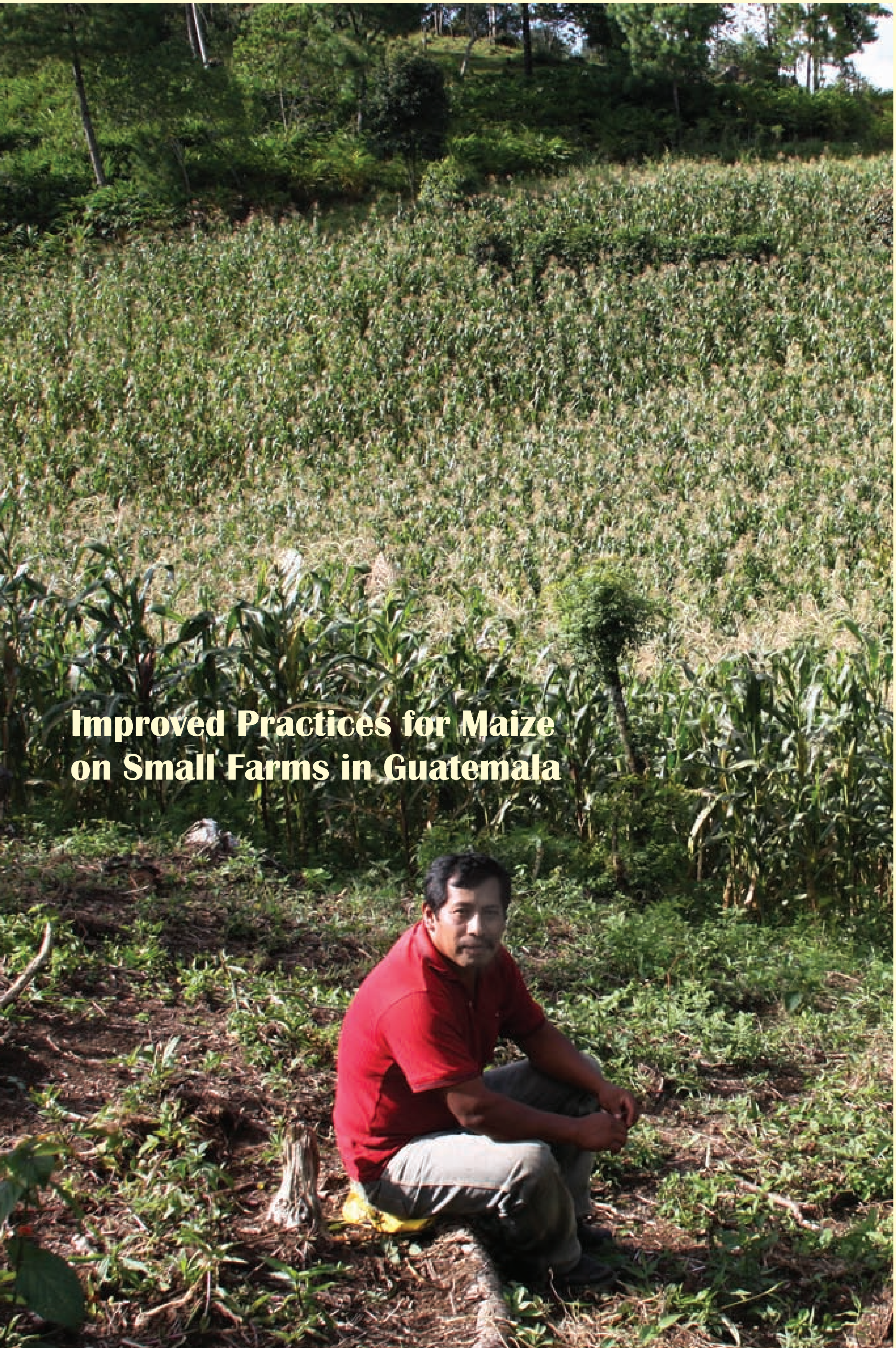

Improved Practices for Maize on Small Farms in Guatemala

In This Issue...

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Our cover: In Guatemala, small farmers are making great progress in maize production. See article on page 18.
Photo by Dr. José Espinosa
Editor: Donald L. Armstrong
Assistant Editor: Katherine P. Griffin
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2010 IPNI Science Award Goes to Dr. Andrew Sharpley, University of Arkansas

The International Plant Nutrition Institute (IPNI) has named Dr. Andrew N. Sharpley, University of Arkansas, Department of Crop, Soil and Environmental Sciences, as the winner of the 2010 IPNI Science Award. He receives a special plaque plus a monetary award of USD 5,000.00 (five thousand dollars).

"We are honored to announce Andrew Sharpley as the recipient of the IPNI Science Award. His distinguished career has been dedicated to improved nutrient management with the goal of sustaining ecologically intensive cropping while protecting water quality. Dr. Sharpley led development and refinement of a Phosphorus (P) Index to identify agricultural fields at greatest risk for nutrient loss and needing remediation. The impact of his work has been positive and far-reaching," said Dr. Terry L. Roberts, President of IPNI. "Dr. Sharpley provides international leadership in determining the fate and transport of P in agricultural systems and its environmental impact."

Dr. Roberts also acknowledged the other outstanding nominees for the award, and encouraged future nominations of qualified scientists. Private or public sector agronomists, soil scientists, and crop scientists from all countries are eligible for nomination. This is the fourth year the IPNI Science Award has been presented since it was established in 2007.

Born in Manchester, England, Dr. Sharpley received his B.Sc. degree from the University of North Wales in 1973. He went on to earn his Ph.D. in Soil Science at Massey University, Palmerston North, New Zealand, in 1977.

Since 2006, Dr. Sharpley has been Professor, Department of Crop, Soil and Environmental Sciences, Co-Director of Agriculture's Watershed Research and Education Center, and Co-Chair of the Environmental Task Force, Division of Agriculture, University of Arkansas, Fayetteville. From 1995 to 2006, he was Soil Scientist with U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS), at University Park, Pennsylvania, and Adjunct Professor at Pennsylvania State University. From 1985 to 1995, he was Soil Scientist with USDA-ARS at Durant, Oklahoma.

Dr. Sharpley was elected Fellow of the American Society of Agronomy (ASA) in 1990 and Fellow of the Soil Science Society of America (SSSA) in 1991. He also received the Environmental Quality Research Award from ASA in 1994 and the Soil Science Applied Research Award from SSSA in 1998. Among numerous other awards and honors, Dr. Sharpley is a 2008 inductee of the ARS Hall of Fame, "For pioneering nutrient research leading to the development of agricultural management practices and strategies that are used nationally and internationally to protect water quality."

Dr. Andrew N. Sharpley

In his research career spanning more than 30 years, Dr. Sharpley has authored or co-authored more than 540 publications (including 290 in peer-reviewed journals), 38 book chapters, 60 popular press articles, and he has edited six books. His published research is widely known and has been cited thousands of times.

The scientific underpinnings of the P Index are based on Dr. Sharpley's findings that most of the P exported (more than 80%) from agricultural watersheds comes from only a small area of the land (less than 20%). The P Index is an educational tool that facilitates interactions between farm planners and farmers, elucidates the water quality implications of management decisions, and helps identify alternative management options for farmers. Dr. Sharpley's research greatly increased the basic understanding of the behavior and fate of P and nitrogen in agricultural systems, and their impact on water resources. He demonstrated that effective strategies of fertilizer, manure, and tillage use can achieve production goals and protect water quality.

The IPNI Science Award is intended to recognize outstanding achievements in research, extension, or education, with focus on efficient and effective management of plant nutrients and their positive interaction in fully integrated crop production that enhances yield potential. Such systems improve net returns, lower unit costs of production, and maintain or improve environmental quality. The recipient is selected by a committee of noted international authorities.

More information and nomination forms for the 2011 IPNI Science Award are available from the headquarters or regional offices of the organization. Website: www.ipni.net/awards.

IPNI Scholar Award Applications Due June 30

Each year, IPNI offers the Scholar Award to honor and encourage deserving graduate students. The process requires students who are candidates for either a M.S. or Ph.D. degree in agronomy, soil science, or related fields to submit an application and supporting information by June 30.

Individual students in any country where an IPNI program exists are eligible. Only a limited number of recipients are selected for the award, worth USD 2,000 each. The application process is available on-line only. Recipients are announced in September. For more about the application requirements, visit the website: www.ipni.net/awards. BC

International Plant Nutrition Institute

ANNOUNCEMENT of the International Plant Nutrition Institute (IPNI) Scholar Awards — 2011

■ About the IPNI Scholar Award:

Awards of US$2,000 each will be conferred to deserving graduate students in sciences relevant to **plant nutrition** and **management of crop nutrients**.

The Award will be made directly to the student. No specific duties will be required of the recipient.

The Award will be granted independent of any assistantship, scholarship, or other award that the student presently holds.

The Application is only available on-line at **www.ipni.net/scholar**

■ Eligibility

Graduate students attending a degree-granting institution located in any country with an IPNI program are eligible.

Candidates for either the M.S. or Ph.D. degrees are eligible. In the case of Ph.D. candidates, preference will be given to students who have a minimum of one year remaining before completion of their studies.

Priority will be given to the relevance of the proposed research in support of IPNI's mission. Students in the disciplines of soil and plant sciences including agronomy, horticulture, ecology, soil fertility, soil chemistry, crop physiology, and other areas related to plant nutrition are encouraged to apply.

Winners are not eligible for reappointment; the awards are for one time only.

■ Requirements

In order to complete the application process, you will need the following:

1. Electronic copy of transcripts of all college work, including cumulative and final grade average records (GPA or percentile).
2. Electronic copy of three letters of support, one of which should be from the major professor. Letters must be signed and written on official letterhead, and must include the phone number and e-mail address of the letter writer.
3. A description of the focus of your thesis or dissertation research presented in a manner that will permit evaluation of its originality, depth, and scope, innovative approaches, and relevance to IPNI's mission.
4. You will be asked to briefly describe any honors or awards you have received, employment, career goals, and other activities you pursue.

Note: You will be required to upload the electronic copy of the transcripts and support letters during the on-line application process. You should have an electronic copy of these documents prepared in advance. Further instructions are provided at the website.

■ Deadlines

Application must be completed by June 30, 2011.

Announcement of the Scholar Awards will be made in September 2011, and checks will be presented to the winners as soon as practical thereafter.

International Plant Nutrition Institute (IPNI)
3500 Parkway Lane, Suite 550
Norcross, Georgia 30092 U.S.A.
Phone: 770.447.0335 Fax: 770.448.0439
E-mail: info@ipni.net Website: www.ipni.net

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

Maize Productivity and Response to Fertilizer Use as Affected by Soil Fertility Variability, Manure Application, and Cropping System

By Shamie Zingore

Studies in sub-Saharan Africa (SSA) show that fertilizer use is consistently more profitable and efficient on fertile fields. When soils are degraded, restoration of soil fertility through balanced fertilization and organic matter additions is necessary to achieve high crop productivity. Other options for managing soil fertility, such as manure, crop rotations, and improved fallows are most effective when strategically combined with fertilizer.

Problems of declining soil fertility are widespread in SSA, largely as a consequence of continued cultivation of crops with low levels of nutrient inputs. To counter growing food insecurity, there are renewed efforts to support the predominantly subsistence farmers to intensify crop production mainly by increasing the use of fertilizers and improved crop varieties. Soil fertility varies considerably at the farm and landscape levels in many smallholder farming systems in Africa, leading to variable crop productivity and crop response to additions of fertilizer and organic nutrient resources (Zingore et al., 2007).

Consequently, large yield gaps arise from soil fertility differences between fields due to a combination of inherent and management factors. Therefore, a major focus should be placed on properly addressing the fundamental issues of providing the crops with adequate nutrients under highly variable soil fertility conditions. Despite a generalized trend of decreasing soil fertility in SSA (Stoorvogel et al., 1993), rates of change in soil nutrient stocks differ between farms and fields within farms. Smallholder farmers typically have limited amounts of nutrient resources that are preferentially used on fields closest to homesteads, leading to steep gradients of decreasing soil fertility with increasing distance from homesteads (Prudencio, 1993). This, combined with inherent variation in soils, results in complex variability in soil fertility between fields on the same farm or between farms differing in access to resources for crop production. Challenges exist to restore agricultural productivity for degraded soils that respond poorly to commonly used NP fertilizers. This article reviews the extent to which variability in soil fertility affects crop productivity, and crop response to fertilizer and various complementary organic resource-based technologies in the sub-humid zone of southern Africa.

The sub-humid zone constitutes 38% of the total land area in SSA and has good prospects for agricultural growth due to favorable rainfall (700 to 1,200 mm/yr) and high potential for maize production. Maize is the staple food crop for the region (FAO, 2002). The soils in SSA are inherently infertile and have been used for agricultural production for many decades with little or no addition of nutrient resources, leading to declining soil fertility (Bationo et al., 1998; Bekunda et al., 1997). Nutrient depletion rates for NPK range between 22 and 72 kg/ha/yr...a reflection on the low yields over the past 5 decades...with cereal productivity in SSA stagnant at about 1 t/ha. Long-term experiments show that with no fertilizer use, yields decline rapidly from an initial level of 5 t/ha when native woodlands are cleared for cultivation, to about 1 t/ha after 3 years **(Figure 1)**.

Abbreviations: N = nitrogen; P = phosphorus; K = potassium; B = boron; Ca = calcium; Zn = zinc.

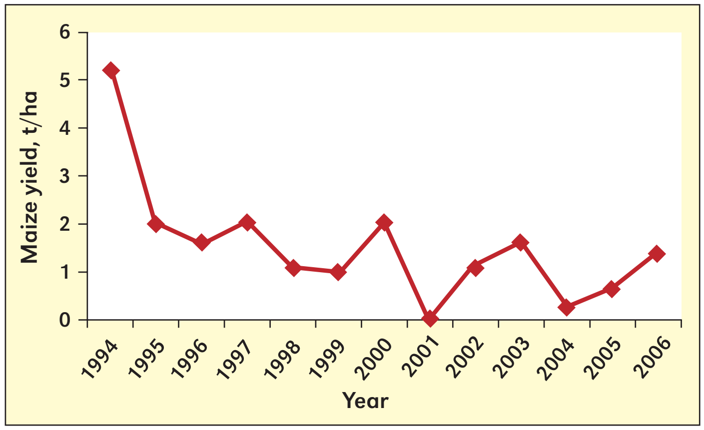

Figure 1. Average maize yields with no fertilizer application from long-term experiments in southern Africa (Waddington et al., 2007).

The use of mineral fertilizers in SSA has been promoted through blanket recommendations that are based on agro-ecological zones. Improving the blanket recommendations to account for variability in soil fertility between land units is necessary to maximize the benefits of projected increases in fertilizer use. Multi-location trials conducted across SSA revealed that baseline yields and yields for different fertilizer treatments increased with increasing soil fertility status (Tittonell et al., 2005; Zingore et al., 2007). Application of N alone gave the largest yield increase for all treatments and for all categories of soil fertility.

Addition of P also led to a significant increase in yields on the high fertility fields, but in medium fertility fields, addition of base cations (K and Ca) and micronutrients (Zn and B) was required to significantly increase crop yields above the N treatment **(Figure 2)**. On the depleted soils, baseline yields were very low, and were increased to less than 1 t/ha by applying N and to less than 2 t/ha by applying N and P. Under such conditions, an increase in soil organic matter can increase the retention of nutrients and water, better synchronize soil nutrient supply with crop demand, and improve soil health through greater soil biodiversity (Vanlauwe et al., 2010). In nutrient depleted soils, strategic fertilizer application with incorporation of crop residues over several seasons would be

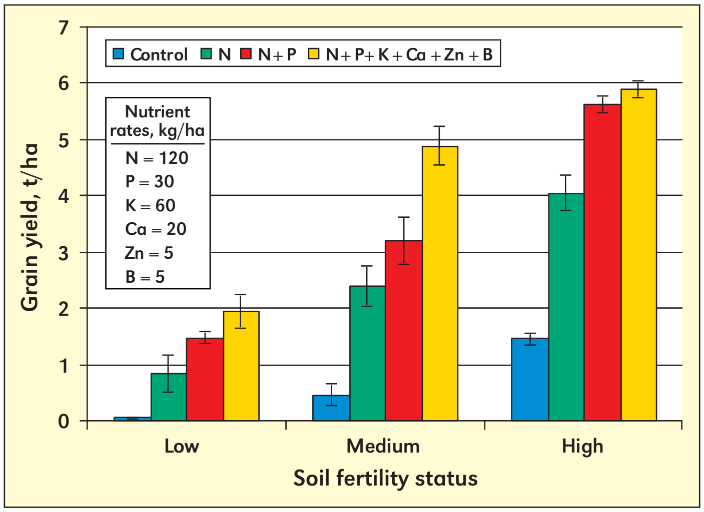

Figure 2. Maize yield response to various nutrient combinations as influenced by soil fertility status.

necessary to increase attainable yields over time. Alternative organic nutrient resources, such as compost and animal manures, may also play an important role in replenishing soil fertility, but available quantities are limited and the quality is often very poor.

Table 1. Maize productivity (t/ha) as affected by N fertilizer and manure application under low and medium soil fertility conditions.

	Control	Manure	N fertilizer	Manure + N fertilizer
Low soil fertility	0.3	0.8	1.2	2.8
Medium soil fertility	0.8	1.7	3.8	4.3
Standard error of difference (SED)	0.12	0.23	0.19	0.24

On low and medium soil fertility conditions, combined application of N fertilizers and manure led to increased productivity above fertilizer treatments alone, and this is most pronounced on degraded soils **(Table 1)**. Many studies in SSA have reported on the positive interaction between fertilizer and manure, with the benefits of manure increasing with decreasing soil fertility (Zingore et al., 2008; Mtambanengwe and Mapfumo, 2005).

Various legume-based technologies, such as rotations of cereal crops with grain legumes, improved fallows, alley-cropping, and green manures have been advocated as viable options for providing supplementary N to cereal crops through biological N fixation (Giller et al., 1997). Within rotations, applying P to grain legumes has variable effects on the subsequent maize crop. The yield of maize following groundnut was greater than continuously fertilized maize, but soybean had no effect on maize productivity **(Table 2)**. Groundnuts can double the yields of the subsequent season maize crop without fertilizer, but gave more additional grain yield when fertilizer was used on the maize.

Intercropping maize with grain legumes offers opportunities to improve overall productivity of both crops, and

Differences in response to fertilizers under low (top photo), medium (middle), and high soil fertility conditions.

Table 2. Rotational effects of grain legumes on productivity of maize in fertilized and unfertilized crop rotations.

	--------- Without fertilizer ---------			--------- With fertilizer ---------		
Legume crop	Continuous maize, t/ha	Maize after legume, t/ha	Rotation yield gain, %	Continuous maize, t/ha	Maize after legume, t/ha	Rotation yield gain, %
Groundnut	1.7	3.0	44	4.4	5.9	25
Soybean	1.1	1.5	24	2.0	2.0	0
SED	0.22	0.26		0.33	0.25	

Table 3. Cost and benefits (USD/ha) of fertilizer use by sole maize and maize-bean intercrop.

Crop system	Maize benefit	Bean benefit	Costs that vary	Net benefit
Sole maize	55	0	31	24
Maize + bean	48	45	42	51

ensure the legumes benefit from fertilizer targeted to maize. Intercrops can result in increased grain output over maize alone, both with and without fertilizers (Snapp and Silim, 2002). Although maize yields when intercropped with beans were lower than for sole maize, the overall economic benefits of fertilizer use were greater for the intercrop than a maize monocrop due to the added benefits of the bean yield. An economic analysis of a maize-bean intercropping system showed that both fertilized and unfertilized intercrops had greater economic returns than corresponding sole maize crops, and that the economic viability of intercrops was substantially increased by fertilizer application **(Table 3)**.

A meta-analysis of fertilizer response under agroforestry in smallholder farming systems showed that fertilizers give the better maize yield response than legume trees and green manures (Sileshi et al., 2008). However, maize yield response to fertilizer application in the tree legumes systems was significantly higher than in green manures, natural fallows, and unfertilized maize. Based on the analysis, amending the post-fallow plots with 50% of the recommended fertilizer rate increased yields by more than 25% over similar plots that were not fallowed. Adding 100% of the recommended fertilizer to the post-fallow plots did not significantly increase yields over the yield obtained with 50% of the fertilizer treatments, as this resulted in oversupply of N. Tree legumes can play an important role in increasing fertilizer use efficiency, especially when fertilizer availability or amounts are limited.

Strategically targeting fertilizer use to variable soil fertility conditions, combined with recycling crop residues, manure application, and various legume-based technologies is necessary for viable fertilizer use in smallholder farming systems in SSA (Giller et al., 2006). Recognition of the spatial heterogeneity within smallholder farms will help to design more effective recommendations that target different soil fertility niches (i.e., poorly-responsive fertile fields, responsive fields, and poorly-responsive poor fields).

However, it is also necessary to develop communication/extension frameworks to build capacity among extension and industry field staff and smallholder farmers for the practical identification of such variability and its effect on fertilizer use and other management interventions. This will allow farmers to fine-tune their decision-making for the allocation of their scarce (labor, cash, and nutrient) resources.

Dr. Zingore is Director, IPNI Africa Program, located in Nairobi, Kenya; e-mail: szingore@ipni.net.

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Information Agriculture Conference July 12-14, 2011

Individuals interested in precision agriculture should mark their calendars for the next edition of the popular Information Agriculture Conference, set for **July 12-14, 2011**, at the Crowne Plaza in Springfield, Illinois. This is the same location as InfoAg 2009 and previous conferences.

InfoAg 2011 is organized by the International Plant Nutrition Institute (IPNI) and the Foundation for Agronomic Research (FAR), with exhibits coordinated by CropLife.

Since the first conference in 1995, InfoAg has been a leading event in precision agriculture. The Information Agriculture Conference occurs at 2-year intervals, alternating years with the International Conference on Precision Agriculture (ICPA). InfoAg 2011 will present a wide range of educational and networking opportunities for manufacturers, Certified Crop Advisers, practitioners, input suppliers, farmers, Extension and NRCS personnel, and anyone interested in site-specific techniques and technology.

Watch for further details and program updates at the conference website: >www.infoag.org <.

Fertilizing for Sustainable Onion Production Systems

By Ethel Ngullie, V.B. Singh, A.K. Singh, and Harmandeep Singh

Studies evaluated straight versus combined applications of manures, fertilizers, and microbial biofertilizers with reference to onion bulb yield and soil nutrient balances. Given the good supply of quality manures, observations favored the combined application of inorganic fertilizers and manures over sole application of either nutrient source. Application of 50 to 75% of the fertilizer recommendation plus any microbial inoculant treatment failed to achieve a viable alternative.

Onion (*Allium cepa* L) is a highly nutrient-responsive crop. Conventional methods of fertilization have undoubtedly helped in improving both bulb yield and quality. But lately, routine management practices in India appear to be incapable of maintaining yields over the long-term. The steady depletion of native soil fertility and the occurrence of multiple nutrient deficiencies in onion fields has led to the identification of nutrient management as a key factor limiting sustainable onion production (Sharma et al., 2003). Integrated nutrient management (INM) offers an effective strategy (Dimri and Singh, 2005; Santhi et al., 2005).

Although the use of manures as nutrient sources for vegetables is common, their effectiveness is potentially limited by nutrient release patterns that are often out of synchrony with crop demand, large variability in source quality and field distribution, and food safety. All of these issues have contributed to experimentation with alternative options. A gradual shift from using purely organic sources to introducing some proportion of inorganic fertilization is gaining acceptance. This shift has formed the basis for INM, which could involve three nutrient sources: microbial inoculants or biofertilizers including azotobacter (Az), azospirillum (Azr), and phosphate solubilizing bacteria (PSB), inorganic fertilizers, and manures. However, INM further prescribes that selected nutrient inputs be used judiciously to ensure optimum supply of all essential nutrients for sustained crop production. Most INM studies conducted with onion have lacked the experimental components required to link soil nutrient budgeting with bulb yield response.

This field experiment was carried out with two major objectives: 1) determine the magnitude and economic value of responses of onion to INM-based treatments, and 2) assess the nutrient uptake pattern to determine net changes in the soil nutrient balance sheet.

The experiment was conducted during the kharif (monsoon) seasons between 2007-09 at the experimental farm (25°45’43” N latitude - 93°53’04” E longitude) of the School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema, Nagaland to study fertilization strategies for sustainable onion (var. Agrifound Dark Red) production. The experimental soil was classified as Typic Rhodustalf with a loam texture (58% sand, 20% silt, and 21% clay), pH 5.2 (1:2), high organic carbon (21.8 g/kg by Walkley and Black method), low available N (248 kg/ha by alkaline permanganate distillation method), low available P (11 kg P_2O_5/ha by Bray’s method), and low available K (178 kg K_2O/ha, ammonium acetate extractable) (Sparks, 1996).

Abbreviations: N = nitrogen; P = phosphorus; K = potassium; SSP = single superphosphate; KCl = potassium chloride; RDF = recommended dose of fertilization; FYM = farmyard manure; PiM = pig manure; PM = poultry manure; Vm = vermicompost; CD = critical difference, equivalent to Least Significant Difference. INR = Indian rupee. Note: USD 1 = approximately INR 44.1.

Combined application of inorganic fertilizers with organic manures offers better results in onion production in India.

Table 1. Response of different INM-based treatments on the onion bulb yield (fresh weight basis).

Treatments	----- Bulb yield, t/ha -----		
	2007-08	2008-09	Mean
T_1 = Control	2.80	2.60	2.70
T_2 = Current recommendation (RDF)	3.32	3.80	3.56
T_3 = FYM	3.10	2.94	3.02
T_4 = Pig manure (PiM)	3.18	3.04	3.11
T_5 = Poultry manure (PM)	3.10	3.50	3.30
T_6 = Vermicompost (Vm)	3.60	3.46	3.53
T_7 = 50% RDF + 50% FYM	3.70	3.98	3.84
T_8 = 50% RDF + 50% PiM	3.50	3.80	3.65
T_9 = 50% RDF + 50% PM	3.40	3.96	3.68
T_{10} = 50% RDF + 50% Vm	3.91	4.19	4.00
T_{11} = 50% RDF + Az	2.81	3.01	2.91
T_{12} = 50% RDF + Azr	2.92	2.76	2.84
T_{13} = 50% RDF + PSB	2.72	2.92	2.82
T_{14} = 75% RDF + Az	2.98	3.04	3.01
T_{15} = 75% RDF + Azr	3.00	3.16	3.08
T_{16} = 75% RDF + PSB	3.18	3.06	3.12
CD (p = 0.05)	0.12	0.18	0.15

Table 1 outlines 16 treatments that were replicated three

Table 2. Balance sheet for nutrient input and output for onion in response to INM treatments (mean of two seasons).

Treatments	Nutrient addition, kg/ha			Nutrient removal, kg/ha			Net balance, kg/ha		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
T_1 = Control	-	-	-	45 (1.68)[1]	25.2 (0.40)	32.4 (0.98)	-45	-25	-32
T_2 = Current recommendation (RDF)	100	60	60	79 (2.22)	45.8 (0.57)	52.8 (1.24)	21	14	7
T_3 = FYM	104	23	162	56 (1.86)	29.8 (0.44)	37.2 (1.02)	48	-7	125
T_4 = Pig manure (PiM)	109	18	95	61 (1.96)	36.6 (0.50)	44.4 (1.20)	48	-19	51
T_5 = Poultry manure (PM)	107	25	91	63 (1.90)	34.3 (0.44)	49.2 (1.12)	44	-9	42
T_6 = Vermicompost (Vm)	102	18	74	75 (2.12)	41.2 (0.50)	48.0 (1.14)	27	-23	26
T_7 = 50% RDF + 50% FYM	106	72	141	74 (1.92)	41.2 (0.46)	50.4 (1.10)	32	31	91
T_8 = 50% RDF + 50% PiM	105	70	108	74 (2.02)	43.5 (0.51)	54.0 (1.24)	31	26	54
T_9 = 50% RDF + 50% PM	104	69	97	73 (1.98)	41.2 (0.48)	51.6 (1.16)	31	27	46
T_{10} = 50% RDF + 50% Vm	101	73	106	96 (2.40)	52.7 (0.58)	64.8 (1.34)	5	20	41
T_{11} = 50% RDF + Az	70	69	36	51 (1.76)	29.8 (0.44)	36.0 (1.02)	19	39	0
T_{12} = 50% RDF + Azr	75	69	36	49 (1.72)	27.5 (0.43)	50.4 (1.88)	26	42	-14
T_{13} = 50% RDF + PSB	50	114	36	50 (1.78)	29.8 (0.46)	37.2 (1.11)	0	84	-1
T_{14} = 75% RDF + Az	95	69	36	55 (1.82)	32.1 (0.46)	40.8 (1.14)	40	37	-5
T_{15} = 75% RDF + Azr	100	69	36	56 (1.83)	34.3 (0.48)	43.2 (1.18)	44	35	-7
T_{16} = 75% RDF + PSB	75	114	36	57 (1.84)	34.3 (0.49)	67.2 (0.18)	18	80	-31
CD (p = 0.05)	-	-	-	5.4 (0.12)	2.5 (0.03)	4.6 (0.16)	-	-	-

[1]Figures in parentheses represent nutrient concentration in % (expressed on elemental basis).

times and tested in a randomized complete block design. Full rates for the FYM (0.8% N, 0.08% P, 1.04% K), PiM (1.82% N, 0.14% P, 1.32% K), PM (2.14% N, 0.22% P, 1.52% K), and Vm (2.04% N, 0.15% P, 1.24% K) were designed to supply approximately the same N (100 kg N/ha) provided by the RDF treatment and were calculated to be 13 t, 6 t, 5 t, and 5 t/ha, respectively. The combined manure + fertilizer treatments were also designed to supply approximately 100 kg N/ha. Inorganic fertilizers sources were urea, single superphosphate (SSP), and potassium chloride (KCl). The anticipated nutrient to be added through the Az, Azr, and PSB biofertilizers was credited to the different treatments as 20 kg N, 25 kg N, and 20 kg P_2O_5/ha, respectively.

Each treatment received its entire dose (rate) of manure each year at the time of land preparation. The full dose of P, K, and half dose of N were applied each year at the time of planting and the remaining half dose of N was applied 30 days after planting. For the biofertilizers, the bulblets were dipped in treatment slurries at the rate of 10 g/kg bulblets and then dried under shade before planting. Experimental plots were treated with *Trichoderma* to minimize the incidence of damping-off disease. The bulblets were planted on raised beds during the first week of September and harvested in first week of January in both the seasons.

The bulbs were harvested after more than 50% of leaves dropped down, and bulb fresh weight was measured. The bulbs were dried in shade, then chopped off and dried at 63 °C ± 2 °C, finely ground, and samples were digested in a 3:1 di-acid mixture of H_2SO_4 and $HClO_4$. In these acid extracts, nutrients were determined as per standard procedures including N by steam distillation using the micro-Kjeldahl method, P by colorimeter using the vanadomolybdophosphoric acid yellow color method, and K by flame photometer (Page et al., 1982). Nutrient budgets were calculated on the basis of nutrient inputs minus nutrient removal by onion bulbs.

Treatments supplying inorganic fertilizers and organic manures, either alone or in combination, generated a significant bulb yield response in both seasons over the control **(Table**

Scene at the National Research Center for Onion and Garlic in Pune, India.

1). Bulb yields were significantly correlated with bulb uptake of N (r = 0.732, p = 0.01), P (r = 0.612, p = 0.01), and K (r = 0.405, p = 0.05). Data averaged over the two seasons revealed VM to be the only manure source able to produce, by itself, bulb yields that were equivalent to those under the RDF. The best bulb yield responses were achieved with 50% RDF+Vm followed by 50% RDF+FYM. On the contrary, biofertilizers were unable to compensate for reduced application rates of inorganic fertilizer. The use of biofertilizers along with 50% or 75% RDF resulted in bulb yield averages that were at best equivalent to the poorer performing manure sources and in some cases were indistinguishable from the control. The positive performance of the reduced rate of inorganic fertilization plus either Vm or FYM does highlight the value of good manure sources as a supplement to inorganic fertilizers. Mineralization of manures aids in soil nutrient buildup that in turn leads to improved nutrient availability to growing crop (Singh et al., 2001).

Nutrient removal under the RDF treatment was hard to distinguish from that measured under any manure treatment **(Table 2)**. A comparison of the effect of combining inorganic fertilizers with manures versus their co-application with selected biofertilizers found significantly higher nutrient uptake with the former compared to the latter. As little as 25% of the RDF could not be replaced through biofertilizer supplementation, but up to 50% of the RDF could be effectively replaced with selected manures. The treatment with 50% RDF+Vm observed the highest average nutrient removal of 96-53-65 kg N-P_2O_5-K_2O/ha.

Table 3. Economics of different INM-based treatments for Kharif onion production (In order of highest net return).

Treatments	[1]Cost, 000' INR/ha	[2]Benefit, 000' INR/ha	Net return, 000' INR/ha
T_{10} = 50% RDF + 50% Vm	15.94	80.00	64.86
T_9 = 50% RDF + 50% PM	10.64	73.60	62.96
T_7 = 50% RDF + 50% FYM	15.14	76.80	61.66
T_2 = Current recommendation (RDF)	10.28	71.20	60.92
T_6 = Vermicompost (Vm)	11.00	70.60	59.60
T_8 = 50% RDF + 50% PiM	17.64	73.00	55.36
T_{16} = 75% RDF + PSB	9.96	62.40	52.44
T_{15} = 75% RDF + Azr	9.46	61.60	52.14
T_1 = Control	2.50	54.00	51.50
T_{14} = 75% RDF + Az	9.46	60.02	50.56
T_{11} = 50% RDF + Az	8.14	58.20	50.06
T_{12} = 50% RDF + Azr	8.14	56.80	48.66
T_{13} = 50% RDF + PSB	8.64	56.40	47.76
T_5 = Poultry manure (PM)	20.00	66.00	46.00
T_3 = FYM	20.00	60.40	40.40
T_4 = Pig manure (PiM)	25.00	62.20	37.20

[1]Cost of treatments based on price of urea at INR 5/kg, SSP at INR 8/kg, KCl at INR 40/kg, PiM, PM and Vm at INR 2/kg, FYM at INR 1/kg, Azr and Azo at INR 50/kg, and PSB cultures at INR 100/kg. It also includes operational charges covering labor charges for land preparation and two weedings at INR 5,000/ha (USD 1 ≈ INR 44.41).
[2]Benefit based on minimum farm rate of onion at INR 20/kg.

Considering the net nutrient balances presented, the current inorganic fertilization recommendation maintained a surplus stock of nutrients over 2 years of study **(Table 2)**. All manure treatments developed P deficits, while the treatments with 50 to 75% RDF treatments used in combination with biofertilizers generated small to moderate K deficits. Treatments providing inorganic fertilizers and manure resulted in no deficit for any of the three primary nutrients.

Economic analysis highlighted that sole reliance on manures is not a cost-cutting measure, but favorable changes in soil quality likely compensate for additional costs per hectare through improved long-term nutrient turnover due to the organic amendments. However, net returns per treatment further substantiated the superiority of any combined fertilizer/manure application compared to a fertilizer or manure application at the rates examined **(Table 3)**.

Onion growers in this region often prefer organic manuring over inorganic fertilization. As is indicated above, this preference is suggested to be a major cause of concern for the spread of multiple nutrient imbalances. Given the good supply of quality manures, our observations favored the combined application of inorganic fertilizers and manures over sole application of either nutrient source. This is a strategy capable of considering the sustainability of onion productivity as well as the preference to maintain a strong dependence on regional sources like FYM. BC

Ms. Ngullie is Horticulture Consultant, Central Institute of Horticulture, Nagaland University, School of Agricultural Sciences and Rural Development (SASRD), Medziphema, Nagaland; e-mail: kaka_ngl@yahoo.com. Dr. V.B. Singh is Professor, Department of Horticulture, SASRD, Nagaland University, Medziphema. Dr. A.K. Singh is Lecturer, Department of Agril. Chemistry & Soil Science, SASRD, Nagaland University, Medziphema. Dr. Harmandeep Singh is Deputy Director, IPNI South Asia Program, West Region; e-mail: hsingh@ipni.net.

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Status of Grain Maize Production and Agronomic Efficiency of Mineral Fertilizer Use

By V. Nosov

The major region of grain maize cultivation in Russia is in the South. This article considers both mineral fertilizer use and maize productivity in the region. The agronomic efficiency of fertilizer applied to maize is summarized for two maize growing zones differing in annual rainfall. The profitability boundary of NPK use is estimated for a direct effect of fertilizers on maize yield, not taking into consideration the residual effect of fertilizer application.

Southern Russia, the major grain maize producing region in the country, consists of the Southern Federal District and the Northern Caucasus Federal District (founded in 2010). However, it is apparent from recent years that maize is continuing to expand into central Russia, which is decreasing the south's share of total maize area and production (**Table 1**). In 2009, the area planted to maize in Southern Russia was distributed as follows: 46% in Krasnodar Krai, 20% in Northern Caucasus Republics (mainly Kabardino-Balkariya and Northern Osetiya-Alaniya), 19% in Rostov Oblast, 9% in Stavropol Krai, and 7% in Volgograd Oblast (ROSSTAT, 2010).

Rainfed maize is grown mostly on leached, typical, and common chernozems. Irrigated maize is produced on southern common chernozems. Irrigated maize is produced on southern chernozems and light chestnut soils. As shown in **Table 2**, the lowest maize yields are observed in the driest regions such as Rostov and Volgograd Oblasts, whereas the highest yields occur in Krasnodar Krai, which is the most favorable region in terms of climatic and also socio-economic conditions for agriculture.

Rainfed maize in Southern Russia is mainly grown between winter wheat and soybean, alternating with soybean, or following maize in a 2-year cropping sequence. Maize may also be included in extended rotations such as soybean or peas-winter wheat-winter barley-maize-winter wheat-sunflower.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; ppm = parts per million; M t = million metric tons; M ha = million hectares.

There is potential to increase maize grain yields in Southern Russia with better fertilization practices.

Table 1. Planted area, production, and yield of maize in the Southern Federal District (ROSSTAT, 2010).

	2005	2006	2007	2008	2009
Area, M ha	0.7 (83)[1]	0.8 (79)	1.1 (72)	1.1 (63)	0.9 (68)
Production, M t	2.5 (81)	2.8 (79)	2.3 (61)	4.6 (68)	2.7 (68)
Average grain yield, t/ha	3.6	3.5	2.1	4.2	3.0

[1]Figures in brackets indicate the percentage in Russia.

Table 2. Average yield and fertilizer use[1] in maize in five regions of the Southern Federal District (ROSSTAT, 2010).

Region	Annual rainfall, mm	Average grain yield 2005-09, t/ha	Fertilizer use in 2009, kg/ha N	P_2O_5	K_2O
Krasnodar Krai	400-800	3.7	41	15	4
Northern Caucasus Republics[2]	500-800	3.3	24	16	7
Stavropol Krai	350-700	3.2	48	29	5
Volgograd Oblast	350-450	2.7	44	14	2
Rostov Oblast	350-550	2.3	38	12	6
Southern Russia		3.3	40	16	5

[1]Fertilizer use in agricultural enterprises (excluding commercial and subsistence farmers).
[2]Kabardino-Balkariya, Northern Osetiya-Alaniya, Dagestan, Ingushetiya, Karachaevo-Cherkessiya, Adygeya, Chechnya.

Limited fertilizer use is likely an important factor that contributes to the low average yields of maize in Southern Russia. For example, in 2009 agricultural enterprises of the region applied on average 40 kg N, 16 kg P_2O_5, and 5 kg K_2O per hectare for grain maize production (**Table 2**).

When precipitation is adequate, it is recommended to make a basal fall application of NPK fertilizers and spring preplant N application. Sidedressing N and incorporation into the soil by cultivator-fertilizer applicator is popular in Krasnodar Krai. Sidedressing 30 kg N/ha on common chernozems at the V5-V7 stage increased grain yield by 4 to 12% (Malakanova et al., 2009). Field experiments conducted on a leached chernozem of the same region (Toloraya et al., 2008) revealed that a soil-incorporated sidedress application of 30 kg N/ha + 20 kg

Field experiments are showing maize yield response to K fertilizer in areas formerly considered rich in soil K.

P_2O_5/ha + 20 kg K_2O/ha at the V5-V6 stage…in addition to a fall application of 60 kg N/ha + 60 kg P_2O_5/ha + 60 kg K_2O/ha… resulted in a 14% grain yield increment (equivalent to 1.0 t/ha) compared to the fall-only basal fertilizer application **(Figure 1)**.

The role of K fertilizer in Southern Russia's agriculture is underestimated. For a long time, the soils of the region have been considered as very rich in available K, enough for obtaining high yields of crops. Nevertheless, recent field experiments indicate rather high efficiency of K fertilizer use in various crops. In a 3-year field experiment conducted in Stavropol Krai, for example, the average grain yield of maize increased from 6.22 to 6.95 t/ha or by 12% due to the application of 60 kg K_2O/ha compared to the treatment with only N fertilizer application (Shmalko and Bagrintseva, 2007). The treatment with NP fertilizers yielded 7.04 t/ha, and the maximum yield of 7.42 t/ha was obtained with NPK fertilizer application. This field trial was conducted on a common chernozem with 257 ppm as K_2O, which is a level that exceeds the medium category for available K extracted by 1% $(NH_4)_2CO_3$.

The agronomic efficiency (AE) of NPK fertilizers applied to various maize hybrids varied considerably, although it tended to increase with annual rainfall **(Table 3)**.

Kravchenko (2009) studied the response of eight maize hybrids of various maturity to 80 kg N/ha + 80 kg P_2O_5/ha + 80 kg K_2O/ha applied in the fall prior to tillage + 30 kg N/ha applied in the spring prior to cultivation on a leached chernozem. He reported that one medium-early maturing hybrid and two early maturing hybrids were less responsive to NPK fertilizer (2.7 to 8.4 kg grain/kg NPK) than medium and medium-late season hybrids. Bagrintseva et al. (2009) also found increasing AE of NPK with later maturing hybrids. When maize was grown after winter wheat the 3-yr average AE of NPK fertilizer was 3.5, 6.5, and 10.5 kg grain/kg NPK, for medium-early, medium and medium-late season hybrids, respectively. Although the same tendency of higher response of later maturing hybrids to fertilizer was revealed when maize followed spring barley, the AE figures were lower: 1.2, 4.6, and 7.9 kg grain/kg NPK, for medium-early, medium, and medium-late season hybrids, respectively.

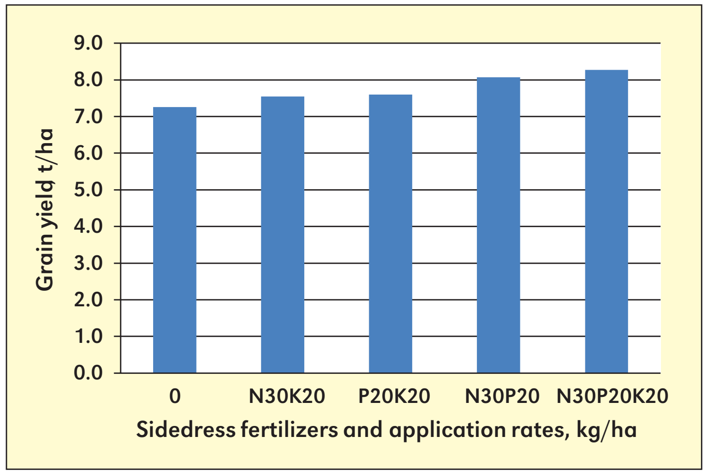

Figure 1. Effect of sidedressing N-P-K fertilizers at the V5-V6 stage on the 3-yr average maize yield after a fall application of 60 kg N/ha + 60 kg P_2O_5/ha + 60 kg K_2O/ha on a leached chernozem in Krasnodar Krai (Toloraya et al., 2008).

The calculations indicate that fertilizer application rates recommended for high yielding maize in this soil-climatic zone (110 kg N/ha + 80 kg P_2O_5/ha + 80 kg K_2O/ha) could be profitable in 2009 if the AE of NPK exceeded 5.9 kg grain/kg NPK, excluding the costs of fertilizer delivery to the farm, fertilizer application, and additional harvesting and drying for the yield increment. For example, in the above-cited field experiment (Kravchenko, 2009), NPK fertilizer application was not profitable for two of the eight maize hybrids studied, which could be considered as an investment in building-up soil fertility without direct effect on maize yield. Two additional factors that need to be considered for more precise economic considerations are the residual effect of fertilizers and the low farm gate grain prices in Russia compared to the world market. The latter raises the profitability boundary of fertilizer use in the country.

As a whole, the low efficiency of fertilizer use in maize when applied at recommended rates in most of the presented research experiments presents a serious question. It seems important to adjust existing fertilizer recommendations by taking into

Recent studies indicate that later-maturing hybrids respond better to fertilizer than early maturing hybrids in Southern Russia.

consideration the nutrient demand of modern maize hybrids. This adjustment could be based on field experiments that need to be conducted in the different soil-climatic conditions of the maize growing regions. This will allow both to improve economic returns on fertilizer investments and to maintain soil fertility. Results of recent short-term field experiments conducted in Southern Russia allow us to conclude that later-maturing hybrids responded better to fertilizer compared to early maturing hybrids. BC

Table 3. Agronomic efficiency of applied NPK ($N+P_2O_5+K_2O$) in maize from recent short-term field experiments conducted in Southern Russia.

Region	Soil type	Number of years	Number of hybrids	kg N/ha + kg P_2O_5/ha + kg K_2O /ha	Agronomic Efficiency of NPK (kg of grain/kg NPK)	Reference
Annual rainfall 500-600 mm						
Stavropol Krai	Common chernozem	3	6	120[1]+90+90	1.8 - 3.5	Bagrintseva and Sukhoyarskaya, 2009
	Leached chernozem	3	8	110[2]+80+80	2.7 - 17.2	Kravchenko, 2009
Rostov Oblast	Common chernozem	2	4	60+40+30	4.2 - 4.6	Beltyukov and Tyurin, 2009
Kabardino-Balkar Republic	Leached chernozem	3	3	90+60+30	5.6 - 5.8	Karova and Shavaev, 2009
	Common chernozem	3	3	90+60+30	5.4 - 5.7	
Annual rainfall 450-550 mm						
Stavropol Krai	Common chernozem	1	12	80+80+80	0 - 7.6	Kravchenko et al., 2009
	Common chernozem	3	3	60+60+60	1.2 - 10.5[3]	Bagrintseva et al., 2009

[1]90 kg N/ha applied in the fall prior to tillage + 30 kg N/ha applied in the spring prior to cultivation.
[2]80 kg N/ha applied in the fall prior to tillage + 30 kg N/ha applied in the spring prior to cultivation.
[3]Figures for maximum plant density in this experiment (70 thousand plants/ha).

Dr. Nosov is Director, IPNI Southern and Eastern Russia Region; e-mail: vnosov@ipni.net. He is located in Moscow. *The author acknowledges Dr. R.V. Kravchenko and Dr. T.R. Toloraya and their co-researchers for providing some details and specifications.*

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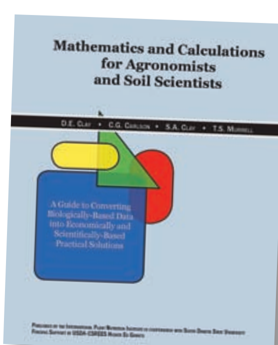
Mathematics and Calculations for Agronomists and Soil Scientists Book Available

The authors of this publication set out to develop a teaching tool that will enable current and future natural resource managers in learning how to integrate mathematics and related technological information into practical decision-making. The book contains 230 pages in 25 different chapter topics, plus three appendix sections. It begins with a review of basic mathematics and progresses through understanding the scientific methods, understanding how experiments are conducted and analyzed, and knowing how to develop and test conceptual and mathematical models.

Most chapters contain a series of exercises which reinforce the principle or concept being presented. An overall goal of this manual is to teach individuals—whether students or working professionals—how to propose, test, and implement innovative strategies that increase productivity while also protecting the environment.



The book was authored by D.E. Clay, C.G. Carlson, S.A. Clay, and T.S. Murrell and published by IPNI (ISBN: 978-0-9629598-8-2). It is available for purchase for US$45.00 per copy, plus shipping and handling. To order or for more information, contact: Circulation Department, IPNI, 3500 Parkway Lane, Suite 550, Norcross, GA 30092 USA; phone 770.825.8082. E-mail: circulation@ipni.net.

Effect of Foliar Potassium Fertilization and Source on Cantaloupe Yield and Quality

By John L. Jifon and Gene E. Lester

Potassium has a strong influence on crop quality parameters. Previously reported work from the Rio Grande Valley of Texas (*Better Crops*, No.1, 2007) demonstrated the impact of foliar K on cantaloupe (muskmelon) quality. The objectives of this multi-year field study were to further evaluate the impact of foliar K on cantaloupe yield and quality in calcareous soils testing high in K, and whether differences exist among K sources for foliar feeding. Foliar K treatments resulted in higher plant tissue K concentrations, higher soluble solids concentrations, total sugars, and bioactive compounds (ascorbic acid and β-carotene). Among the different K salts, KNO_3 consistently resulted in non-significant effects on fruit quality compared to control treatments. Yields were significantly affected by late-season foliar K treatments in only one year.

Potassium is well recognized as the essential plant nutrient with the strongest influence on many quality parameters of fruits and vegetables (Usherwood, 1985). Although K is not a constituent of any functional molecules or plant structures, it is involved in numerous biochemical and physiological processes vital to plant growth, yield, and quality (Marschner, 1995). Adequate K nutrition has been associated with increased yields, fruit size, increased soluble solids and ascorbic acid concentrations, improved fruit color, increased shelf life, and shipping quality of many horticultural crops (Lester et al., 2005, 2006; Geraldson, 1985).

Uptake of K from the soil solution depends on plant factors, including genetics (Rengel et al., 2008). In many species, uptake occurs mainly during the vegetative stages when root growth is not inhibited by carbohydrate availability. Competition for photoassimilates between developing fruits and vegetative organs during reproductive growth stages can limit root growth/activity and K uptake. Increasing soil K fertilization may not be enough to alleviate this developmentally-induced deficiency partly because of reduced root growth/activity during reproductive development and also because of competition from other cations for binding sites on roots (Marschner, 1995). Previous greenhouse studies have shown that supplementing soil K supply with foliar K applications during the fruit development period can improve fruit quality and that differences may exist among K compounds for foliar feeding (Lester et al., 2005, 2006). The objectives of this multiyear field study were to determine whether mid-to-late season foliar K applications during the fruit development and maturation stages can ameliorate the developmentally-induced K deficiency thereby improving muskmelon fruit quality, and to determine whether differences exist among potential K salts for foliar feeding.

Table 1. Tissue K concentrations, fruit soluble solids concentrations (Brix), and sugars of field-grown muskmelons ('Cruiser') determined at fruit maturity following weekly foliar applications of K during the fruit development period using various salts.

Treatment (K salt)	Petiole K	Fruit K	Fruit Brix	Total Sugars
	----- mg/gdw -----		%	mg/gfw
2005				
Control	32.5 c [z]	22.0 d	8.2 c	47.2 c
Potassium chloride	40.2 b	26.0 bc	10.5 ab	59.3 ab
Potassium nitrate	41.7 ab	24.3 cd	8.9 bc	50.5 bc
Potassium sulfate	42.2 ab	25.6 a	11.2 a	59.1 ab
Potassium metalosate	47.1 a	25.6 ab	10.1 ab	62.1 a
2006				
Control	48.2 d	26.2 b	9.0 c	53.2 d
Potassium chloride	55.0 bc	33.5 a	10.3 ab	61.4 bcd
Potassium nitrate	47.5 d	29.2 ab	9.1 bc	54.7 cd
Monopotassium phosphate	51.6 cd	33.9 a	10.3 ab	67.3 abc
Potassium sulfate	50.2 d	31.4 a	10.6 a	72.5 ab
Potassium thiosulfate	64.2 a	32.4 a	11.2 a	69.1 ab
Potassium metalosate	57.8 b	34.0 a	10.6 a	76.3 a
2007				
Control	55.1 b	21.9 c	8.0 c	36.7 a
Potassium chloride	63.3 ab	24.1 bc	9.8 ab	44.5 a
Potassium nitrate	55.3 b	22.9 bc	8.5 bc	39.9 a
Monopotassium phosphate	61.3 ab	24.6 bc	10.0 a	44.3 a
Potassium sulfate	59.7 ab	25.6 b	9.7 ab	45.0 a
Potassium thiosulfate	73.8 a	29.2 a	10.1 a	43.8 a
Potassium metalosate	66.5 ab	25.6 b	9.4 abc	44.7 a

[Z] Means within a column and within a year followed by the same letter are not significantly different using the Ryan-Einot-Gabriel-Welsch multiple-range test.

Materials and Methods

This study was conducted during the Spring growing seasons (February-May) of 2005, 2006, and 2007 in fields near Weslaco, Texas (annual rainfall ~ 22 in.). Soils are predominantly calcareous and test high in K (>500 ppm). Soil type at the study fields is a Hidalgo sandy clay loam soil. In each study year, netted muskmelon (*Cucumis melo* L. var 'Cruiser') was planted in early spring (February-March) following standard commercial practices for spring muskmelon production, including irrigation, nutrient management, and pest control. Plants were fertilized at the two-leaf stage with liquid N (50 kg N/ha; urea ammonium nitrate, 32% N) and P (20 kg P/ha) fertilizers and again at the vine elongation stage (50 kg N/ha, plus micronutrients). No additional soil K was added since pre-plant soil analyses indicated high K levels.

Foliar K treatments were applied weekly, starting at fruit set, and continuing until fruit maturation. The treatments

Abbreviations and notes: K = potassium; ppm = parts per million; Ca = calcium; KNO_3 = potassium nitrate; KCl = potassium chloride; K_2SO_4 = potassium sulfate.

Table 2. Effects of weekly foliar K applications using various K salts on fruit mesocarp total ascorbic acid (TAA) concentrations, beta-carotene concentrations, internal color, and firmness of field-grown muskmelon ('Cruiser').

Treatment (K salt)	TAA mg/100gfw	Beta-carotene µg/gfw	Fruit color h°	Fruit firmness N
2005				
Control	30.3c [Z]	14.2 b	72.8 a	12.7 b
Potassium chloride	33.2abc	18.8 a	71.8 ab	17.1 a
Potassium nitrate	31.6bc	16.7 ab	71.9 ab	14.5 ab
Potassium sulfate	35.5a	18.1 a	71.3 b	15.4 ab
Potassium Metalosate	34.5ab	18.0 a	71.2 b	16.2 a
2006				
Control	19.3 c	18.3 b	72.7 a	10.6 b
Potassium chloride	22.8 a	21.1 ab	72.2 ab	11.8 ab
Potassium nitrate	20.0 bc	18.0 b	72.4 ab	10.1 b
Monopotassium phosphate	21.4 abc	21.3 ab	72.0 ab	13.7 a
Potassium sulfate	22.1 ab	19.8 ab	72.1 ab	11.9 ab
Potassium thiosulfate	22.4 ab	21.1 ab	71.3 b	13.2 a
Potassium Metalosate	23.7 a	23.9 a	71.7ba	12.7 a
2007				
Control	15.7 a	10.3 b	73.0 a	8.5 b
Potassium chloride	16.7 a	11.1 ab	71.9 abc	10.3 ab
Potassium nitrate	16.9 a	10.8 ab	72.8 ab	8.7 b
Monopotassium phosphate	17.1 a	11.5 ab	71.6 c	11.0 a
Potassium sulfate	18.1 a	10.9 ab	72.2 abc	10.6 ab
Potassium thiosulfate	18.6 a	11.6 ab	72.3 abc	11.2 a
Potassium Metalosate	18.4 a	13.0 a	71.9 bc	11.3 a

[Z] Means within a column and within a year followed by the same letter are not significantly different using the Ryan-Einot-Gabriel-Welsch multiple-range test.

were: control (no K, de-ionized water), KCl, KNO_3, K_2SO_4, and a glycine amino acid-complexed K (Potassium Metalosate™, KM, 20% K; Albion Laboratories, Inc, Clearfield, Utah). In 2006 and 2007, two additional K sources were included: monopotassium phosphate (PeaK™, 24% K, Rotem BKG LLC, Ft Lee, New Jersey), and potassium thiosulfate (KTS™ , 20% K, Tessenderlo Kerley Inc., Phoenix, Arizona). A non-ionic surfactant (Silwet L-77; Helena Chem. Co., Collierville, Tennessee) was added to all treatment solutions at 0.3% (v/v). Proprietary fertilizer K sources were formulated according to manufacturer recommendations. Treatment solutions, except the control, were formulated to supply the equivalent of 4 lb K_2O/A (3.7 kg K/ha) during each foliar application. All treatments were applied between 5 a.m. and 8 a.m. on each spray event.

Matured (full slip), marketable fruits from each plot were harvested, weighed, and classified by size as small (≤ 1 kg), medium (1 to 2 kg), or large (≥ 2.0 kg). To minimize variability in fruit quality parameters, fruits were further graded on the basis of maturity/harvest date and size before processing and analysis. For brevity, only data from fruits collected during early harvests ('crown-set' fruit which is set near the base of the plant) are included in this report. After firmness and soluble solids determinations, fruit middle-mesocarp tissue samples were freeze-dried and used for dry matter, K, sugars, ascorbic acid, and beta-carotene analyses following the procedures of Lester et al. (2005, 2006).

Results and Discussion

Foliar K applications significantly increased tissue (leaf, stem, petiole) K contents ($P < 0.001$; **Table 1**) compared to the control treatment, suggesting that plant K uptake from this calcareous soil was not sufficient to satisfy plant K requirements and that the K supplying power of this soil may be low, even though soil test K was high. The impaired K supplying capacity of this soil may be attributable to high Ca and Mg concentrations since these conditions are known to suppress crop K uptake, presumably, through competitive and antagonistic uptake mechanisms (Marschner, 1995; Brady 1984).

Among the K salts evaluated, KNO_3 tended to have only non-significant increases in tissue K. Foliar fertilization with KNO_3 during the fruit development stages significantly increased leaf and petiole N concentrations, but reduced Mg concentrations in petioles and stems probably due to a dilution effect resulting from N stimulation of vegetative growth at the expense of roots and fruits. Fruit sugar contents **(Table 1)** and phytochemical compounds (ascorbic acid and beta-carotene; **Table 2**) responded positively to foliar K applications in two of the three study years. The relatively low sugar contents in 2007 were likely due to reduced leaf CO_2 assimilation rates resulting from frequent cloudy weather conditions in that year. These weather conditions delayed canopy development and fruit set, leading to a reduction in the fruit development and maturation period. Although fruit quality enhancements were generally higher with organic K sources (potas-

Dr. Jifon checks cantaloupe plants in a study plot.

sium metalosate), differences among K salts were not always significant, except for KNO_3, whose effects were nearly always statistically similar to those of control fruit.

Fruit firmness, a good indicator of shipping quality, texture, and shelf life of horticultural produce (Harker et. al., 1997), was also increased by foliar K feeding **(Table 2)**. This may be related to increased fruit tissue pressure potential (Lester et al., 2006) as well as enhanced phloem transport of Ca to fruits following K applications.

Fruit yields ranged from 16,000 to 25,000 lb/A and were generally higher in 2006 than in 2005 or 2007 **(Table 3)**. Even though foliar K-treated plots had slightly higher yields in all 3 study years, significant yield increases were recorded only in 2007 and with one K salt. Significantly more non-marketable fruits (culls) were harvested from KNO_3-treated plots than from plots treated with the other K-salts. Fruit yields from KNO_3-treated plots were also slightly lower than those from plots treated with the other K-salts. A plausible mechanism for the yield increase in 2007, following foliar K treatments, is increased stress tolerance resulting from adequate K status. Ascorbic acid and beta-carotene (both of which were increased by foliar K applications) are antioxidants capable of protecting plants and humans from the damaging effects of oxidative stress during unfavorable environmental growth conditions such as those encountered during the 2007 season.

Table 3. Effects of weekly foliar K applications during the fruit development period using various K salts on yield and fruit numbers (by size class) of field-grown muskmelon ('Cruiser'). Sizes were: small (≤ 14 cm diam. or ≤ 1kg), medium (15 to 16 cm diam. or 1 to 2 kg), or large (≥ 17 cm diam. or ≥ 2.0 kg).

Treatment (K salt)	Yield, lb/A	Small	Medium	Large	Culls lb/A
		--------	x 1000 ha	--------	
2005					
Control	17,096 a[z]	3.4 a	4.1 a	1.4 a	2,491 b
Potassium chloride	18,700 a	2.4 a	4.5 a	2.5 a	1,432 b
Potassium nitrate	16,793 a	3.3 a	4.0 a	1.9 a	6,063 a
Potassium sulfate	20,581 a	3.0 a	5.6 a	3.1 a	1,382 b
Potassium Metalosate	20,394 a	1.9 a	6.2 a	2.1 a	1,602 b
2006					
Control	21,641 a	3.2 a	4.6 a	1.7 a	1,780 b
Potassium chloride	22,968 a	2.7 a	5.2 a	2.9 a	1,194 b
Potassium nitrate	20,330 a	3.6 a	4.8 a	1.5 a	3,236 a
Monopotassium phosphate	21,903 a	2.5 a	6.5 a	2.5 a	1,529 b
Potassium sulfate	24,775 a	2.8 a	5.9 a	3.0 a	1,158 b
Potassium thiosulfate	25,635 a	2.8 a	7.0 a	2.6 a	1,691 b
Potassium Metalosate	23,655 a	2.6 a	6.1 a	2.9 a	1,594 b
2007					
Control	18,054 b	6.2 a	2.7 a	1.4 a	2,373 b
Potassium chloride	20,049 ab	5.5 a	4.0 a	2.0 a	1,593 b
Potassium nitrate	17,920 b	6.1 a	2.6 a	1.6 a	4,315 a
Monopotassium phosphate	20,989 ab	4.6 a	3.3 a	2.1 a	2,039 b
Potassium sulfate	20,475 ab	5.2 a	2.4 a	2.4 a	1,544 b
Potassium thiosulfate	22,719 a	5.4 a	2.5 a	1.9 a	2,255 b
Potassium Metalosate	20,668 ab	5.1 a	3.3 a	2.1 a	2,126 b

[z] Means within a column and within a year followed by the same letter are not significantly different using the Ryan-Einot-Gabriel-Welsch multiple-range test.

Salt crystallization and injury (leaf 'burn') symptoms were not observed with any of the treatments, in part, because all treatments were applied between 5 a.m. and 8 a.m. when high air relative humidity (>80%), low air temperatures (<25 °C) and low wind speeds (<1 mph) prevailed. Several studies have shown that such effects are common when compounds such as KCl with high salt indices (approx. 120; Mortvedt, 2001) and relatively high point of deliquescence (POD, 86%; Schönherr and Luber, 2001) are used, and this is more pronounced when applied under conditions of high temperature and/or low humidity. These observations indicate that the experimental conditions (solution concentrations and timing) during foliar K applications in this study were adequate for minimizing residue formation and salt injury. The consistent lack of significant differences between controls and KNO_3-treated plots indicates that this source of K may not be suitable for late-season foliar nutrition because of its N component. Although N is the mineral nutrient required in the greatest quantity by plants, and productivity is strongly correlated with N nutrition, excessive N availability is known to stimulate vegetative growth (shoots and leaves), and reduce fruit quality. Given that K is the nutrient most associated with quality, and that calcareous soils may have an impaired K supplying capacity, the current results call for a reassessment of nutrient management strategies to improve the quality of crops grown on such soils. BC (IPNI Proj. TX-52F)

Dr. Jifon is with Texas A&M University System, Texas Agri-Life Research Center, Weslaco, Texas; e-mail: jljifon@ag.tamu.edu. Dr. Lester is Research Plant Pathologist with USDA-ARS. He is now located at Beltsville, Maryland, and formerly at Kika de la Garza Subtropical Research Center at Weslaco, Texas.

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Winners of IPNI 2010 Crop Nutrient Deficiency Photo Contest

IPNI has announced the winners of the 2010 Crop Nutrient Deficiency Photo Contest. "We received a record number of submissions in 2010 so we are also glad to see a continued growth in interest for our contest," noted IPNI President Dr. Terry Roberts. "It is proving to be a valuable way for our readers to share their examples of nutrient deficiency in crops, and show off their field observation and photography skills."

This year's group of entrants was indeed global in scope and our judges were provided with a very diverse collection to evaluate. Entries were judged on the overall visual quality of the image and any supporting data provided. IPNI extends congratulations to all winners and thanks to all entrants. Please look for details later in 2011 as we start-up the contest again.

Grand Prize: Mg Deficiency in Avocado

Grand Prize (USD 200) – Luiz Antônio Zanão Júnior, Agricultural Research Institute of Paraná, Ponta Grossa, Paraná, Brazil, captured this image of an avocado plant in Uberlândia, Minas Gerais State. It had received Mg fertilizer only during crop establishment, 8 years ago. Older leaves are showing advanced interveinal chlorosis, with necrosis developing in the highly chlorotic tissue between the veins and occasionally along the leaf margins. These leaves dropped off prematurely. Plant tissue analysis and soil test values both indicated a deficiency of Mg.

Nitrogen Category: N-Deficient Cabbage

First Prize (USD 150) – James Walworth, Department of Soil, Water and Environmental Science, University of Arizona, Tucson, Arizona, USA, provided an interesting N deficiency example for cabbage, which was being grown in a zero N plot as part of a soil fertility field trial in Palmer, Alaska.

Runner Up (USD 75) – P. Jeyakumar, Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, captured a close-up of N deficiency in cowpea 40 days after sowing. The crop exhibited gradual yellowing of old as well as young leaves. The veins remain green and the acute deficiency causes stunted growth and leaf drying. The leaf tissue N content was less than 1.18% and the available soil N was 78.6 kg/ha. The problem is alleviated by two foliar sprays of urea at 0.5% at an interval of 10 days.

Abbreviations and notes: Mg = magnesium; N = nitrogen; P = phosphorus; K = potassium; S = sulfur; B = boron.

Phosphorus Category: P-Deficient Sweet Potato

First Prize (USD 150) – Dr. S. Srinivasan, Agricultural College and Research Institute, Killikulam, Tamil Nadu, India, shot this close-up showing P deficiency in a one-month-old severely stunted sweet potato plant. The plant received no P after planting and is showing classic symptoms such as purpling in lower leaves while upper leaves have a dark green color. Poor root growth was also observed. The soil test (Olsen-P) revealed that P content was very low (less than 1.8 mg P/kg). Leaf tissue analysis also registered a lower value of 0.11%.

Runner-Up (USD 75) – Dr. Ch. Srinivasa Rao, Central Research Institute for Dryland Agriculture, Hyderabad, Andhra Pradesh, India, submitted this conspicuous example of purple pigmentation in maize during cob formation stage (Hybrid DHM 117). While being grown in a P omission plot, the soil had low available P at 7 mg/kg (Bray) and leaf analysis indicated a P content of 0.21 % in deficient leaves. Weak and small size cobs were also observed.

Potassium Category: K-Deficient Grapevine

First Prize (USD 150) – James Fisher, Soil Solutions LLC, Malvern, Pennsylvania, USA, submitted this example of K deficiency in grapevine. The shot was taken pre-harvest (October) and soil testing confirmed the visual symptoms of K deficiency, which were exacerbated by a slight Mg deficiency.

Runner-Up (USD 75) – Muthukumar Bagavathiannan, University of Arkansas, Fayetteville, Arkansas, USA, shot this classic example of K deficiency in corn wherein K-deficient plants exhibited chlorosis along the leaf margins and tips of the older leaves. The symptoms spread from the tip to the base then turn necrotic. In severe cases such as this one [photographed during early grain filling stage (R2 to R3)], the leaves appear dry and scorched along the edges and tips.

Other Category: S-Deficient Corn

First Prize (USD 150) – Matt Wiebers, The Mosaic Company, Plymouth, MN, USA, provided this example of S deficiency in corn taken in a farm field near Cedar Falls, Iowa, during V5 stage. The site was light textured, but the nutrient deficiency was likely enhanced by the fact that this was the first corn crop to follow a multi-year hay crop at this site. Tissue tests confirmed S deficiency.

Runner-Up (USD 75) – Yogesh Mahida, Arya Agro Biotech and Research Center, Borsad, Gujarat, India, submitted this very interesting case of B deficiency in papaya (honey dew variety). Plants in this plantation were 1 to 1.5 years old. The bumpy appearance on these fruits is a symptom of B deficiency.

Poverty Alleviation through Balanced Fertilization for Corn and Integral Family Development

By José Espinosa, Arturo Melville, and Kenneth Hylton

A high percentage of the rural population of Guatemala lives in poverty. This poverty can be observed in most households and steps to free rural families from this burden can lead to prosperity and stability. With such a high level of poverty, getting money in the pockets of rural poor is particularly important. Agriculture in the highlands of Guatemala centers primarily on corn (maize) production, and is a fundamental part of the region's history and culture. To address the issues of hunger, malnutrition, and future economic autonomy, a robust, sustainable agricultural program is needed. Fertilizer, used in accordance with site-specific nutrient management concepts, is an integral part of that program.

Soft corn varieties for human consumption are grown in extensive areas of the highlands of Guatemala. Farmers own small farms and face limitations in capital and technology, so grain production is generally low. However, sustainable yields have the potential to be high enough to provide adequate income to support the household and provide savings to invest in farm improvement.

According to HELPS International, a non-governmental organization (NGO), a farm family in rural Guatemala needs approximately 1,700 kg of corn per year, but the traditional method of growing corn yields only about 700 kg of corn per year. The head of the family has to work outside his community to obtain the resources needed to purchase additional corn. Increasing the ability of farmers to grow higher yields is one way of helping families to achieve a better way of life.

In 2006, HELPS International developed and implemented an expandable Corn Program for economic and rural development in the province of Alta Verapaz. This effort was started in coordination with DISAGRO, a local fertilizer distributor. In late 2008, The Mosaic Company and International Plant Nutrition Institute (IPNI) joined in the program. Since joining the program, Mosaic has contributed agronomic expertise, soil and plant testing, and greatly expanded the program in the Alta Verapaz region of the country. Today, Mosaic contributes approximately USD 400,000 annually to administer the program and to provide 0% interest loans to the growers. Repayment of these loans by the growers is a condition for them to remain in program. Repayment rates are typically greater than 90%.

Corn farmers in Guatemala are eager to learn about better management.

Corn Program activities started with community organizing. Farmer communities willing to participate in the program were identified and their leaders contacted. A local agricultural association was established at each of the communities with the respective board of directors to handle the Corn Program specifically. The general objective of the Corn Program was to increase grain yield through technical assistance and credit for fertilizer and other agricultural inputs.

Planting four or five seeds in a hill causes uneven growth and is a factor in low yields.

The first region where the program was implemented was Cotzal in Quiché, and began with 24 families and 3.24 ha of land. HELPS has been working in the communities of this region for many years with other poverty alleviation programs. Participating farmers own or rent small plots of land with an average size of 0.5 ha. The specific objective of the Corn Program was to develop farmer skills to produce enough corn to cover the needs of the family for one year with enough surplus to pay back credit and to generate savings. The extra income can cover other basic needs of the family, especially health care and education.

The main limitations of small corn producers in the highlands of Guatemala are soil degradation (erosion), declining soil fertility, and inadequate crop management. Work conducted in the past with small farmers in the highlands of South America has demonstrated that plant population and nutrient

Omission plots help to demonstrate the effects when corn does not receive various nutrients.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Mg = magnesium; B = boron; Zn = zinc.

management can improve and sustain yields high enough to satisfy food need and to help grow income.

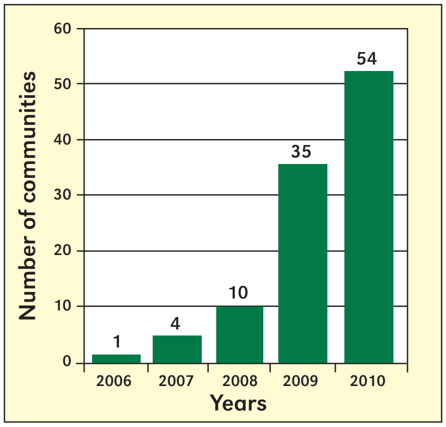

Figure 1. Number of communities included in the Corn Program by year.

Long-term use of the land for corn cultivation, without returning depleted nutrients, degrades soil fertility and lowers yields. The farmers' lack of income prevents use of fertilizers and the cycle of degradation deepens. It was obvious to HELPS that fertilizer use was a key component of the program. However, crop management by farmers was also not conductive to high yields. Traditionally, small farmers tend to have a very low plant population and uneven distributions of plants in the field. Four to five seeds of local open pollinated corn varieties are placed in a hill and each hill is approximately one meter apart. Plants grow unevenly in the hill due to competition. Farmers tend to plant this way to assure the survival of one or two plants per hill, thus guaranteeing at least some harvest in the prevalent conditions. Attempts to introduce hybrid maize seed was not well received by farmers because the grain was not good for tortillas and other culinary uses in comparison with the locally grown varieties. Given these conditions, the first steps of the program were to help farmers choose good local seed and develop a fertilizer program based on local experience. The initial year was also the time of practical training for the HELPS staff, mostly young bilingual personnel from the area who had agricultural education from vocational schools. The group was led by an agronomist with DISAGRO.

Carrying fertilizer to the field.

The program established a basic balanced nutrition approach to manage fertilizer application. The fertilizer application rate was based on DISAGRO experience and the consensus obtained from other experts in the region. Fertilizer was applied in two split applications, one at planting time and again 45 days later. Planting was conducted using the traditional methods of the farmers. Results of the first year harvest were encouraging, producing grain yields that ranged from 3 to 5 metric tons per hectare (t/ha) in the fertilized farmer fields. Yields of this nature were sufficient to meet the grain needs and to generate surplus to pay the loans. The program showed success and more farmers joined during the following years to reach a total of 54 communities, 1,169 farmers, and a total of 636 hectares in 2010.The growth of the program is presented in **Figure 1** and **Figure 2**.

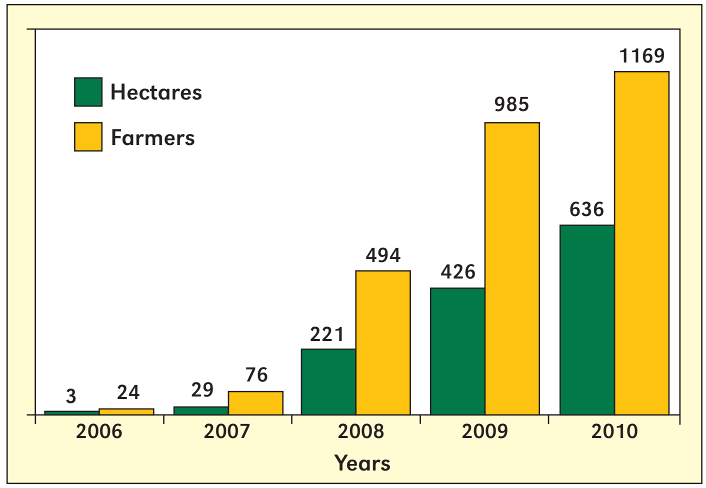

Figure 2. Number of hectares and farmers in the Corn Program.

Based on the experience accumulated by the program in the past, a new more systematic approach was implemented to understand the cropping system and to accumulate reliable data to manage the crop. In tropical conditions, corn yield potential and nutrient needs differ among agro-ecological growing zones. The Alta Verapaz region of Guatemala is somewhat different from other areas of the country where there is more information about corn production. These different social and agronomic growing conditions require different nutrient recommendations and crop management approaches. Because soil testing is rarely used by small farmers, a site-specific nutrient management approach, based on the omission plot technique, was introduced to study the influence of local agro-ecological conditions on nutrient requirements as a tool to develop fertilizer recommendations to achieve high sustainable yields for the region.

Farmer training includes learning about nutrient deficiency symptoms.

For the study, a simple experiment was designed to compare a balanced fertilizer treatment 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/ha, locating four to five 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 reducing yield potential. A balanced fertilizer treatment was designed based on the experience accumulated by the program during the past 2 years. The new 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. Nitrogen and P omission treatments were also established.

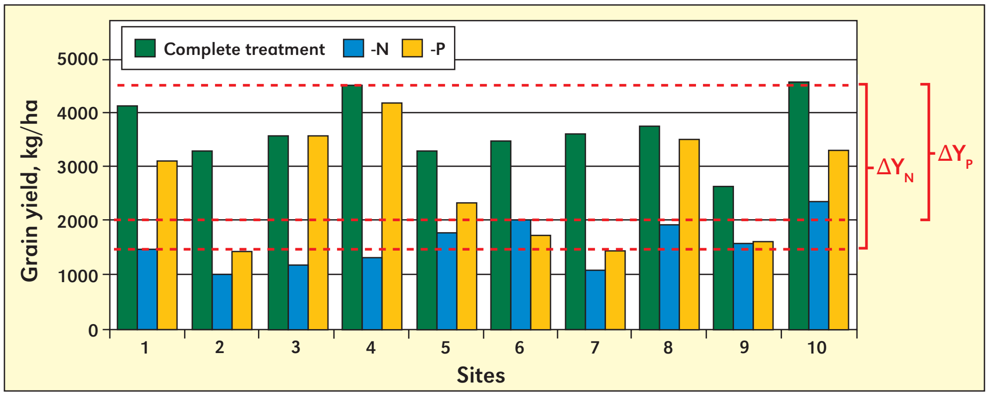

Figure 3. Data from 10 field experiments at Alta Verapaz, Guatemala, comparing a complete balanced fertilizer treatment to N and P omission plots (all nutrients except the nutrient in question). Assumed obtainable yield of 4500 kg/ha.

Ten experimental sites were established at Alta Verapaz during 2009 and 2010. These are plots fertilized with all nutrients except the omitted nutrient, and they allow the determination of the yield that can be obtained with the native soil reserve. Nitrogen in the complete treatment and in the P omission plot was split three times during the cycle: 30% was applied at planting time and 35% at V6 and V10. Field results determined with certainty the attainable yield under this new crop and nutrition management and yields under N and P limitation. This provided enough information to calculate rates needed to achieve a yield target in the coming years. Results from both years are presented in **Figure 3**.

Market time for harvested corn.

Grain yield from the 10 sites ranged from 2.7 to 4.6 t/ha for the complete treatment, with an average of 3.7 t/ha. The N omission plots ranged from 2 to 3 t/ha, averaging 1.6 t/ha, and the P omission plots from 1.5 to 4.2, averaging 2.7 t/ha. The high variation among sites is understandable given the hilly conditions of farmer fields and the natural adjustment to handling the new planting procedure. Some reasonable assumptions can be made from the accumulated data. It can be assumed that a yield of 4.5 t/ha is a realistic attainable yield for the conditions prevalent in Alta Verapaz. More controlled experiments conducted in the region testing Zn sources have produced average yields greater than 5.5 t/ha (data not shown), which has become the target yield for the immediate future. It can also be assumed that, in general, grain yields of around 1.5 t/ha can be obtained without N and 2.5 t/ha without P. Finally, it can also be assumed an agronomic efficiency (AE) of 20 kg of grain/kg of N used and 40 kg of grain/kg of P used. These numbers can be used as a reference for corn production in the region until more accurate figures are obtained by research.

Better crop and nutrient management will increase yields and improve N and P AE. Nitrogen and P fertilizer rates were then calculated using the proposed figures as follows: rate = yield complete treatment minus yield of the omission plot/AE. Calculated fertilizer rates with the assumptions stated previously are close to those already utilized in the experiment: 150 and 90 kg/ha of N and P_2O_5, respectively. The difference is that there are concrete parameters for attainable yield and AE, which now need to be improved by better farmer management of the crop. 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 returns for local farmers.

The corn program continued in the field during 2009 and 2010, utilizing the experience gathered in previous years. One of the main activities during this period was training. Training sessions were conducted to instruct old and new program technical staff in implementing the best management practices proven to be effective in farmer fields. Trained staff then instructed participating farmers and worked with them in the field at planting time. During the growing cycle, the differences between participating fields and traditional fields were evident. Just before harvesting, staff provides assistance to improve the seed selection and the training was reinforced, particularly on planting distances, pest and disease control, and nutrient management. A pilot project was implemented with support of ENCA (National School of Agriculture), to develop a reference manual for best management practices. The manual was distributed among technical staff and farmers. After harvesting, the program enables farmers to sell their corn at the best prices – accomplishing one of the main objectives of the program. The process to select new participants for the next season begins with the help of technicians and participant farmers alike.

Home Improvement Progress

HELPS International has been providing a home improvement program for several years in many poor rural areas. In many households of rural Guatemala and Central America, inadequate living conditions deepen the cycle of poverty. Approximately half of the people of rural Guatemala still cook on open fires in their homes. As a result, lethal levels of carbon monoxide can accumulate in the home. The number one killer of children under the age of 5 is pulmonary diseases contracted in homes with interior open fires. In addition, women must spend hours daily gathering wood or spend half their income to buy firewood, and then they have to tend these fires for 5 to 6 hours a day. These conditions represent a high risk for eye problems and even fatal carbon monoxide poisoning. Pregnant women can have low-weight babies with potential pulmonary problems.

Water filters have helped improve family health.

The HELPS International solution to this problem was the development of the ONIL Stove. It is a highly efficient design which allows cooking with a very small fraction of wood compared to an open fire. The health and environmental benefits

Dr. José Espinosa Retires, Dr. Raúl Jaramillo Named New Director of IPNI Northern Latin America Program

Dr. Raúl Jaramillo has been promoted to Director of the Northern Latin America (NLA) Program of the International Plant Nutrition Institute (IPNI) effective January 1, 2011. Dr. José Espinosa, who had served as Director of the NLA Program, retired effective December 31, 2010. The office for the Program is located in Quito, Ecuador.

In recent years, Dr. Espinosa also had responsibility for IPNI activities in Mexico and Central America. Dr. Armando Tasistro has been named Interim Director for Mexico and Central America. He joined the IPNI staff as Communications Specialist in 2009 and is based in the IPNI headquarters office in Norcross, Georgia, USA.

"We expect a smooth transition during this time and plan to maintain positive and productive programs in these important regions," noted IPNI President Dr. Terry Roberts. "Dr. Espinosa has accomplished significant and lasting advances for the agriculture and people of all the areas he served throughout his career. His positive influence extended to our programs worldwide."

In 1989, Dr. Espinosa joined the staff of the Potash & Phosphate Institute (PPI), the predecessor of IPNI. A native of Quito, he completed undergraduate training in agronomy at the Central University of Ecuador before earning his M.Sc. from Michigan State University in 1979 and his Ph.D. at the University of Kentucky in 1986. He later held important responsibilities with the National Institute of Agronomic Research (INIAP) in Ecuador and served as a consultant in soil fertility and crop management.

"Dr. Espinosa has set a high standard in his achievements, and he also produced an impressive record of practical and well-used publications, plus a network that delivers science to farmers throughout much of the region. The numerous awards and honors he has received are well-deserved and speak highly of his reputation for integrity," added Dr. Paul E. Fixen, IPNI Senior Vice President, Americas and Oceania Group, and Director of Research. "Because Dr. Jaramillo has the benefit of more than 2 years of experience as Deputy Director, IPNI programs will continue to progress."

Dr. Jaramillo, also a native of Ecuador, joined the IPNI staff in 2008. He completed undergraduate studies at Central University in 1994, then worked with the International Potato Center (CIP) before earning his M.Sc. degree at the Wageningen Agricultural University in Holland. Dr. Jaramillo completed his Ph.D. program at The Pennsylvania State University. His region now includes Peru, Ecuador, Colombia, Venezuela, Panama, Costa Rica, Dominican Republic, Puerto Rico, and Cuba.

Dr. Tasistro, a native of Uruguay, received his Ph.D. in soil fertility in 1993 at the University of Georgia and was research scientist in the Agricultural and Environmental Services Laboratory there before joining the IPNI staff in 2009. He was with the International Maize and Wheat Improvement Center (CIMMYT) in Mexico from 1984 to 1993. BC

Dr. José Espinosa retired from IPNI at the end of 2010.

Dr. Raúl Jaramillo became NLA Program Director January 1, 2011.

Dr. Armando Tasistro will serve as Interim Director for Mexico and Central America.

Guatemala corn *(continued)*

derived from the use of the ONIL Stove are impressive. With initial funding by the Shell Foundation, these stoves are now produced in two factories, one in Guatemala and one in Mexico. Currently, around 80,000 stoves have been implemented in Guatemala and Mexico. In addition to the ONIL Stove, other items to improve home quality of life are outdoor stoves, water filters, and solar light systems. Participants of the 2009 and 2010 Corn Programs were also involved with the home improvement program. Installation of stoves and water filters were an incentive for their commitment to the program. The experience HELPS International gained during the 2009-2010 corn and home improvement programs will be useful in providing a more integrated approach for better family living. Future steps in this integrated approach are better distribution of space in homes to keep adults and children in different rooms, and small vegetable gardens to provide better nutrition for the family and to teach basic agricultural practices. BC

Dr. Espinosa was formerly IPNI Northern Latin America Program Director (now retired); e-mail: jespinosa@ute.edu.ec. Mr. Melville is with HELPS International Guatemala; e-mail: Amelville@helpsinternational.com. Mr. Hylton is with The Mosaic Company, USA; e-mail: Kenneth.Hylton@mosaicco.com.

Midseason Nitrogen Fertilization Rate Decision Tool for Rice Using Remote Sensing Technology

By Brenda S. Tubaña, Dustin Harrell, Timothy Walker, and Steve Phillips

In drill-seeded, delayed flood rice production in the mid-southern United States, N fertilizer is most commonly applied using a two-way split application. The second application occurs at midseason near the panicle initiation stage of rice development where approximately one-third of the estimated N fertilizer requirement is applied. Midseason N rates are often adjusted either up or down by rice producers or crop consultants by visual assessment of the rice. In rice cropping systems such as these, instruments which could make in-season estimates of yield potential and available soil N would provide the initial framework to predict midseason N needs and greatly improve N fertilizer use efficiency in rice.

More time and research has been devoted to understanding N than any other nutrient. It is the most limiting nutrient in non-legume cropping systems and the least predictable. Mismanagement of N fertilizer can impact both economic and environmental aspects of crop production. Available soil N and yield level are determinants of a crop's N requirement and are essential parameters to quantify optimal N application rates. Making precise N prescriptions are difficult because tremendous variability exists for available soil N and yield across time and space.

Several destructive and non-destructive methods have been tested and established to assist in making midseason N fertilization rate decisions for rice. The chlorophyll meter and leaf color chart are among the tools that were developed to monitor rice N status (Peng et al., 1993; Stevens and Hefner, 1999). Nitrogen use efficiency was increased when in-season, sensor-based estimates of yield potential and crop responsiveness to N fertilization were used to determine midseason N rate for corn and wheat (Raun et al., 2002; Tubana et al., 2008). A study was initiated in 2008 at different sites in Louisiana and Mississippi to build a database required for the development of similar decision tool for rice. The database consists of grain yield and NDVI readings of three different rice varieties (Catahoula, Neptune, and CL151), which were collected at different growth stages from plots that received varying amounts of preflood N.

Spatial and Temporal Variability in Yield, Response to N, and Optimal N Requirement

Rice yield level and responsiveness to N fertilization (a function of available soil N) may, independently or in combination, affect optimal N requirement. Non-linear regression analysis was conducted on grain yield data with respect to preflood N rate to estimate optimal N rate for each site year. There were no distinct trends observed between percent increase in yield due to N and maximum yield level **(Figure 1)** nor with the estimated optimal N rate for each site from 2008 to 2010 **(Table 1)**. There were sites where maximum yield was similar over years, but had large differences in response to N fertilization, e.g. Rayville site in 2008 and 2009. Large differences in optimal N rates across site years were also observed **(Table 1)**. For example, the Crowley site in 2008 and 2010 maximized grain yield at 11,967 and 12,162 lb/A, respectively, with application rates of 138 and 126 lb N/A, but not in 2009 where 160 lb N/A yielded only 8,703 lb/A. Little benefit of N fertilization was observed at the Rayville site in 2009 (37%) which translated to an optimal N rate requirement of only 99 lb N/A. This is lower than the current state recommendation (120 to 160 lb N/A, Saichuk et al., 2009). The outcome of this analysis implies that prescribing N fertilizer on a need basis requires an estimation procedure for rice yield and rice response to N which are both in-season and on-site.

Abbreviations and Notes: N = nitrogen; NDVI = normalized difference vegetation index; USD = U.S. dollar.

Collecting NDVI readings using a GreenSeeker handheld sensor at panical differentiation stage at LSU AgCenter Rice Research Station in Crowley, Louisiana.

Midseason N Rate Decision Tool

Remote sensing technology offers a non-invasive method of obtaining crop information. Therefore, it can be used for in-season and on-site estimations of yield and rice response to N fertilization. However, this requires calibration of NDVI readings with yield (Raun et al., 2001; Teal et al., 2006) and in-season estimates of rice response to N (Mullen et al., 2003). In 2009, the components of the midseason N decision tool were established using the data collected in 2008 similar to the method by Raun et al. (2002). The initial version of the midseason N decision tool was evaluated using Catahoula variety as part of the experimental procedure in 2009 and is continually being refined as the collection of yearly data continues and the database becomes more robust. Contrast analysis for the effect of preflood N rate and N recommendation scheme on grain yield, N use efficiency (NUE), and net return to N was conducted. **Table 2** shows the mean rice grain yield, NUE, and net return to N at different preflood N rates and N recommendation schemes (fixed N vs. sensor-based) for each site year. The higher preflood N rates provided a significant increase in grain yield in 2010, but not in 2009 ($P<0.05$). With

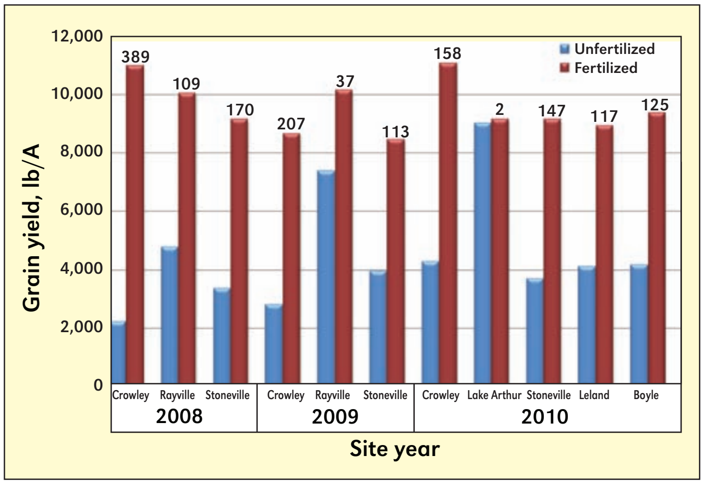

Figure 1. Mean rice grain yield of unfertilized and highest-yielding N-fertilized plots across sites in Louisiana and Mississippi, 2008-2010. Numerical values above the fertilized plot bar are percent increase in yield due to N.

Table 1. Maximum yield and optimal N rate from response trials conducted at different sites in Louisiana and Mississippi using the linear-plateau model, 2008-2010.

Year	Site	Maximum yield ------ lb/A ------ Actual⁺	Estimate§	Optimal N rate, lb/A	r^2
2008	Crowley	10,685	11,967	138	0.92
	Rayville	9,954	11,149	165	0.59
	Stoneville	8,965	10,041	210	0.88
2009	Crowley	7,771	8,703	160	0.50
	Rayville	10,049	11,255	99	0.33
	Stoneville	8,206	9,191	173	0.94
2010	Crowley	10,860	12,162	126	0.88
	Lake Arthur‡	8,940	-	-	-
	Stoneville	8,881	9,947	166	0.88
	Leland	9,094	10,185	159	0.84
	Boyle	9,220	10,326	134	0.91

Linear-plateau model level of significance, P<0.05.
‡No response to N fertilization.
⁺Actual – highest grain yield measured at harvest.
§Estimated maximum yield and optimal N rate using linear-plateau model.

the exception of the Boyle site, grain yield, NUE, and net return to N were statistically the same between sensor and fixed N rates (P<0.05), regardless of whether the sensor recommended higher or lower than the fixed 45 lb N/A. In cases where the sensor recommended a lower N rate, NUE values tended to be higher than the fixed N rate and also resulted in a higher net return at the Crowley and Rayville sites in 2009. At the Stoneville location across both years, the sensor recommended a higher N rate than the fixed 45 lb N/A. This resulted in similar NUE values between the fixed and sensor-based rates. However, the sensor-based rate resulted in a numerically higher net return to N fertilizer. On the other hand, the sensor demonstrated its limitation in 2010 where its recommendations did not result in gain in net return compared with fixed N rates, even though NUE was increased in most cases. The results of our preliminary evaluations demonstrate not only the potential of this midseason N decision tool to improve N fertilizer use efficiency in rice, but also highlight the potential areas where refinement should be made to ensure profitability for every unit of N invested. BC

Table 2. Grain yield, N use efficiency (NUE), and net return to N fertilizer as affected by preflood N rate and midseason application scheme, 2009 and 2010.

Year	Site	Preflood N lb/A	Mid-season N ----- lb/A ----- Fixed^π (45)	Sensor	Grain Yield ----- lb/A ----- Fixed	Sensor	NUE ----- % ----- Fixed	Sensor	Net return§ ---- USD/A ---- Fixed	Sensor
2009	Crowley	75 a	*120*	*108 (43)*	6,976	7,106	41	46	546	568
		105 a	*150*	*139 (34)*	7,273	7,339	35	40	573	590
	Rayville	75 a	*120*	*125 (50)*	8,838	8,874	30	31	333	336
		105 a	*150*	*121 (16)*	8,878	8,765	21	37	313	332
	Stoneville	120 a	*165*	*178 (58)*	7,697	7,601	23	23	421	440
		150 a	*195*	*206 (56)*	7,645	7,817	23	21	425	481
2010	Crowley	75 b	*120*	*114 (39)*	9,314	9140	57	60	525	509
		105 a	*150*	*136 (31)*	10,509	10,040	60	61	640	596
	Stoneville	90 b	*135*	*148 (58)*	7,252	7,559	29	29	317	344
		120 ab	*165*	*172 (52)*	8,068	8,292	32	32	390	411
		150 a	*195*	*197 (47)*	8,608	8,745	31	32	434	448
	Leland	90 b	*135*	*158 (68)*	8,168	8,217	35	32	371	366
		120 ab	*165*	*179 (59)*	8,641	8,879	33	35	407	426
		150 a	*195*	*203 (53)*	9,255	9,472	32	33	459	448
	Boyle‡	90 c	*135*	*98 (8)*	8,894	8,175	39	42	443	384
		120 ab	*165*	*120 (0)*	9,561	8,887	37	46	500	450
		150 a	*195*	*150 (0)*	9,761	8,990	35	38	507	447

Different lower case letter within the preflood N for each site year indicates significant difference in grain yield (P<0.05).
†Values in parentheses are mid-season N rate applied based on sensor reading.
πFixed mid-season N rate of 45 lb N/A.
‡Site-year with significant difference in grain yield, NUE, and net return to N between fixed N and sensor-based N.
NUE – N use efficiency computed as = (grain N uptake$_{fertilized}$ – grain N uptake$_{check}$)/unit of N fertilizer x 100
§Net return to N fertilizer determined by subtracting the cost of fertilizer from the gross income (grain yield increase due to N application x price of grain) where price of N = USD 0.53 per lb for 2009 and USD 0.49 per lb for 2010, while rice grain = USD 0.14 per lb for 2009 and USD 0.12 per lb for 2010 (USDA-NASS, 2010).

(continued on next page)

Midseason N fertilization at panicle differentiation stage, LSU AgCenter Rice Research Station in Crowley, Louisiana.

Variety x N trial at the LSU AgCenter Rice Resarch Station, Crowley, Louisiana.

Dr. Tubaña (e-mail: btubana@agcenter.lsu.edu) is Assistant Professor, School of Plant, Environmental, and Soil Sciences, and Dr. Harrell is Assistant Professor, Louisiana State University Agricultural Center, Rice Research Station. Dr. Walker is Associate Professor, Delta Research and Extension Center at Mississippi State University. Dr. Phillips (sphillips@ipni.net) is IPNI Southeast U.S. Region Director, located in Alabama.

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Soil Test Levels in North America, 2010 Summary Update Publication/CD Available

With the cooperation of more than 60 public and private soil testing laboratories, IPNI has completed a summary of results of tests performed on approximately 4.4 million soil samples collected in the fall of 2009 and spring of 2010. The 2010 summary contains information about phosphorus (P), potassium (K), sulfur (S), magnesium (Mg), zinc (Zn), chloride (Cl^-), and pH.

"The summary can be viewed as an indicator of the nutrient supplying capacity or fertility of soils in the U.S. and Canada," notes Dr. Paul Fixen, IPNI Senior Vice President and Director of Research. He coordinated the efforts of IPNI North America staff and others in collecting the data and compiling the report. The 2010 summary is probably the most comprehensive evaluation of soil fertility ever conducted in North America.

The new summary offers a snapshot view of soil test levels in the U.S. and Canada in 2010, but also provides a comparison to the previous two summaries which were completed in 2005 and 2001. Since the 2010 summary is the third in which laboratories were asked to complete frequency distributions of soil test results, temporal changes in soil test level distributions can be viewed for the second time for states and provinces.

The 42-page publication (Item # 30-3110) is available for purchase for US$25.00. An accompanying CD-ROM contains a PDF file showing the pages of the report, a PowerPoint file of all figures and graphs in the report, and an Excel workbook of the major tables to facilitate construction of custom graphs for regions of interest.

The CD alone (Item # 82-3110) is available for US$10.00. The combination of the publication plus the CD (Item # 90-3110) is available for US$30.00. Shipping and handling costs are added.

For more information or to order, contact: Circulation Department, IPNI, 3500 Parkway Lane, Suite 550, Norcross GA 30092; phone 770.825.8082. E-mail: circulation@ipni.net.

More information about the report is also available at this website: http://info.ipni.net/soiltestsummary

Effect of Resolution of Digital Elevation Models on Soil-Landscape Correlations in Hilly Areas

By Wei Wu, Zhengyin Wang, and Hongbin Liu

A study of six different digital elevation model (DEM) grid sizes and their impact on the relationships between soil properties and their physical terrain found that the most accurate model is not always produced at the highest resolution. The knowledge of which DEM resolution produces an appropriate model for a particular landscape can be used as a guideline for optimizing field sampling strategies.

A DEM is a representation of the continuous topography of the Earth in digital format, and is widely used in terrain analysis and other spatial applications (Moore et al., 1991). Use of appropriate spatial resolution within a DEM can be a challenge for researchers involved in topography-based modeling. Most studies have led to the conclusion that as resolution decreases, slope and curvature derived from a DEM decrease and many delicate landscape features are lost. To a certain degree, micro-topography remains very important and must be appropriately preserved according to the specific research goal. The loss of important local landscape features with an increase in DEM cell size may lead to decreased accuracy for a given area. Therefore, it is important to remember that a particular landscape demands an appropriate DEM resolution. The objective of this work was to assess the effects of various DEM resolutions on the relationships between soil properties and their landscape attributes.

The study area was located at 28°28' to 29°28' N and 105°49' to 106°36' E in southwest China **(Figure 1)**. The region's climate is mild sub-tropic, with mean annual temperatures of 16 °C and mean annual precipitation of 1,030 mm. Major soils types are classified as purple humid Cambosols, according to Chinese Soil Taxonomy (2001). The site measures 100 ha and has slopes of 0 to 34 degrees **(Figure 1)**.

Soil was sampled at 121 field locations using a 100 x 100 m grid strategy. At each site, 10 soil samples were taken at a depth of 0 to 20 cm within a 10 m radius of the geo-referenced grid point. Soil pH, OM, Ca, Mg, P, S, and Cu **(Table 1)** were measured by the Systematic Approach developed by Agro Services International Inc. (Portch and Hunter, 2002). Based on a skewness indicator range between -1 and 1, soil pH, OM, and Cu fell into normal distributions, while the remaining soil properties were considered non-normal or skewed. The coefficient of variation decreased in the order: P > Mg = Ca = S > Cu > OM > pH. Soil pH mainly fell between 4.4 and 5.0. The majority of values for OM and P were low, mainly between 0.4 to 0.8% and 1.35 to 10.0 mg/L, respectively. Distributions for other nutrients were mainly between 100 to 300 mg Mg/L, 20 to 60 mg S/L, 1 to 3 mg Cu/L, and 500 to 1,500 mg Ca/L.

Abbreviations: OM = organic matter; Ca = calcium; Mg = magnesium; P = phosphorus; S = sulfur; Cu = copper; L = liter; GIS = geographic information system.

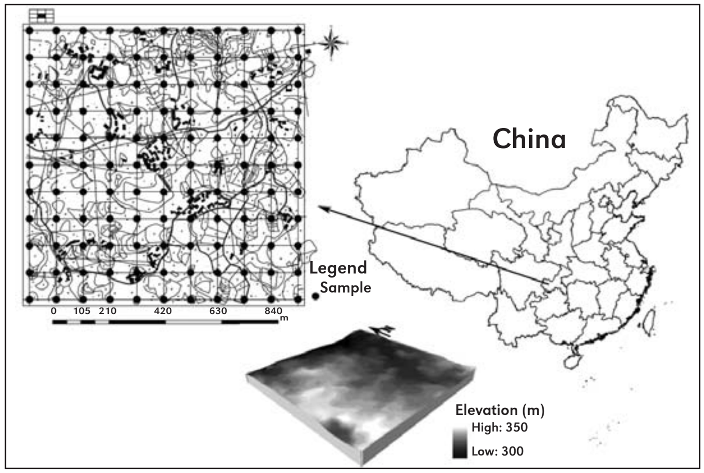

Figure 1. Location of the study area, distribution of sampling sites, and its digital elevation model (DEM).

A 2 m resolution DEM was created using ANUDEM (Hutchinson, 1995). Six different resolution DEMs (4, 6, 8, 10, 20, and 30 m) were developed through a GIS (ARC/INFO 9.0; ESRI, 1995; **Figure 2**). Terrain attributes of slope, aspect (or slope direction), plan curvature, elevation, specific catchment area (SCA), and topographic wetness index (TWI) were also calculated (Moore et al., 1993). Pearson correlation coefficients (r) were employed to examine the relationships between each soil property and terrain attribute at all DEM resolutions.

The spatial distribution of the terrain indices for each sample location and DEM grid size are shown in **Figure 3**. Changing DEM resolution produced clear variations in most topographic index values, excluding elevation and topographic aspect. Collectively, the observations that follow are mainly attributed to the smoothing of the topography resulting from a lower resolution DEM. In general, the larger grid size caused landscape details, such as shorter slopes, to be lost.

Although the minimum elevation was over estimated by 2 m using the broadest DEM of 30 m, statistical analyses failed to show any significant bias in its estimation of the median or range of elevation **(Figure 3a)**. Based on the 4 m DEM, the site's higher elevations mainly existed in its southwest regions and such general trends were also seen in the 6 to 30 m

Table 1. Descriptive statistics of soil properties.

Soil property	Mean	Median	Min.	Max.	Stdev	Skewness	Kurtosis	CV%
pH	4.8	4.8	4.1	5.8	0.3	0.98	2.20	6
OM, %	0.7	0.6	0.4	1.1	0.2	0.25	-0.43	22
Ca, mg/L	1,203	1,040	277	3,596	648	1.52	2.34	54
Mg, mg/L	248	208	50	884	140	1.63	3.91	57
P, mg/L	18.3	13	1.4	110.8	19.7	2.60	7.67	108
S, mg/L	51.2	46.6	8.6	153.3	25.7	1.13	1.70	50
Cu, mg/L	2.2	2.2	1.0	5.2	0.8	0.63	1.17	34

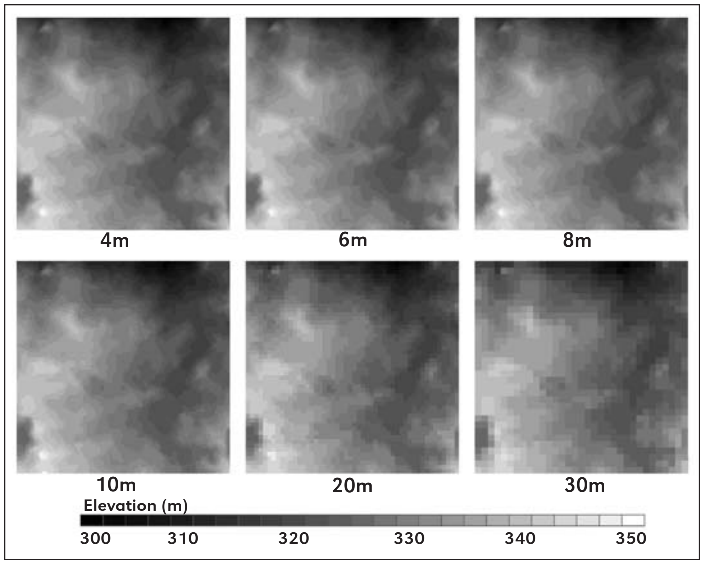

Figure 2. DEMs with grid size from 4 to 30 m.

DEMs **(Figure 2)**. The coarser DEM was unable to accurately estimate the spatial distribution of the mean slope angle. However, a steady decrease of the mean and standard deviation of the mean slope gradient existed as DEM cell size increased from 4 to 30 m as did the range of slope percentage **(Figure 3b)**. No clear trend was found for topographical aspect across the different DEM resolutions **(Figure 3c)**. In general, the range and the standard deviation of plan curvature decreased with an increase in the DEM cell size **(Figure 3d)**. Similar trends were found for maximum and mean of plan curvature when the 6 m DEM was excluded from the analysis. A clear increase in the natural logarithm of the specific catchment area [ln(SCA)] was found with coarser DEM cell sizes **(Figure 3e)**. A similar trend was found in TWI **(Figure 3f)**. Furthermore, the range of ln(SCA) and TWI decreased with a decrease in DEM resolution.

Relationships that remained across the full range of DEM resolutions included elevation which was negatively related to pH, Ca, and S, and positively related to OM and P **(Table 2)**. This is mainly attributed to the narrow range of elevation in this study site (300 to 350 m). Others that were independent of DEM resolution included the consistent relationships between topographical aspect and OM, Ca, and Mg; the negative relationship between slope and S; the positive relationship between plan curvature with S; the positive relationship between SCA and S; and the significant relationships between P (negative) and S (positive) with TWI.

Conclusion

Soil properties are highly variable across hilly landscapes in Southwest China, but attempts to assess these properties across various DEM grid sizes revealed many consistent relationships. Thus, regardless of a measurable loss in the detail of the landscape with coarser DEMs, the expectation for significant change in the interpretation of how soil properties vary within this landscape should be small. An understanding of the effect of DEM grid size on soil-landscape relationships provides useful information for optimizing grid-based field sampling designs, which can be prohibitive in their adoption at practical scales due to excessive costs associated with time and labor. BC

Table 2. Soil-landscape relationships based on different DEM resolutions.

Topographic index	Soil variable	DEM Resolution, m 4	6	8	10	20	30
Elevation	pH	neg**	neg**	neg**	neg**	neg**	neg**
	OM	**	**	**	**	**	**
	Ca	neg*	neg*	neg*	neg*	neg*	neg*
	Mg	ns	ns	ns	ns	ns	ns
	P	**	**	**	**	**	**
	S	neg**	neg**	neg**	neg**	neg**	neg**
	Cu	ns	ns	ns	ns	ns	ns
Aspect	pH	ns	*	ns	ns	ns	ns
	OM	neg*	neg**	neg**	neg**	neg**	neg**
	Ca	*	**	**	**	**	**
	Mg	**	**	**	**	**	**
	P	ns	ns	ns	ns	ns	ns
	S	ns	ns	ns	ns	ns	ns
	Cu	ns	ns	ns	ns	ns	ns
Slope	pH	ns	ns	ns	ns	ns	ns
	OM	ns	ns	ns	ns	ns	ns
	Ca	ns	ns	ns	ns	ns	ns
	Mg	ns	ns	ns	ns	ns	ns
	P	ns	ns	ns	ns	ns	ns
	S	neg**	neg**	neg**	neg**	neg**	neg**
	Cu	ns	ns	ns	ns	neg**	neg**
Plan curvature	pH	ns	ns	ns	ns	ns	ns
	OM	ns	ns	neg*	ns	ns	ns
	Ca	ns	ns	ns	ns	ns	ns
	Mg	ns	ns	ns	ns	ns	ns
	P	ns	ns	neg**	neg**	neg**	neg*
	S	*	**	**	**	**	**
	Cu	*	ns	ns	**	*	ns
Specific Catchment Area (SCA)	pH	ns	ns	ns	ns	ns	*
	OM	ns	ns	ns	ns	ns	ns
	Ca	ns	ns	ns	ns	ns	neg*
	Mg	ns	ns	ns	ns	ns	ns
	P	ns	ns	ns	ns	ns	neg*
	S	**	**	**	**	**	**
	Cu	ns	ns	ns	ns	ns	ns
Topographic Wetness Index (TWI)	pH	ns	ns	ns	ns	ns	ns
	OM	ns	ns	ns	ns	ns	ns
	Ca	*	*	*	*	ns	ns
	Mg	ns	*	*	ns	ns	ns
	P	neg*	neg**	neg*	neg**	neg**	neg**
	S	**	**	**	**	**	**
	Cu	**	**	**	**	ns	ns

** and * refer to 0.01 and 0.05 levels of significance, respectively; "neg" refers to a negative correlation; "ns" refers to a non-significant correlation.

Dr. Wu (wuwei_star@163.com) is Associate Professor, College of Computer & Information. Mr. Wang and Dr. Liu (lhbin@swu.edu.cn) are Professors, College of Resources & Environment, Southwest University, Chongqing, China.

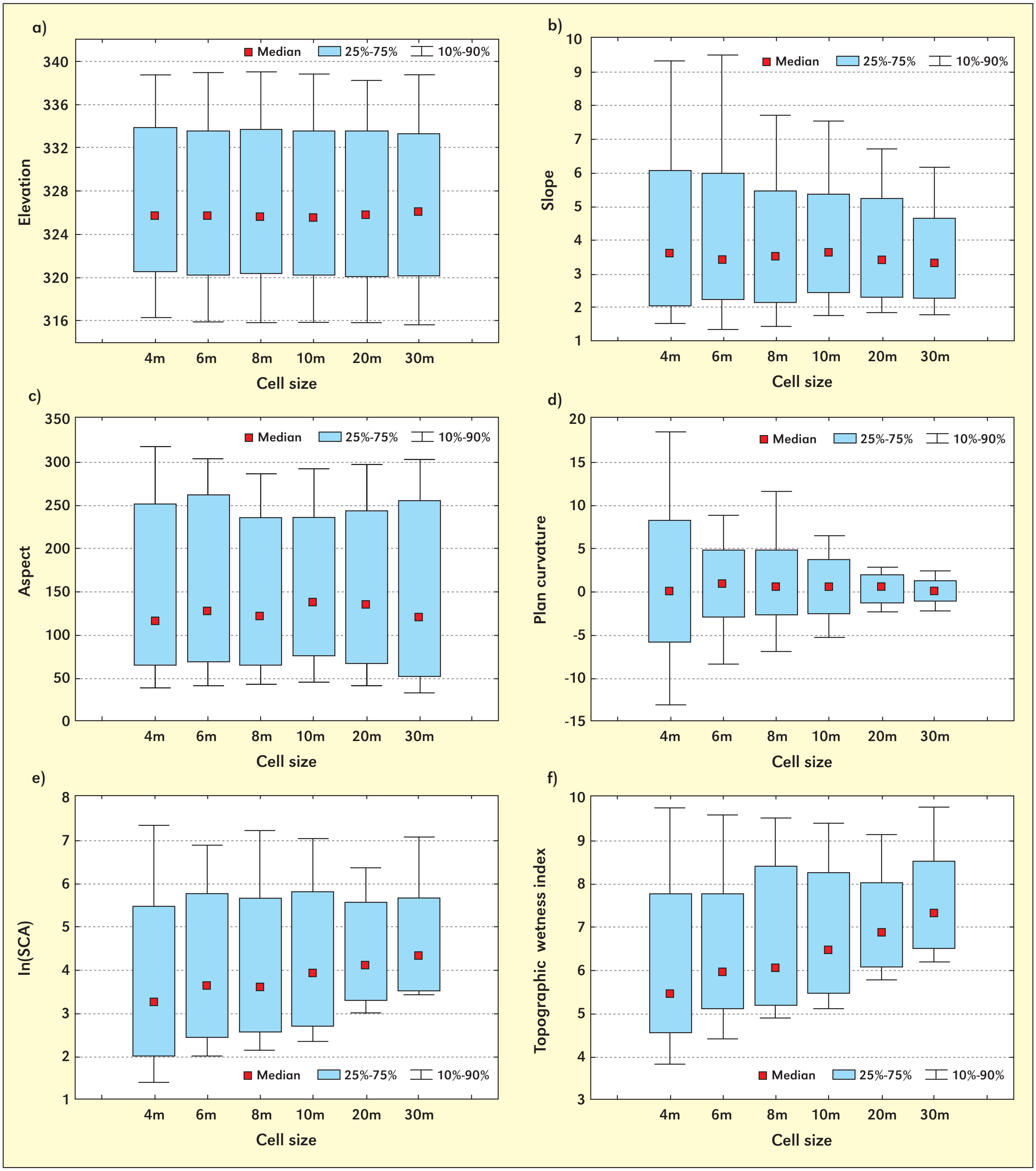

Figure 3. Values of topographic indices for different DEM resolutions a) Elevation, b) Slope, c) Aspect, d) Plan curvature, e) Natural logarithm of Specific Catchment Area (SCA), f) Topographic wetness index, respectively (median and percentiles).

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Spring Snowmelt Impact on Phosphorus Addition to Surface Runoff in the Northern Great Plains

By Tom Jensen, Kevin Tiessen, Esther Salvano, Andrea Kalischuk, and Don N. Flaten

Recent research in Alberta and Manitoba, Canada, confirms that snowmelt runoff is the dominant portion of annual total runoff from agricultural watersheds in the Northern Great Plains (NGP) of North America. The region is characterized by relatively level landscapes and a dry climate with cold winters and warm summers. Many of the methods used to estimate the risk of P movement into surface streams and lakes were designed for warmer, more humid environments and steeper topography where rainfall runoff is dominant and particulate P associated with soil erosion is the main non-point P source from agricultural land. In the NGP, however, soluble P originating from surface soil, plant residues, and surface-applied manure is a larger proportion of total P runoff than particulate P, especially during the spring snowmelt. Soil erosion control methods that help reduce P loading into surface waters in warmer, more humid climates may be less effective in reducing P losses in the NGP. Recent research in the region also suggests that soil-test P is highly correlated with total P losses in snowmelt runoff. In the NGP, these studies show that P losses in runoff can be most effectively reduced and controlled by avoiding the development of excessively high soil-test P levels.

Movement of nutrients in surface runoff is a natural process in the environment. Under so-called pre-settlement conditions in the NGP, surface runoff naturally moved nutrients from grasslands, parklands, and forests. Nutrients in runoff exist primarily in either dissolved form or particulate form (attached to soil particles). Movement of nutrients in runoff is essential to aquatic ecosystem health as a source of nutrients for microbes, aquatic plants, and aquatic animals.

The movement of nutrients from the landscape to water bodies, however, can be enhanced by human activities including agriculture, forestry, urbanization, industry, and recreation. These activities can promote nutrient loss through land clearing, and the application to land of fertilizers, manures, treated sewage, industrial waste effluents, and sludges. As an example, an 8-year water quality monitoring study of 23 agricultural watersheds in Alberta showed that as agricultural intensity increased, water quality decreased, including increased N and P concentrations in surface water (Lorenz et al., 2008). These additions along with continuing nutrient movement from undisturbed grasslands, parklands, and forests all contribute to the total nutrient loads in surface waters.

Excess P, and N to a lesser extent, can enhance growth of algae (i.e., algal blooms) and other aquatic plants causing eutrophication in freshwater streams, sloughs, and lakes. The growth and subsequent death and decomposition of algal blooms can reduce oxygen content (anoxia) in these surface water bodies. Reduced oxygen content can harm aquatic plants and animals. One example for this concern is the deteriorating water quality in Lake Winnipeg in Manitoba, Canada (the10th largest freshwater lake in the world). The Lake Winnipeg watershed includes most of the southern parts of Alberta, Saskatchewan, and Manitoba. Similar to other water bodies in the NGP, this lake has experienced more frequent and intense algal blooms in recent years, primarily attributed to excess P loading from the watershed (Lake Winnipeg Stewardship Board, 2006).

The actual loading of P in surface waters is dominated by snowmelt runoff in much of the NGP where regular snowfall is received. This is different compared to warmer and more humid areas of the world where loading of P is typically dominated by runoff caused by intense rainfall. Runoff caused by rainfall is often associated with soil erosion, and the majority of total P (TP) entering surface water is particulate P (PP). In contrast, snowmelt runoff is usually less erosive because snowmelt has lower kinetic energy than rain-drops and flows over soil that is often still frozen. The majority of P in snowmelt water is dissolved P (DP) rather than PP. Two recent field studies, in Alberta and Manitoba, have shown that the amount of P lost during the snowmelt process is strongly related to the concentration of soil-test P in surface soils (Little et al., 2007; Salvano et al., 2009).

Image courtesy of Alberta Agriculture and Rural Development

Snowmelt runoff in the Northern Great Plains.

In the study from Alberta, runoff was monitored from eight field-scale watersheds for 3 years (Little et al., 2007). One of the objectives of this research was to determine the relationships between soil-test P (STP) and the degree of soil P saturation (DPS) with runoff P including TP and dissolved reactive P (DRP). The volume of water and nutrient content of water samples were collected from field-sized catchments under spring snowmelt and summer rainfall conditions. All eight sites had high runoff potential, uniform management, and no farmyard or non-agricultural influences. The watersheds in the study ranged in size from 5 to 613 acres. The majority of runoff (>90% among all sites) was generated from spring snowmelt. Strong linear relationships between STP and P in runoff were determined in this study. Soil-test P accounted for 88% of variation in TP concentrations in the runoff from the watersheds. Reduced levels of STP following the cessation of manure application corresponded directly with reductions in runoff P. Although a number of different STP sampling strategies were examined, a simple average of all soil sampling points was as good a predictor of runoff P concentrations

Abbreviations and notes: P = phosphorus; N = nitrogen; NO_3^- = nitrate; NH_4^+ = ammonium.

compared to more detailed soil sampling procedures. There were no significant differences among the relationships using different soil sampling depths of 0 to 1 in., 0 to 2 in., and 0 to 6 in. Therefore, it is likely that a common agronomic soil sampling depth of 0 to 6 in. can be used to predict P in runoff from agricultural land in Alberta. Although the DPS holds promise for predicting runoff and leaching losses of P, STP is the standard for agronomic sampling in Alberta and the results suggested that there is no strong reason to use DPS instead of STP.

In the study from Manitoba, Salvano et al. (2009), evaluated the relationship between water quality data for P and three existing P loss risk indicator methods developed to estimate P loss at a regional scale: 1) Birr and Mulla's P Index for Minnesota, 2) the Preliminary P Risk Indicator for Manitoba, and 3) a preliminary version of Canada's National Indicator of Risk of Water Contamination by Phosphorus. Validation of the P loss risk indicators was conducted using long-term water quality monitoring data consisting of TP concentrations collected from 14 watersheds in Manitoba, representing nearly level and rolling landscapes in eastern and western regions of the province, respectively. Water quality data in the watersheds were collected for 11 years from 1989 to 1999. Available STP data for each watershed from 2000 to 2003 were provided by Bodycote Testing Group for fields in each watershed. This was compared to estimated fertilizer P application rates at the regional level using data extracted from the 2001 Census of Agriculture database and Canadian fertilizer consumption records

Salvano et al. (2009) reported that correlations between the three P risk indicators and P losses to surface waters were poor and generally insignificant. It was thought that the poor correlation was because of the emphasis on soil erosion risk in the risk indicator methods; soil particulate runoff is a low proportion of P in runoff during spring snowmelt, which is the dominate form of runoff. In contrast, STP accounted for

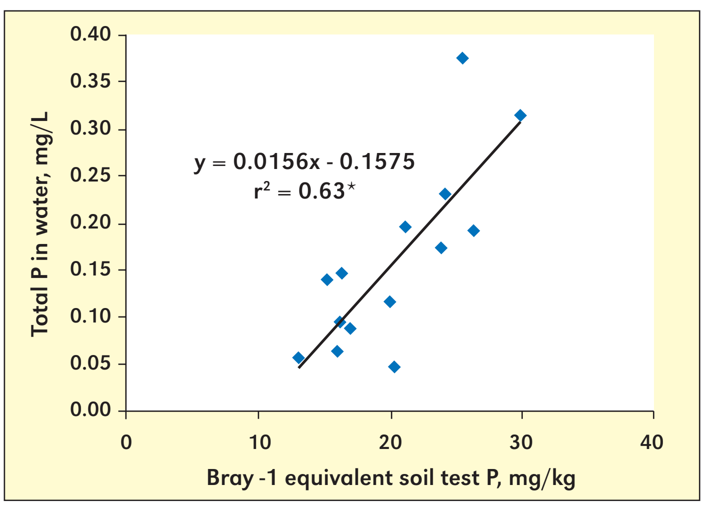

Figure 1. Relationship between overall mean total P in surface water of 14 regional watersheds and Bray-1 equivalent STP concentrations in watersheds.

* Significant at $p < 0.01$. (adapted from Salvano et al. 2009)

63% ($p<0.01$) of the variation in TP concentrations in water samples **(Figure 1)**. Although soil erosion had the most influence on the values generated by the three P risk indicators, STP had the most influence on TP concentrations in runoff water. Therefore, these P risk indicators appear to be too heavily weighted towards soil erosion processes for use under Manitoba conditions.

Figure 2. Division between the paired watersheds: conventional (on left) and conservation tillage (on right), October 2005.

The extremely poor relationship between erosion and TP concentrations may have implications regarding the value of erosion control measures for reducing P loading in the Manitoba prairie region watersheds. For example, recent studies have determined that P loading to Manitoba waterways is either reduced by only a small degree or even increased by traditional erosion control best management practices (BMPs) such as vegetative buffer strips (Sheppard et al., 2006), and conservation tillage (Glozier et al., 2006), respectively. Therefore, to quantify the risk of P loss and the relative contribution of P loss, Salvano et al. (2009) suggest that research should be conducted that will develop and evaluate BMPs designed to reduce the snowmelt-driven losses of P, mostly in dissolved forms, throughout the nearly level landscapes of the prairie region of southern Manitoba.

Expanding on the report of Glozier et al. (2006), Tiessen et al. (2010) compared the seasonal runoff and nutrient losses from two long-term, adjacent paired watersheds in southern Manitoba. One watershed was 10 acres in size and under conventional tillage (i.e., <30% surface reside after planting, receiving primary and secondary tillage operations followed by a harrowing operation before planting). The other was 13 acres in size and under conservation tillage (i.e., direct seeded or no-till with moderate disturbance and >30% residue from the previous crop remaining on the soil surface after planting) **(Figure 2)**. The paired watersheds were monitored between 1993 and 2007, before and after conservation tillage was introduced in 1997 on the 13 acre watershed. Data were separated into three principle time-periods: 1) a 4-year calibration period (1993-1996); 2) a 7-year transitional period (1997-2003); and 3) a 4-year treatment period. The watersheds are 93 miles southwest of Winnipeg, Manitoba.

Yearly runoff patterns at the paired watersheds displayed a spring melt peak, typically in March or April, and multiple rainfall event peaks at various times between May and November. This region of the Canadian prairies typically has one snowmelt period lasting several days, if not weeks, and fewer than five rainfall-induced runoff events per year (Tiessen et al., 2010). Data were split into snowmelt and rainfall seasonal periods. Soil samples were collected after harvest in the fall, before the conventional tillage field was cultivated, from both of the watersheds in each year of the 2004 to 2007

Table 1. Four-year average (2004 to 2007) of residue cover and soil-test data at the Manitoba paired watershed study (Tiessen et al., 2010).

Watershed	Residue cover, %	Snow-water equivalent, in.	Nitrate-N 0 to 6 in., lb N/A	Olsen-P 0 to 6 in., mg/kg	Organic matter, 0 to 6 in., %
Conservation tillage	56 a*	0.32	5.8 b	19.1 a	3.8
Conventional tillage	19 b	0.31	7.4 a	13.1 b	3.5

*Within columns values followed by different letters are significantly different ($p<0.05$).

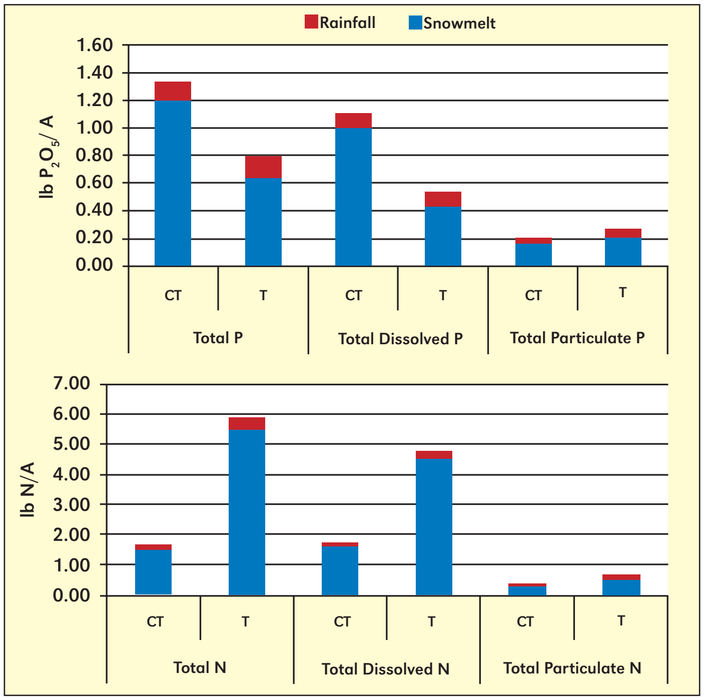

Figure 3. Total, dissolved, and particulate P_2O_5 and N export as annual, snowmelt and rainfall runoff by tillage systems, 4-year average (2004 to 2007). (Note, not controlled for differences in watersheds and seasonal climate variability.)
CT = Conservation Tillage; T = Tilled

study period. Crop residue cover percentage was also determined in the spring after all field operations were conducted. To determine the quantity of water available for runoff within each watershed, snow depth and density were measured in late winter, just before the spring snowmelt **(Table 1)**.

Tiessen et al. (2010) report that snowfall accounted for only 25% of total annual precipitation during the study period. However, snowmelt runoff accounted for 80 to 90% of total annual runoff export from these two watersheds. In this study, on average, concentrations of dissolved nutrients in runoff were higher during snowmelt than rainfall events, whereas, concentrations of total suspended sediment (TSS) and particulate nutrients were greatest during rainfall events during the treatment period. However, because snowmelt was the dominant hydrological process, the majority of particulate and dissolved nutrient export occurred during the snowmelt period **(Figure 3)**.

Additionally, of total N and P nutrient export, dissolved nutrients were the dominant form of nutrients compared to particulate nutrients from the two watersheds, in both the spring and summer. The importance of dissolved nutrients was especially evident during the spring snowmelt period when >80% of N and P were exported in the dissolved form **(Figure 3)**.

The effectiveness of no-till in reducing TSS losses has been well documented (Baker and Laflen, 1983). However, previous studies have reported that no-till reduces total losses of nutrients because of significant decreases in runoff volume and sediment mass. In the study by Tiessen et al. (2010), snowmelt runoff was similar for the two tillage systems at 10,389 and 10,432 ft^3/A for conservation tillage and conventional tillage, respectively, while rainfall runoff was about half for conservation tillage compared to conventional tillage (1,143 and 2,472 ft^3/A, respectively). These results suggest that under the climatic conditions of sub-humid southern Manitoba, conservation tillage can be effective in reducing rainfall runoff, but not snowmelt runoff. One suggested reason is because in this part of the eastern, more humid, portion of the NGP, the snow pack was typically large and pre-melt snow water equivalent on the conventional tillage and conservation tillage watersheds were almost identical **(Table 1)**. In the more arid western part of the NGP, where snowfall can be less and warm Chinook winds occur sporadically during the winter and early spring, there may be differences in snowpack (the magnitude of the snow trapping effect by conservation tillage is expected to be greatest in regions with very little snow), melting, and runoff sessions between conventional and conservation tillage cropping (Pomeroy and Gray, 1995).

Interestingly, Tiessen et al. (2010) report that the two tillage systems affected N and P differently **(Figure 3)**. Converting to conservation tillage resulted in lower export of total N (TN), but greater export of TP. After controlling for 1) differences between the two watersheds that existed prior to introducing conservation tillage to one of them, and 2) seasonal and yearly climate and hydrological variability between the two watersheds, particulate P export was determined to have been reduced by 37% after conversion to conservation tillage.

The total dissolved P export, however, increased by 36% after conversion to conservation tillage. Since dissolved P was the dominant form of P export from both watersheds, this increase in dissolved P more than offset any decreases in particulate P export. This increase in P export occurred because the conservation tillage system was more susceptible to losses of soluble P in snowmelt runoff – likely due to the stratification of P at the soil surface **(Table 1)** and the leaching of P from crop and weed residues. Even though the total P losses in this study (i.e., average export of 1.33 lb P_2O_5/A/yr from the conservation tillage watershed from 2004 to 2007) may be minor from an agricultural perspective, they are of ecological significance because as little as 2 to 5 lb P_2O_5/A/yr has been associated with accelerated eutrophication of lakes in the United States (Sharpley and Rekolainen, 1997).

Management practices such as conservation tillage used to improve water quality by reducing sediment and sediment-bound nutrient export from agricultural fields and watersheds in warm, humid regions may be effective for reducing sediment and N losses, but less effective for reducing P losses in cold, dry regions where the nutrient export is snowmelt driven and primarily in the dissolved form. In these situations, it may be more practical to implement management practices that reduce the accumulation of nutrients in crop residues and surface soils. One possible management option raised in the study by Tiessen et al. (2010) is that there may be potential benefits from some tillage operations in the fall prior to freeze-up and snow events. These tillage operations would incorporate a portion of crop and weed residues, as well as any manure applications, so that less soluble P will be at the soil surface and available to be exported from fields during snowmelt runoff. However, further research is required to test this theory.

From a practical viewpoint, all of the studies mentioned above show that STP is a very important factor in the amount of P lost from fields in the NGP, suggesting that P in runoff can be minimized if STP levels are not excessive. The same principles can be applied to N management, in that N additions from manure and inorganic fertilizer sources should be sufficient to supply crop needs, but not excessive to result in unnecessarily high levels of residual inorganic N (NO_3^- and NH_4^+) in topsoil. There needs to be further research determining what STP level guidelines should be, and what management practices can be used to control P losses from fields in cold climate regions of North America. BC

Dr. Jensen is IPNI Northern Great Plains Regional Director, located in Saskatoon, Saskatchewan; e-mail: tjensen@ipni.net. Dr. Tiessen was formerly Research Associate, University of Manitoba, Winnipeg, Manitoba and currently Senior Program Officer, International Development Research Centre, Ottawa, Ontario. Dr. Salvano is Climate Change Manager, Manitoba Agriculture, Food and Rural Initiatives, Winnipeg, Manitoba. Andrea Kalischuk is Section Head, Water Quality Section, Alberta Agriculture and Rural Development, Lethbridge, Alberta. Dr. Flaten is Professor, Department of Soil Science, University of Manitoba, Winnipeg, Manitoba.

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Conversion Factors for U.S. System and Metric

Because of the diverse readership of *Better Crops with Plant Food*, units of measure are given in U.S. system standards in some articles and in metric units in others…depending on the method commonly used in the region where the information originates. For example, an article reporting on corn yields in Illinois would use units of pounds per acre (lb/A) for fertilizer rates and bushels (bu) for yields; an article on rice production in Southeast Asia would use kilograms (kg), hectares (ha), and other metric units.

Several factors are available to quickly convert units from either system to units more familiar to individual readers. Following are some examples which will be useful in relation to various articles in this issue of *Better Crops with Plant Food*.

To convert Col. 1 into Col. 2, multiply by:	Column 1	Column 2	To convert Col. 2 into Col. 1, multiply by:
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in.	2.54
	Area		
2.471	hectare, ha	acre, A	0.405
	Volume		
1.057	liter, L	quart (liquid), qt	0.946
	Mass		
1.102	tonne[1] (metric, 1,000 kg)	short ton (U.S. 2,000 lb)	0.9072
0.035	gram, g	ounce	28.35
	Yield or Rate		
0.446	tonne/ha	ton/A	2.242
0.891	kg/ha	lb/A	1.12
0.159	kg/ha	bu/A, corn (grain)	62.7
0.149	kg/ha	bu/A, wheat or soybeans	67.2

[1]The spelling as "tonne" indicates metric ton (1,000 kg). Spelling as "ton" indicates the U.S. short ton (2,000 lb). When used as a unit of measure, tonne or ton may be abbreviated, as in 9 t/ha. A metric expression assumes t=tonne; a U.S. expression assumes t=ton.

IPNI Connects With Social Media for Agriculture

For many years, agricultural information exchange has been successfully accomplished by traditional media such as magazines, newspapers, radio, and television, and by time-honored and effective methods such as field days, grower meetings, extension publications, and an array of other techniques. In recent years, however, technology awareness and computer literacy have increased rapidly across all demographics and various forms of social media are being used more and more by people looking for news, education, and other information related to agriculture. Social media can be defined as internet-based applications that allow the creation and exchange of user-generated content. It is the blending of technology and social interaction that creates value in these types of media.

Education and outreach efforts by industry and university extension personnel have often been identified as valuable or successful based on the face-to-face interaction with clientele. For example, a well-known precision agriculture extension specialist at a major university sees social media as a means of enriching his efforts, not a hindrance to them. He says: "If I restrict dialogue only to a one-on-one conversation, then only that person can take advantage of it." By sharing the information exchanged during one face-to-face encounter through his social media network, the specialist has the opportunity to serve potentially millions of other growers asking the same questions or facing similar challenges. Social media tools also provide growers a quick and easy way to build relationships and to interact with other people in agriculture that they might never have connected with otherwise.

There are many different forms of social media, including web, social, and micro blogs (a blend of the term web log), podcasts, video, and other file-sharing sites. Some specific applications that the International Plant Nutrition Institute (IPNI) is currently using are YouTube and Twitter. YouTube is a video-sharing website where users can upload and view videos. IPNI has created a "channel" on the YouTube site where all of our posted videos are collected. The web address is www.youtube.com/PlantNutritionInst. You do not need an account to view videos, only to post your own. All of the videos are also available through the IPNI website: www.ipni.net. The value of using YouTube is that viewers with no knowledge of IPNI can find the videos and be directed back to the IPNI website to become familiar with the Institute. For example, only 23% of the viewers of one of our posted videos, "The Right Way to Grow Wheat", were referred from the IPNI website. The majority of viewers find our videos by using a YouTube search or by viewing related videos. YouTube also facilitates downloads of our videos to mobile devices, such as smart phones and iPads, which have become a more frequent means of viewing our material over the past several months.

Twitter is a microblogging service that allows users to post and read text-based messages of up to 140 characters. The messages or "tweets" are usually visible to the public. However, authors may restrict delivery to only their subscribers or "followers". Users can send or receive messages via the Twitter website or mobile devices. The IPNI twitter account can be accessed at www.twitter.com/PlantNutrition. A tweet from IPNI will typically be a short statement about a new posting on the website and a link to the full article or news item, such as: "*Better Crops with Plant Food* (2010, No. 3) is loaded with articles on spatial variability. #ag http://info.ipni.net/Y53U6"

The value of using Twitter to call attention to these postings is that it draws immediate visibility to an item that might not be seen otherwise by people who don't frequently visit the website. Another advantage is that a user can "retweet" any message to their list of followers, broadening the distribution beyond IPNI subscribers. As is done in this example tweet, an additional way to increase the number of viewers is by appending the message with a "hashtag". In the case of IPNI tweets, the hashtag is #ag. This link makes the tweets searchable to others within the agriculture community who might be following related users, but are not familiar with IPNI.

Another social media service available from IPNI is our RSS web feed, which we use to update subscribers on newly released information associated with our website. Readers can subscribe to timely updates by simply clicking the RSS icon located on any web browser while viewing our website. IPNI's RSS feed is simply: http://www.ipni.net/news.rss

Social media techniques provide a quick and responsive network for people involved in agriculture to gather and exchange information. This enables immediate dissemination of important emerging issues and the sharing of positive information among producers and consumers of agricultural products. IPNI is committed to providing science-based plant nutrition and fertilizer use information to industry, farmers, agricultural and environmental leaders, scientists, public policymakers, educators, and other important audiences. So, follow us on Twitter @PlantNutrition, and subscribe to our RSS web feed to receive all the latest updates.

Steve Phillips
IPNI North American Program
Director, Southeast United States

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