BETTER CROPS
WITH PLANT FOOD

A Publication of the International Plant Nutrition Institute (IPNI)   2009 Number 2

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WITH PLANT FOOD

Vol. XCIII (93) 2009, No. 2

Our cover: Strip tillage develops a uniform seedbed that warms faster in the spring. Fertilizer can be banded in the rootzone.
Photo courtesy of Case-IH

BETTER CROPS WITH PLANT FOOD (ISSN:0006-0089) is published quarterly by the International Plant Nutrition Institute (IPNI). Periodicals postage paid at Norcross, GA, and at additional mailing offices (USPS 012-713). Subscription free on request to qualified individuals; others $8.00 per year or $2.00 per issue.
POSTMASTER: Send address changes to Better Crops with Plant Food, 3500 Parkway Lane, Suite 550, Norcross, GA 30092-2806.
Phone (770) 447-0335; fax (770) 448-0439. Website: www.ipni.net.

Better Crops with Plant Food is registered in Canada Post.
Publications mail agreement No. 40035026
Return undeliverable Canadian addresses to:
PO Box 503, RPO West Beaver Creek
Richmond Hill, ON L4B 4R6 CANADA
The Government of Saskatchewan helps make this publication possible through its resource tax funding. We thank them for their support of this important educational project.

C O N T E N T S

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Forage Fertilizer Decisions in an Uncertain Market

By Tom Bruulsema and Gilles Bélanger

An important principle of plant nutrition is that plants don't care about market conditions. Top yields of quality forage are crucial to the success of most ruminant livestock production systems. Both yield and quality depend on the application of the right source of nutrients at the right rate, at the right time, and in the right place.

High prices for fertilizers and crop commodities in 2008 focused a lot of attention on fertilizing cash crops. What about forages? A producer may ask, "What are the implications of economic uncertainty on the way I should fertilize my forage crops?"

Prices of both crops and fertilizers fluctuated widely in 2008, and price uncertainty continues. **Figure 1** shows that prices in the USA for both hay and fertilizer have increased since 1980. Prices for hay increased relative to fertilizer from 1980 to 2002, but from 2003 through 2008 the relative increase was larger for fertilizer than for hay.

The change in price ratio may reduce economically optimum rates, but the question is how much. It is important for the producer to thoroughly consider all consequences of rate reductions – to yield, quality, and soil fertility. Fertilizer price increases reduce profitability of fertilizer use more in the short term than in the long term.

When K prices increase, short-term optimum rates can fall substantially, as illustrated in **Figure 2**. Yields at these rates also decrease sharply when soil tests for K are less than high. A producer needs to consider the impact of the shortfall in forage production on the viability of the livestock operation. This is difficult to judge at the time of the fertilizer decision, since in years with poor weather, forage value may exceed average prices.

In this example, optimum rates fall well below removal for all three sites. If less is applied than removed, the resulting decline in soil test levels leads to an eventual increase in K requirements. So the optimum rates for a longer time frame become substantially higher than those in the short term.

Field research documents economic returns to NPK fertilizer for forages.

An example confirming the long-term difference comes from a study on timothy hay that was conducted near Fredericton in New Brunswick (Bélanger et al., 1989). This study had four levels each of N, P, and K fertilizer – a total of 64 plots. After the same rates had been applied annually for 25 years, yields measured in each plot for 3 more years were fit to a regression model that allowed computation of what the long-term yield would be for any combination of N, P, and K applied an-

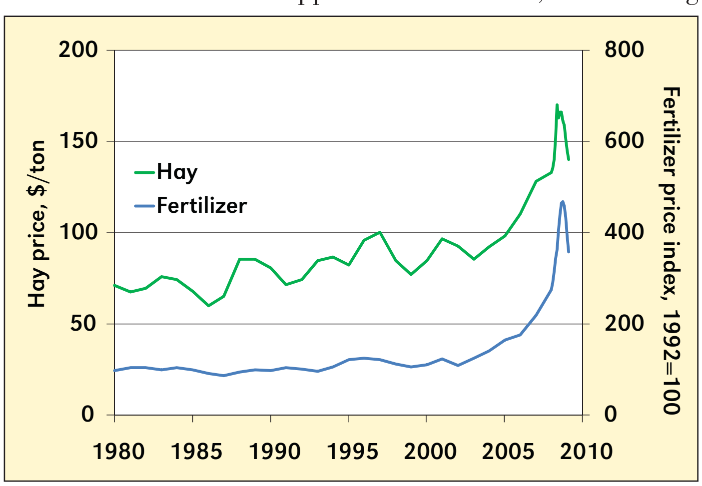

Figure 1. Average prices received for hay and paid for fertilizer (N, P, and K) by farmers in the USA, 1980-2008. (USDA-NASS).

Abbreviations and notes for this article: DCAD = dietary cation-anion difference; GT = grass tetany index; N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; Na = sodium; Cl^- = chloride; S = sulfur.

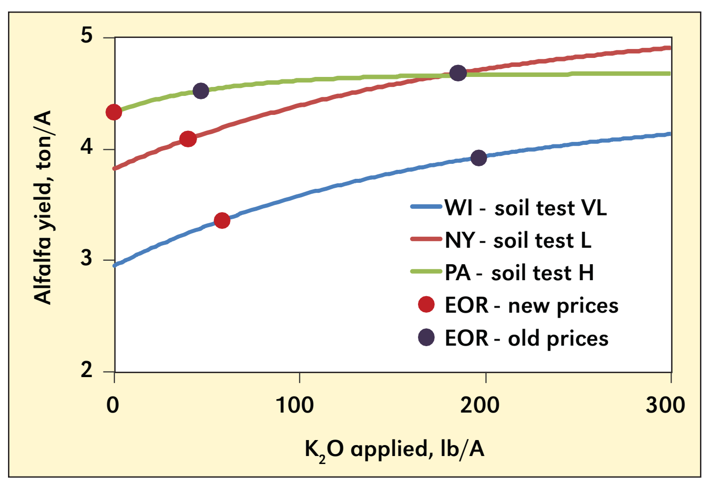

Figure 2. Responses of alfalfa to annual application of K over 3- to 4-year periods. Old and new prices assume \$75 and \$140/ton for hay and \$0.20 and \$0.83/lb for K_2O, respectively. Data from S.D. Klausner (New York), D.B. Beegle (Pennsylvania), and D. Smith, Agron J. 67:60-64 (Wisconsin).

nually, long-term. The factorial experimental design—all possible combinations of four levels of each of the three nutrients – allowed for the inclusion of interaction effects as well. One of the main findings of this long-term study was that balanced N, P, and K application was required for persistence of highly productive species…in this case timothy.

A comparison of two price scenarios, from 1989 and 2009, is shown in **Table 1**. The 2009 scenario has higher prices for both hay and fertilizer. Optimum rates of each of the three major nutrients declined, reducing hay yields by 14%. However, the net return to fertilizer use increased for N and P, and was still substantial for K. In fact, each dollar invested in fertilizer would still return more than two dollars, and this was true for each of the three nutrients. These data demonstrate that fertilizer use continues to be profitable. The response model developed from these data also confirms the "law of the minimum" in that responses to each of the three nutrients depend on adequate supply of the others.

If an old stand of timothy shows economic responses to even the currently high-priced K, the same would be expected in the long term for forages produced from legumes and mixtures as well. Forages remove large amounts of K, and production is simply not sustainable without inputs to replace the removal.

Table 1. Yields and net economic return to fertilizer use for timothy hay production, from a long-term NPK factorial experiment in New Brunswick, with price scenarios from 1989 and 2009.

	Scenario	
Price Assumptions	1989	2009
Hay price, $/ton	$75	$140
Fertilizer price, $/lb		
N	$0.32	$0.43
P_2O_5	$0.36	$0.37
K_2O	$0.12	$0.83
Results		
Optimum annual rate, lb/A		
N	136	115
P_2O_5	90	47
K_2O	114	77
Net return to fertilizer use, $/A		
N	$45	$57
P_2O_5	$54	$90
K_2O	$87	$74
Hay yield, ton/A	3.0	2.6

Table 2. Mineral nutrient concentration and removal in farm forages analyzed by Dairy One Laboratories, Ithaca, New York, from 2000 to 2008.

	Hay				Silage				
	Legume	Mixed mostly legume	Mixed mostly grass	Grass	Legume	Mixed mostly legume	Mixed mostly grass	Grass	Corn
Samples	90,191	15,645	25,638	34,629	30,800	72,679	64,383	26,176	139,501
Dry matter, %	91	90	91	92	40	39	38	40	34
Nutrient concentration, % dry matter basis									
Crude protein	21	17	12	11	21	19	16	15	8
P	0.28	0.29	0.26	0.24	0.34	0.33	0.32	0.33	0.24
K	2.4	2.2	1.9	1.9	2.8	2.7	2.4	2.5	1.1
Ca	1.5	1.2	0.7	0.5	1.4	1.2	0.8	0.7	0.3
Mg	0.31	0.28	0.22	0.20	0.28	0.26	0.24	0.23	0.17
S	0.27	0.21	0.18	0.17	0.25	0.23	0.21	0.21	0.10
Cl	0.73	0.54	0.52	0.63	0.68	0.64	0.65	0.79	0.28
DCAD[2], meq/kg	422	388	334	298	502	476	434	420	192
GT[2], meq ratio	0.6	0.7	0.9	1.1	0.8	0.8	1.0	1.2	1.1
Nutrient removal, lb/ton fresh basis[1]									
N	54 - 70	40 - 60	25 - 46	20 - 44	23 - 31	20 - 27	15 - 23	14 - 24	8 - 10
P_2O_5	9 - 14	10 - 14	8 - 14	7 - 14	5 - 7	5 - 7	4 - 7	4 - 8	3 - 4
K_2O	41 - 64	36 - 58	30 - 55	28 - 56	22 - 32	20 - 29	17 - 27	17 - 30	7 - 11
Ca	23 - 33	16 - 28	8 - 18	5 - 14	9 - 14	7 - 12	4 - 8	3 - 7	1 - 2
Mg	4 - 7	4 - 6	3 - 5	2 - 5	2 - 3	2	1 - 2	1 - 3	1
S	3 - 7	3 - 5	2 - 4	2 - 4	2	2	1 - 2	1 - 2	1
Cl	7 - 19	5 - 15	3 - 16	4 - 19	3 - 8	3 - 7	3 - 7	3 - 10	1 - 3

[1]Range is one standard deviation above and below average (includes two-thirds of all samples).

[2]DCAD calculated as K+Na-Cl-0.6S. GT = grass tetany index, calculated as K/(Ca+Mg). Forage DCAD should be below 290 for dry cows, and GT should be below 2.2 (Pelletier et al., 2008).

Intensive management of forage fertilizer pays economic returns.

Forage analysis information is useful for managing mineral nutrition, just as much for field crops as for animals. The information in **Table 2** shows nutrient concentrations and removals measured in different categories of hay and silage submitted for analysis from farms in the Northeastern USA. Most cool season forages, when fertilized at levels adequate for optimum yields, will contain 2.6 to 3.4% N, 0.27 to 0.33% P (Bélanger and Ziadi, 2008), and 2.0 to 3.0 % K. These very general ranges will be modified depending on:

- species (legumes tend to have higher nutrient concentration);
- stage of growth at harvest (nutrient concentrations decline as the sward matures);
- harvest conditions (hay that is rained on loses mineral nutrients; fermentation of silage tends to increase nutrient concentration).
- age of the sward (older grass swards tend to have lower nutrient concentration)

For diagnostic purposes, consult guidelines for critical nutrient concentrations appropriate to the crop species, stage of growth, and harvest conditions.

Mineral nutrient concentrations in forages play major roles in the indexes for either grass tetany or milk fever. The ratio of K to Ca and Mg is critical for grass tetany, and the DCAD, calculated from K, Na, Cl^-, and S, is important for minimizing risk of milk fever when feeding dry cows. Choosing the right sources, rates, timing, and placement of fertilizers helps ensure a forage composition meeting the needs of the livestock.

Forages remove large amounts of nutrients, whether harvested as hay or haylage (**Table 2**). Nutrient removals give approximate values of fertilizer replacement required per unit of forage harvested from the field. This information guides decision-making in selecting best management practices for fertilizing forages.

Changes in price ratios rarely call for large changes in application rates. When prices increase, first ensure the agronomy behind the management of plant nutrients is sound. Is every tool available being used to choose the right product, to predict the right rate, to apply it at the right time, and to place it where it's most effective? Price ratio theory can help fine-tune rates, but only after sound agronomic principles have been applied. Here is a decision checklist for the fundamentals of fertilizing forages.

Right Source

- Balance NPK, as well as secondary nutrients and micronutrients.
- Analyze for nutrients in manures and composts.
- Credit N from legumes.

Right Rate

- Assess soil nutrient supply using soil tests, forage analysis, and crop scouting.
- Consider long-term as well as short-term.
- Calculate nutrient removal and balance.

Right Time

- Build up soil fertility before establishing a stand.
- Apply P and K, if required, after first cut and before critical fall harvest period.
- Split-apply N for each cut from grasses.

Right Place

- Calibrate equipment for accurate spread.
- Map soil zones for site-specific management.
- Near-seed placement for forage establishment. BC

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11th International Symposium on Soil and Plant Analysis July 2009

The Soil and Plant Analysis Council will present the "11th International Symposium on Soil and Plant Analysis" July 20-24, 2009, at Santa Rosa, California. The purpose of the symposium is to ensure a forum for research, practitioners, and experts working in agricultural laboratories, fertilizer consulting, or instrumentation industries to meet the challenges of the 21st century while meeting its needs for environmental sustainability (soil, water, air, biosphere). Main topics for the 2009 Symposium include water analysis, managing nutrients in a vineyard, petiole and soil testing in vineyards, turf analysis, precision agriculture, global warming, and management for biofuels. For more information, call the Soil and Plant Analysis Council at 970-686-5702, or visit the website at: >www.spcouncil.com/symposium.htm< BC

Economic Viability of Rice-Rice Cropping as Influenced by Site-Specific Nutrient Management

By V.K. Singh, R. Tiwari, S.K. Sharma, B.S. Dwivedi, K.N. Tiwari, and M.S. Gill

Averaged over study locations, the best system (two crop) grain yield under site-specific nutrient management (SSNM) was 12,850 kg/ha in comparison to 10,270 kg/ha under farmer practice (FP) – a 25% increase in productivity. SSNM resulted in an additional produce value of US$607 (gross) and US$464 net after deducting costs for extra inputs. These results clearly establish the importance of responsible nutrient management for breaking the prevailing situation of yield stagnation.

India's intensive rice-rice cropping covers more than 6 million (M) ha and represents the country's most important food production system. Continued slowdown in the growth of yield within this intensive irrigated system is a serious cause for concern (Yadav et al., 2000). Incidence and expansion of multi-nutrient deficiencies in the soils under intensive cropping in general, and in rice-based cropping systems in particular, can be linked to inadequate and unbalanced nutrient input and are considered major reasons for observed declines in productivity associated with fertilizer use (Dwivedi et al., 2001). The common tendency for farmers to practice N-driven fertilizer management not only aggravates the extent of soil fertility depletion, but is also harmful in terms of low nutrient use efficiency, poor quality of produce, and enhanced susceptibility of crops to biotic and abiotic stresses. It is also a potential groundwater pollution threat due to excessive leaching of nitrate beyond the root zone (Dwivedi et al., 2003; Singh et al., 2005).

Unfortunately, the fertilizer recommendations being adopted in most states inadvertently promote unbalanced fertilization as they fail to account for crop yield goals or emerging multi-nutrient deficiencies (Dwivedi et al., 2006). In these circumstances, development of a site-specific nutrient supply package seems to be the only way to enhance nutrient use efficiency and arrest the ever-increasing occurrences of soil nutrient deficiencies (Dobermann et al., 2004).

Multi-locational on-station research was initiated to evaluate the significance of soil test-based SSNM in breaking yield stagnation. Field experiments were conducted during 2003-04 to 2005-06 to evaluate rice-rice cropping at seven locations spread across India. The soils were alluvial sandy clay loam at Jorhat (Assam - Humid Ecosystem), deep black red sandy soil at Coimbatore (Tamil Nadu - Semi-arid Ecosystem), medium black to deep black at Maruteru (Andhra Pradesh) and Navsari (Gujarat-Coastal Ecosystem), red soil of deltic origin of Karjat (Maharashtra) and Thanjavur (Tamil Nadu-Coastal Ecosystem), and Bhubaneswar (Orissa-Subhumid Ecosytem). By and large, soils were neutral to slightly alkaline in nature (pH 6.0 to 8.2) but acidic at Maruteru (pH 5.2) and Jorhat (Assam) (pH 4.8), low to medium in available N, K, B, and Mn, and medium to high in available P, S, Zn, Cu, and Fe. The initial ASI soil analysis was done as per methods described by Portch and Hunter

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; Zn = zinc; B = boron; Mn = manganese; Cu = copper; Fe = iron.

View of farmer practice plot.

(2002) and SSNM recommendations were developed for pre-set yield targets of 10 t/ha of hybrid rice. A similar approach was adopted successfully to achieve yield goals of 10 t/ha of rice and 6 t/ha of wheat in a rice-wheat system (Singh et al. 2008). These approaches and recommendations were different from the conventional approach used by soil testing laboratories in India as all the deficient nutrients were considered, including all major, secondary, and micronutrients which were deficient (**Table 1**). Both crops in the system received NPK while S and micronutrients were applied to *kharif* rice only and the succeeding *rabi* rice benefited from residual amounts. The efficacy of the SSNM treatment was compared with State fertilizer recommendation (SR) and FP at each location.

Fertilizer application at planting included the entire quantities of P, K, S, micronutrients, and one-third of total N. The remaining N was top-dressed in two equal splits. The best available hybrid rice variety (cv. PHB 71) was grown at all the locations. Crops were raised under optimum management conditions and apart from differences in nutrient application rates, all other management practices were the same for SSNM, SR, and FP plots. The crop was harvested manually at maturity and the yield results reported here are an average of 3 years.

The economics of the various fertilizer treatments was calculated for individual crops and the complete cropping system. Comparisons included analysis of the extra fertilizer costs, value of extra produce, net return, and net return per unit invested in applied nutrients under the SSNM.

Table 1. Experimental location and the nutrients applied in the rice-wheat cropping system

		Nutrient applied, kg/ha					
		Kharif rice			*Rabi* rice		
Location	State	SSNM	SR	FP	SSNM	SR	FP
Jorhat	Assam	$N_{150}P_{100}K_{150}B_5Zn_{40}$ Cu_{10} Mn_{20}	$N_{100}P_{40}K_{40}$	N_{25} P_{40} +1 t FYM	$N_{150}P_{100}K_{150}$	$N_{100}P_{40}K_{40}$	N_{25} P_{40}
Bhubaneswar	Orissa	$N_{150}P_{100}K_{40}S_{40}Zn_{40}$ B_5	$N_{80}P_{40}K_{40}$	$N_{60}P_{30}$ K_{30}	$N_{150}P_{100}K_{40}$	N_{80} $P_{40}K_{40}$	$N_{60}P_{30}$ K_{30}
Karjat	Maharashtra	$N_{150}P_{100}K_{150}S_{60}Mn_{30}$	$N_{100}P_{50}K_{50}$	$N_{45}P_{45}K_{45}$	$N_{150}P_{100}K_{150}$	$N_{100}P_{50}K_{50}$	$N_{45}P_{45}K_{45}$
Navsari	Gujarat	$N_{150}P_{80}K_{120}S_{25}Zn_{40}$ Fe_{40}	$N_{150}P_{75}K_{60}$	N_{100} P_{30} +5 t FYM	$N_{150}P_{80}K_{120}$	$N_{150}P_{75}K_{60}$	N_{100} P_{30} +5 t FYM
Maruteru	Andhra Pradesh	$N_{150}P_{80}K_{120}B_5$	$N_{60}P_{40}K_{40}$	N_{80} P_{40}	$N_{150}P_{80}K_{120}$	$N_{60}P_{40}K_{40}$	N_{80} P_{40}
Coimbatore	Tamil Nadu	$N_{150}P_{80}K_{60}S_{50}$	$N_{150}P_{60}K_{60}$ Zn_{25} +12.5 t FYM	$N_{150}P_{50}K_{50}$	$N_{150}P_{80}K_{60}$	$N_{150}P_{60}K_{60}$ Zn_{25} +12.5 t FYM	$N_{150}P_{50}K_{50}$
Thanjavur	Tamil Nadu	$N_{150}P_{30}K_{100}S_{60}Mn_{30}$	$N_{80}P_{34}K_{96}S_{93}$ Zn_{25}	$N_{120}P_{50}K_{50}$ Zn_{25}	$N_{150}P_{30}K_{100}$	$N_{80}P_{34}K_{96}S_{93}$	$N_{120}P_{50}K_{50}$

Sources of N, P, K, S, Zn, B, Mn, Cu, and Fe were urea (46% N), diammonium phosphate (18% N and 46% P_2O_5), potassium chloride (60% K_2O), elemental S, zinc sulfate (21% Zn and 10% S), Borax (10.5 % B), manganese sulfate (30.5% Mn, 17.5%), copper sulfate (24% Cu, 12% S) and iron sulfate (19% Cu, 10.5% S), respectively.
SSNM = Site-specific nutrient management; SR = State recommended fertilizer dose; FP = Farmer practice.
P and K amounts are expressed as P_2O_5 and K_2O.

Effect on Productivity

***Kharif* Rice** — The mean grain yield obtained through SSNM was 6,240 kg/ha as compared to 5,660 kg/ha from SR fertilizer use and 5,210 kg/ha under FP. On average, SSNM out-yielded FP by 1,030 kg/ha (+20%) and SR by 450 kg/ha (+9%). The extra yield obtained by growing *kharif* rice through SSNM (over FP) ranged from 340 kg/ha at Maruteru to 2,500 kg/ha at Jorhat (**Table 2**). The yield advantage was 10% or more in *kharif* rice at four out of seven sites. In terms of rice productivity, the SSNM treatment out-yielded FP by more than 1 t/ha at two out of seven locations (i.e., Jorhat and Karjat).

***Rabi* Rice** — The mean grain yield of *rabi* rice in this rice-rice system was 6,630 kg/ha under SSNM and 5,080 kg/ha under FP. On average, the SSNM plots out-yielded FP by 1,570 kg/ha (+31%). The extra yield obtained through SSNM (over FP) ranged from 600 kg/ha at Thanjavur to 2,800 kg/ha at Maruteru, indicating an almost four-fold difference among locations. This yield advantage was 25% or more at four out of seven sites. The magnitude of yield improvement by SR over FP was smaller, and ranged from 3% at Thanjavur to 25% at Jorhat. Results further indicated that the yield advantages accrued from SSNM were more in *rabi* rice compared with *kharif* rice at all locations except Jorhat and Thanjavur. The higher rice productivity during *rabi* season at different locations may be ascribed to more hours of sunshine and increased photosynthetic rates compared to the *kharif* (rainy season) crop. Also, there is relatively more incidence of pests (insects, diseases and weeds) during *kharif* compared to *rabi* season.

Rice-Rice System — Averaged over locations, the best system grain yield was 12,850 kg/ha under SSNM. Average yield under FP was 10,270 kg/ha. Although a mean yield productivity of 10 t/ha grain under FP is itself substantial, on average, SSNM out-yielded FP by 2,580 kg/ha (25%). The extra grain yield obtained from both rice crops through SSNM over FP ranged from 1,180 kg/ha at Thanjavur to 4,530 kg/ha at Karjat, indicating an almost four-fold difference. The yield advantages accrued due to SSNM was more in *rabi* rice compared with *kharif* rice at all locations except Jorhat and Thanjavur.

Economic Analysis

SSNM in *kharif* rice involved an average additional expenditure of US$93/ha over FP and among sites ranged between US$47 to US$155/ha (**Table 3**). However, these additional expenditures generated an average extra produce value (grain + straw) of US$233/ha and varied from US$76/ha at Maruteru to US$562/ha at Jorhat. The added net return per ha also varied among locations ranging from US$15/ha at Navsari to US$425/ha at Jorhat. After deductions for additional SSNM costs, the resulting average extra net return was US$140/ha, with a benefit-to-cost ratio (BCR) of 1.3.

Farmer practice plot (left) and SSNM plot.

Table 2. Grain yield response to SSNM and state recommended fertilizer doses over farmer nutrient management practice.

	Kharif rice			*Rabi* rice			Rice-rice system		
		Response			Response			Response	
Treatment	Yield, kg/ha	kg/ha	%	Yield, kg/ha	kg/ha	%	Yield, kg/ha	kg/ha	%
Jorhat									
SSNM	5,470	2,500	84	3,530	1,410	66	9,000	3,910	77
SR	3,840	870	29	2,650	530	25	6,490	1,400	28
FP	2,970	–	–	2,120	–	–	5,090	–	–
Bhubaneswar									
SSNM	5,240	570	12	5,890	1,010	21	11,140	1,590	17
SR	4,970	300	6	5,070	190	4	10,040	490	5
FP	4,670	–	–	4,880	–	–	9,550	–	–
Karjat									
SSNM	7,770	2,060	36	7,720	2,470	47	15,490	4,530	41
SR	6,320	610	11	6,210	960	18	12,530	1,570	14
FP	5,710	–	–	5,250	–	–	10,960	–	–
Navsari									
SSNM	5,150	380	8	7,400	1,320	22	12,350	1,500	14
SR	5,030	260	5	6,620	540	9	11,650	800	7
FP	4,770	–	–	6,080	–	–	10,850	–	–
Maruteru									
SSNM	3,980	340	9	7,580	2,800	59	11,560	3,130	37
SR	4,160	520	14	5,300	520	11	9,460	1,030	12
FP	3,640	–	–	4,780	–	–	8,430	–	–
Coimbatore									
SSNM	6,840	830	14	6,980	1,380	25	13,820	2,200	19
SR	6,250	230	4	6,290	690	12	12,540	920	8
FP	6,020	–	–	5,600	–	–	11,620	–	–
Thanjavur									
SSNM	9,260	570	7	7,310	600	9	16,580	1,180	8
SR	9,050	360	4	6,880	170	3	15,930	530	3
FP	8,690	–	–	6,710	–	–	15,400	–	–
Mean over location									
SSNM	6,240	1,030	20	6,630	1,570	31	12,850	2,580	25
SR	5,660	450	9	5,580	520	10	11,230	960	9
FP	5,210	–	–	5,060	–	–	10,270	–	–
CD at 5%	450	–	–	510	–	–	900	–	–

CD = critical difference

Moving from FP to SSNM within the *rabi* season involved an additional fertilizer expenditure of US$50/ha with the range being between US$13 to US$86/ha across locations. In general, lower additional investment was needed in *rabi* rice compared to *kharif* rice because all costs incurred for S and micronutrients were debited to the *kharif* season. Since *rabi* rice benefits from the residual value of nutrients applied to *kharif* rice, the net return would be affected proportionally. On average, the value of additional *rabi* rice produce was US$374/ha with a net return of US$324/ha. At five of seven locations, the additional returns were above US$250/ha with the highest being at Maruteru (US$605/ha). These additional net returns were associated with a BCR of 8.2, with a range of 2.9 to 18. The improvements over FP were made at a BCR of 5 or more at five of seven locations. The higher BCR in *rabi* rice compared to *kharif* can be ascribed to the additional input cost debited to *kharif* rice and the higher yield responses in *rabi* rice.

For the complete rice-rice system, adoption of SSNM involved an additional expenditure of US$143 and resulted in additional produce value of US$607 (gross) and US$464 after extra input costs are considered. This improvement was achieved at an average BCR of 3.5 – meaning that for every extra unit invested in nutrients, 3.5 in extra crop value (net) was harvested. Any technology with a BCR of such a high magnitude would be highly remunerative and sustainable for large-scale adoption within India's rice-rice systems. BC

Table 3. Changes in economic returns while shifting from farmer nutrient management practice to SSNM in rice-rice cropping system.

		SSNM vs. Farmers' practice			
Location	Crop	Extra cost of fertilizer, US$/ha	Value of extra produce, US$/ha	Net return, US$/ha	Net return, US$/US$ extra invested in nutrients
Jorhat	Kharif	137	562	425	3.1
	Rabi	86	337	251	2.9
	System	223	899	676	3.0
Bhubaneswar	Kharif	105	129	24	0.2
	Rabi	54	240	186	3.4
	System	160	370	210	1.3
Karjat	Kharif	155	463	308	2.0
	Rabi	70	595	525	7.5
	System	225	1,058	833	3.7
Navsari	Kharif	70	85	15	0.2
	Rabi	56	313	257	4.6
	System	126	398	272	2.2
Maruteru	Kharif	57	76	19	0.3
	Rabi	55	660	605	11.0
	System	111	735	624	5.6
Coimbatore	Kharif	47	186	139	3.0
	Rabi	17	328	311	18.0
	System	65	513	448	6.9
Thanjavur	Kharif	81	128	47	0.6
	Rabi	13	144	131	10.3
	System	94	273	179	1.9
Mean over location					
	Kharif	93	233	140	1.3
	Rabi	50	374	324	8.2
	System	143	607	464	3.5

Prices of different nutrients used were Rs.10.5/kg N Rs.16.5/kg P_2O_5, Rs.26.5/kg S, Rs.20/kg zinc sulfate, Rs.30/kg manganese sulfate, Rs.13/kg copper sulfate Rs.8/kg ferrous sulfate, and Rs.34/kg borax. Grain price: Rs.7.60/kg, Straw price: Rs.1.0/kg; Rs.1 = US$0.02

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Acknowledgments

This research project was supported by the IPNI India Program. We are grateful for financial support and technical input of the Institute. Authors also greatly appreciate and acknowledge the contribution of the Chief Agronomist/Agronomist of various centers of the All India Coordinated Research Project on Cropping Systems involved in the project.

View of SSNM plot.

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Starter Fertilizer Application Method and Composition in Reduced-Tillage Corn Production

By W.B. Gordon

Field studies were conducted at the North Central Kansas Experiment Field to evaluate four methods of starter fertilizer application (in-furrow, 2x2, 2x0, and placed in an 8-in. wide band centered on the row). Starter fertilizer consisted of 5, 15, 30, 45, or 60 lb N/A with 15 lb P_2O_5 and 5 lb K_2O/A. A no starter check was also included. Starter placed in the seed furrow reduced plant populations and yield. Dribble (2x0) application of starter in a narrow surface band was approximately equal to 2x2 applied starter. Increasing the amount of N in the starter up to 30 lb/A consistently increased P uptake and yield. The use of a dicarboxylic copolymer product in starters was also evaluated and found to be beneficial in increasing P fertilizer performance and corn yield.

Conservation tillage production systems are being used by an increasing number of producers in the central Great Plains because of several inherent advantages. These include reduction of soil erosion losses, increases in soil water-use efficiency, and improved soil quality. However, the large amount of surface residue present in reduced-tillage systems can reduce seed zone temperatures, which may inhibit root growth and reduce nutrient uptake.

Starter fertilizer applications have proven effective in enhancing nutrient uptake, even on soils that are not low in available nutrients. Many producers favor placing fertilizer with seed (in-furrow) or surface starter applications because of the low initial cost of planter-mounted equipment and problems associated with knife and coulter systems in high-residue environments. It has long been recognized that crop injury can occur when excessive amounts of fertilizer containing N and/or K are placed in contact with the seed. However, surface application of starter fertilizer is an option that has not been extensively investigated and compared to sub-surface applications. Additionally, a new class of long-chain, high cation exchange capacity polymers that apparently has the ability to enhance fertilizer P performance has recently become available. This product is marketed under the name AVAIL®[1]. The objective of this research was to determine corn response to different liquid starter fertilizer combinations using four application methods, and to evaluate the use of AVAIL® in starters.

Irrigated, reduced-tillage experiments were conducted at the North Central Kansas Experiment Field on a Crete silt loam soil (fine, smectitic, mesic Pachic Argiustoll). Soil test P values were in the upper-part of the medium range and soil test K was in the high range. Soil organic matter was 2.5% and pH was 7.0.

The study consisted of four methods of starter fertilizer application: in-furrow with the seed; 2 in. to the side and 2 in. below the seed at planting (2x2); dribbled in a narrow band on the soil surface 2 in. to the side of the row at planting (2x0); and placed on the soil surface in an 8 in. band centered on the row. Starter fertilizer consisted of combinations that included either 5, 15, 30, 45, or 60 lb N/A with 15 lb P_2O_5/A and 5 lb K_2O/A. Nitrogen as 28% UAN was balanced so that all plots received 220 lb N/A regardless of starter treatment. Starter fertilizer combinations were made using liquid 10-34-0, 28% UAN, and KCl (muriate of potash). Additional studies compared starter fertilizer with and without the AVAIL® additive.

When starter fertilizer containing 5 lb N and 5 lb K_2O/A was applied in-furrow with the seed, plant population was reduced by over 6,000 plants/A (**Table 1**). As N rate increased, plant population continued to decrease. When averaged over starter fertilizer rate, corn yield was 36 bu/A lower when starter fertilizer was applied in-furrow with the seed than when applied 2x2 (**Table 2**).

Dribble application of starter fertilizer in the 2x0 configuration was statistically equal to starter that was placed in

Table 1. Starter fertilizer placement and composition effects on plant population, 3-year average.

Starter, lb/A $N-P_2O_5-K_2O$	In-furrow	2x2	2x0	Row band
	---------------- plants/A ----------------			
5-15-5	25,202	31,266	31,170	31,266
15-15-5	23,142	30,729	31,655	31,552
30-15-5	23,307	31,266	30,492	30,589
45-15-5	21,329	30,976	30,392	30,492
60-15-5	20,371	30,687	30,613	30,298
Average	22,670	30,985	30,864	30,839

Table 2. Starter fertilizer placement and composition effects on corn grain yield, 3-year average.

Starter, lb/A $N-P_2O_5-K_2O$	In-furrow	2x2	2x0	Row band
	---------------- bu/A ----------------			
5-15-5	172	194	190	179
15-15-5	177	197	198	180
30-15-5	174	216	212	192
45-15-5	171	215	213	195
60-15-5	163	214	213	201
Average	171	207	205	189

[1] The mention of a product does not imply endorsement by Kansas State University or by this publication.

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium; UAN = urea ammonium nitrate.

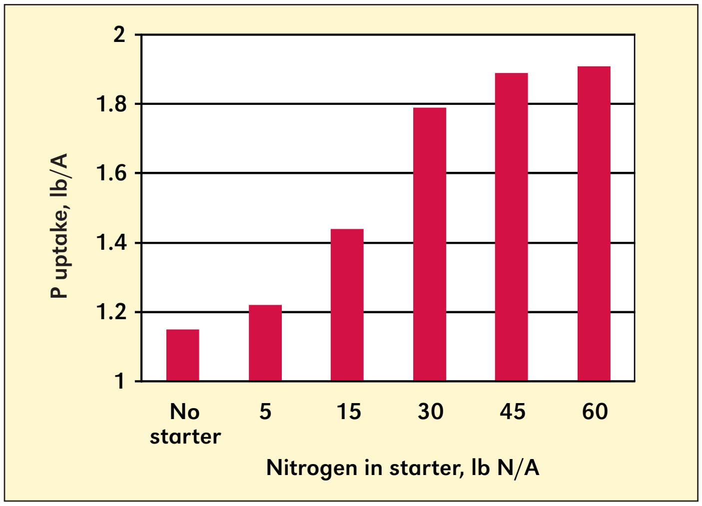

Figure 1. Average starter N-rate effects on 6-leaf stage whole plant P uptake (P and K rate constant at 15 lb P_2O_5 and 5 lb K_2O/A), 3-year average.

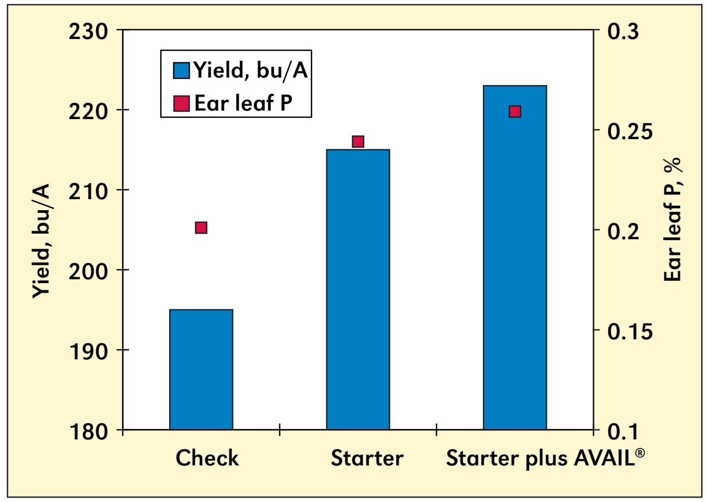

Figure 2. Starter and starter plus AVAIL® effects on corn grain yield and ear leaf P concentration, 3-year average.

the traditional 2x2 band. A surface band is much easier and less costly for producers to apply than the 2x2 band. The 8-in. band over the row treatment resulted in yields that were greater than the in-furrow treatment, but less than the 2x2 or 2x0 treatments. The wide fertilizer band was just too diffuse to provide the full benefit of a starter fertilizer application. Regardless of whether the starter fertilizer was placed 2x2 or 2x0 , yields increased with increasing starter N rate up to the 30 lb N/A rate. Plant P content also increased with increasing N up to the 30 lb N/A rate (**Figure 1**).

The results of this research have shown that the addition of AVAIL® can improve P fertilizer performance. This work compared a no-starter check to fluid starter containing both N and P with and without AVAIL®. Use of starter increased corn grain yield by 19 bu/A over the no starter check (**Figure 2**). The addition of the polymer AVAIL® to the starter fertilizer further increased yield by an additional 9 bu/A. Corn ear leaf concentrations at silking were greater in plots receiving the starter plus polymer than in plots receiving no starter or starter alone. This indicates that the use of AVAIL® can result in an increase in P uptake by plants and ultimately in higher grain yield. BC

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Plot at left received no starter, while plot at right shows response to 2x2 starter application.

Stand loss in this corn plot is due to in-furrow placement of starter.

The Role of Fertilizer in Growing the World's Food

By T.L. Roberts

According to the United Nations (UN), the global population of 6.7 billion is expected to reach 9.2 billion by 2050. The Millennium Project and its State of the Future (2008) report indicated that food production will have to increase by 50% by 2013 and double in 30 years to help solve the current food crisis. This increased food production will have to occur on less available arable land and this can only be accomplished by intensifying production. However, intensifying production must be done in an environmentally safe manner through ecological intensification. The goal of ecological intensification is to increase yield per unit of land, approaching the "attainable yield" of farming systems, with minimal or no negative environmental impact.

The world will not be able to meet its food production goals without biotechnology and improved genetics, and without fertilizer. Commercial fertilizer is responsible for 40 to 60% of the world's food production. Our responsibility is to develop and employ management practices that use fertilizer effectively and efficiently. This article explores the role of fertilizer in producing the world's food and associated best management practices (BMPs) that help ensure production and environmental goals are met.

Early in 2008, the world was focused on the food crisis. A doubling of rice, wheat, and maize prices in early 2008 sparked food riots in poor nations and caused some countries to impose limits on crop exports. The food crisis resulted in the Food and Agriculture Organization of the UN (FAO) convening a "High-Level Conference on World Food Security" in Rome where governments and other organizations from 185 countries met to discuss the challenges that climate change, bioenergy, and food prices caused to world food security. By midyear, global attention had shifted from food security to credit as food prices declined and the financial crisis emerged. However, the food crisis has not subsided, but the sense of urgency associated with it has given way to the global recession.

The number of undernourished people in the world reached an estimated 923 million in 2007, up from 848 million in 2003-05 and from the 1990-92 World Food Summit baseline of 842 million (FAO, 2008a). About 98% of the chronically hungry are in the developing world. The world was making progress towards the Millennium Development Goal to halve hunger by 2015. The proportion of undernourished people steadily declined from the baseline of 20% in 1990-92 to 16% in 2003-05, but by the end of 2007 the trend had reversed and we were no longer making progress.

FAO estimates that 37 countries are facing a food crisis. The "Millennium Project 2008 State of the Future" report attributes the food crisis to increased demand for food in developing nations, high oil prices, biofuels, high fertilizer prices, low global cereal stocks, and market speculation (Glenn et al. 2008). Food security is one of the great challenges facing humanity. With the current world population of 6.7 billion expecting to reach 9.2 billion by 2050, the 2008 State of the Future report suggests that food production has to increase by 50% by 2013 and double in 30 years. The report's authors identify better rain-fed agriculture and irrigation management, genetic engineering for high yielding crops, precision agriculture, drought-tolerant crops, and several other factors required for new agricultural approaches as critical long-term strategies to feed the world, but they say little of the role of fertilizer.

Many believe that plant biotechnology holds the key to producing more food. The genetics and biotech industries have assured us they can deliver increased yields, promising leaps in genetic yield potential of 3 to 4 % per year (Fixen, 2007; Jepson, 2008). Monsanto, the world's largest seed company, promised to develop new varieties of corn, soybeans, and cotton by 2030 that will yield twice as much grain and fiber per acre while using two-thirds the water (Monsanto, 2008). These kinds of technological advances will be required if we hope to feed the world's hungry. However, history suggests genetic advances alone may not be able to solve the world's food shortage. For example, Cassman and Liska (2007) point out the 40-year trend for maize (corn grain) yields in the USA has been linear, with an annual increase of 112 kg/ha or a 1.2% relative gain compared to the current 9.2 t/ha yields. This 1.2% annual yield increase has been supported by the introduction of hybrids, expansion in irrigation, conservation tillage, soil testing, and balanced fertilization, plus the introduction of transgenic insect resistant "Bt" maize. If the genetics industry can deliver on the promised yield increases and if that genetic potential can be converted into more yield, nutrient consumption will increase significantly. Going forward through 2020, Fixen (2007) estimated the extra production from a 3% annual increase in maize yields in the USA would require an additional 18% N, 21% P, and 13% K compared to average fertilizer use from 2004 to 2006.

Future increases in food production will have to occur on less available arable land, which can only be accomplished by intensifying production. And, it must be done in an environmentally safe manner through ecological intensification. The goal of ecological intensification is to increase yield per unit of land, i.e. intensify production, while meeting acceptable standards of environmental quality (Cassman, 1999).

Abbreviations and notes for this article: N = nitrogen; P = phosphorus; K = potassium.

World Fertilizer Situation

Food supply and inflation and fertilizer prices made headline news at the beginning of 2008. Such media attention has made politicians and the general public more aware of the fertilizer industry than ever before. World fertilizer consumption increased steadily from the early 1960s through the mid 1980s and then declined through the mid 1990s before starting to rise again (**Figure 1**). Since 2001, N use has grown by 13%, P_2O_5 by 10%, and K_2O by 13%. Global cereal production and fertilizer consumption are closely correlated (**Figure 2**).

Fertilizer is a world market commodity subject to global supply and demand and market fluctuations. This past year saw unprecedented demand for fertilizer and record prices (**Figure 3**). World price for fertilizer remained relatively constant from 2000 through 2006, but in 2007 prices started to escalate. Prices peaked in September and October of 2008 before declining in December. Fertilizer prices increased so dramatically for a variety of reasons (TFI, 2008; IFA, 2008). Rising global demand and a shortage of supply was the major driving force in price increases. Other factors putting pressure on fertilizer prices included: increasing ethanol production, higher transportation costs, a falling US dollar, strong crop commodity prices, and some countries curbing fertilizer exports.

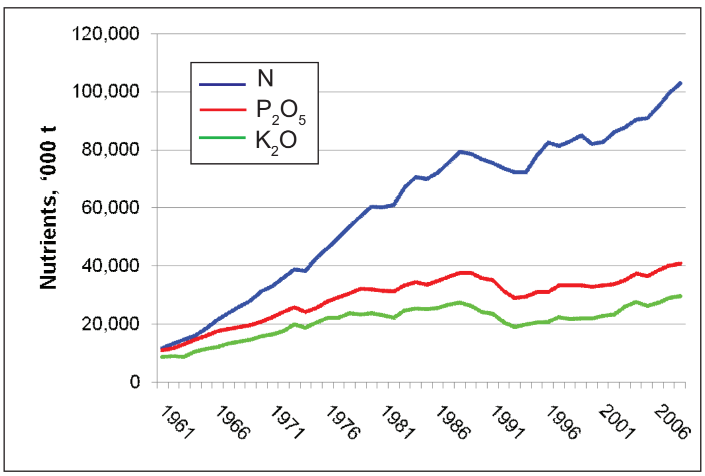

Figure 1. World consumption of N, P_2O_5, and K_2O (IFA Statistics 2007).

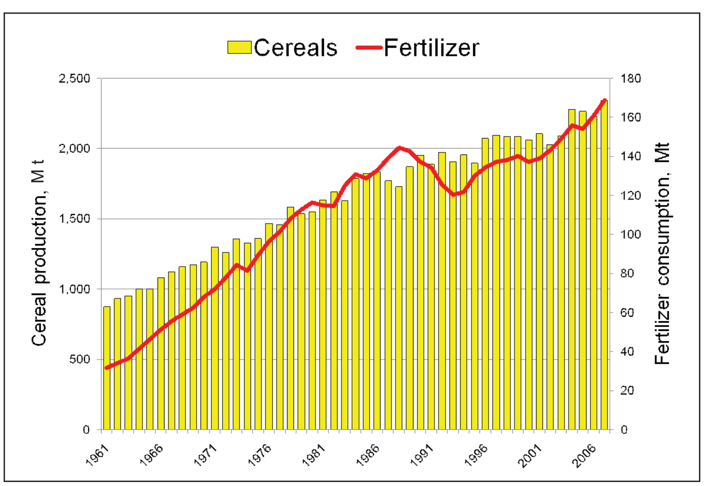

Figure 2. World cereal production and fertilizer production, 1961-2007 (IFA Statistics, 2007; FAOSTAT, 2008).

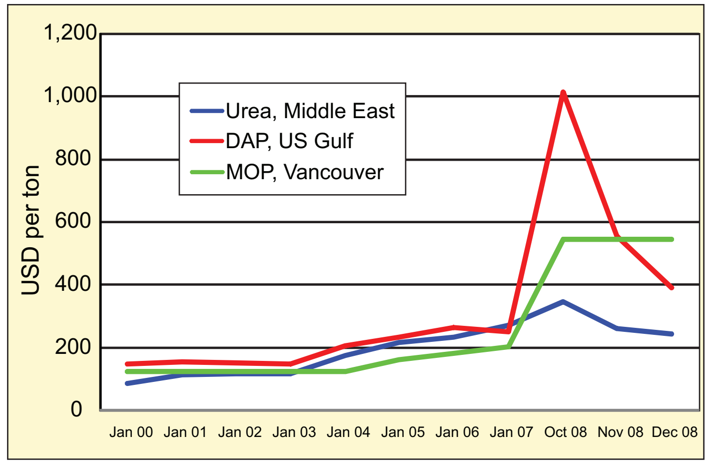

Figure 3. World fertilizer prices, monthly averages from January 2000 to December 2008 (Pike & Fischer, Green Markets).

Despite the recent volatility in the fertilizer market, demand is expected to remain strong. Solid economic growth in many developing countries has resulted in more money available to improve nutrition and human diets are shifting from low-protein, starch-based foods to more animal-based protein. The developing world still lags behind the developed world in meat consumption, but people are making the shift towards more meat. Since 1995, meat consumption in the developing world has increased by 16% and in China it has increased by almost 40%. Increasing demand for meat protein means greater demand for feed grains. Demand for feed grain is projected to double between 1995 and 2020 to 445 million metric tons (M t), while cereals for food consumption are projected to increase by 40% to 1,013 M t (Pinstrup-Andersen et al., 1999). World ethanol and biodiesel production is projected to continue to increase over the next decade (FAPRI, 2008). World cereals stocks have been declining and continue to be low despite a record cereal harvest in 2008 (FAO, 2008b). Crop yields for rice, maize, and soybeans in China, India, and Brazil continue to lag behind the USA, which presents a great opportunity to increase yields with better genetics, improved nutrient management, better water use efficiency, and other BMPs.

In May 2008, the International Fertilizer Industry Association (IFA) forecast total fertilizer demand to increase by an average of 3.1% per annum over the next 5 years (**Table 1**). However, the fertilizer industry was not isolated from the global financial crisis in the latter part of 2008, and as a consequence, consumption in the second half of 2008 was down.

Table 1. Medium-term global fertilizer consumption forecasts to 2012/13.

	Consumption, M t			
	N	P_2O_5	K_2O	Total
Ave. 2005/06 to 2007/08 (e)	95.8	38.6	27.6	162.1
2012/13 (f)	115.6	45.7	33.0	194.3

Heffer, 2008a
e = estimated; f = forecast

Later in the year, IFA adjusted their short-term forecast downward for the 2008/09 fertilizer season (**Table 2**). Nitrogen use is forecast to increase slightly by 0.5%, but P and K fertilizer use is expected to be down 4.6 and 8.3%, respectively, compared to 2007/08. However, global consumption is expected to recover in the 2009/10 season, with each nutrient expected to increase by at least 3% compared to this year.

Table 2. Short-term global fertilizer consumption forecasts to 2009/10.

	Consumption, M t			
	N	P_2O_5	K_2O	Total
2007/08 (e)	100.5	39.3	28.9	168.7
2008/09 (f)	101.1	37.5	26.5	165.0
2009/10 (f)	104.5	38.8	27.5	170.9

Heffer, 2008b

Contribution of Fertilizer to Cereal Production

Commercial fertilizer is necessary to maintain global crop productivity at current levels and will be even more crucial if yields are to be increased. In many countries fertilization is inadequate and unbalanced, which limits the expression of yield potential and negatively impacts crop quality. Even if the biotechnology industry can deliver on their promise to increase crop yields through genetics and improve nutrient uptake efficiency, fertilizer is still critical to avoid depletion of soil nutrients and ensure soil quality.

It is difficult to determine exactly how much crop yield is due to the use of commercial fertilizer because of inherent soil fertility, climatic conditions, crop rotations, management, and the crop itself. Some crops (e.g. legumes) are not responsive to N fertilization and crops differ in their nutrient requirements. Nevertheless, meaningful estimates of the contribution of commercial fertilizer to crop yield have been made using omission trials and long-term studies comparing yields of unfertilized controls to yields with fertilizer. Stewart et al. (2005) reviewed data representing 362 seasons of crop production and reported at least 30 to 50% of crop yield can be attributed to commercial fertilizer inputs. A few examples will be cited here.

Table 3 shows the impact of omitting N fertilizer on several cereal crops in the USA. Without N, average maize yields declined 41%, rice 37%, barley 19%, and wheat 16%. Eliminating N from soybeans and peanuts (both leguminous crops) had no effect on yield (data not shown). Had the authors measured the effect of eliminating P and K, the reductions were expected to be even greater.

Table 3. Estimated effect of omitting N fertilizer on cereal yields in the USA.

	Estimated crop yield, t/ha		% reduction
Crop	Baseline yield	Without N	from no N
Maize	7.65	4.52	41
Rice	6.16	4.48	27
Barley	2.53	2.04	19
Wheat	2.15	1.81	16

Stewart et al., 2005

The Magruder Plots, established in 1892 in Oklahoma, are the oldest continuous soil fertility research plots in the Great Plains region of the USA. Nutrient treatments have changed since the plots were established, with annual N (37 to 67 kg/ha) and P (15 kg/ha) applications starting in 1930. Averaged over 71 years, N and P fertilization in these plots was responsible for 40% of wheat yield (**Figure 4**).

The Sanborn Field at the University of Missouri was started in 1888 to study crop rotation and manure additions. Commercial fertilizer was introduced in 1914. Although application rates have varied over the years, comparing the plots receiving N, P, and K fertilizer to the unfertilized control showed that fertilizer contributed to an average of 62% of the yield of the 100-year period (**Figure 5**).

The Broadbalk Experiment at Rothamsted, England, has the oldest continuous field experiments in the world. Winter wheat has been grown continuously since 1843. Application of N fertilizer with P and K over many decades has been responsible for 62 to 66% of wheat yield compared to P and K applied alone (**Figure 6**). From 1970 to 1995, growing high-yielding winter wheat continuously receiving 96 kg N/ha, omitting P decreased yield an average of 44% and omitting K reduced yields by 36%.

These three long-term studies from temperate climates clearly show how essential fertilizer is in cereal productivity, accounting for at least half of the crop yield. Fertilizer is even more critical to crops in the tropics where slash and

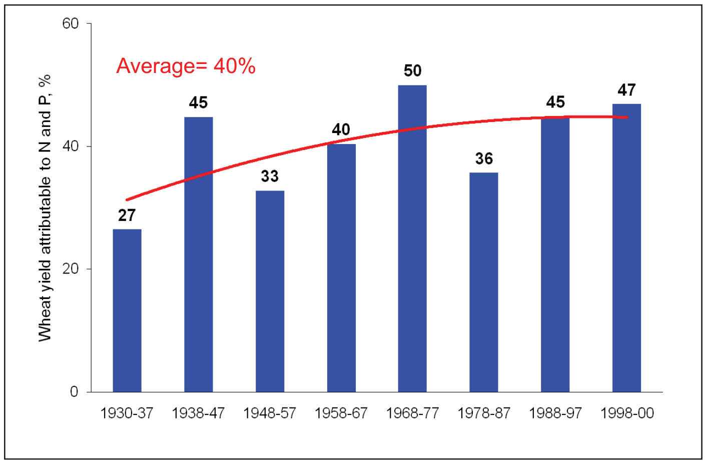

Figure 4. Wheat yield attributable to N and P fertilizer in the Oklahoma State University Magruder plots, 1930-2000 (Stewart et al., 2005).

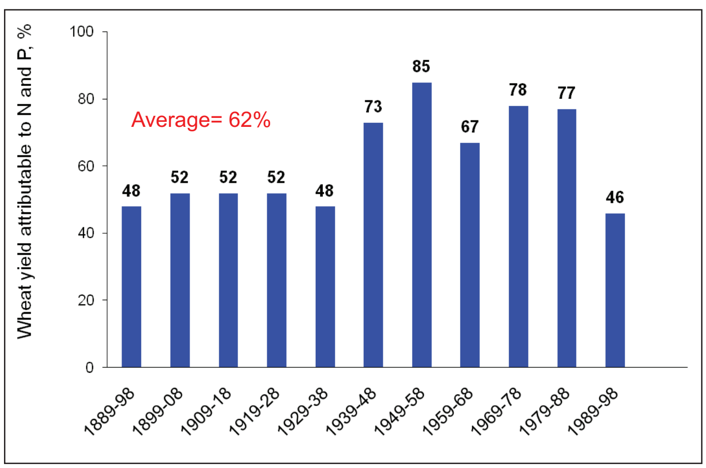

Figure 5. Wheat yield attributable to fertilizer, in the University of Missouri Sanborn Field plots, 1889-1998 (Stewart et al., 2005).

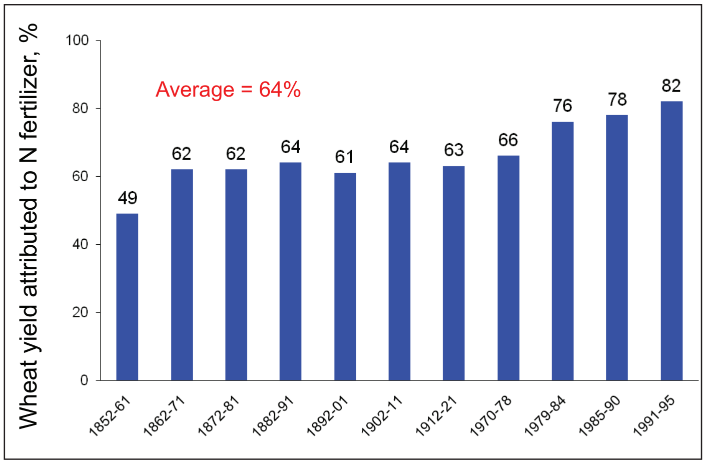

Figure 6. Wheat yield attributable to N fertilizer with adequate P and K compared to P and K alone in the Broadbalk experiments in Rothamsted, England, 1952-1995 (Stewart et al., 2005).

burn agriculture devastate inherent soil fertility. Stewart et al. (2005) refer to examples of continuous grain production in the Amazon Basin in Brazil and in Peru, where fertilizer applied the second year after slash-and-burn clearing was responsible for 80 to 90% of crop yield.

Fertilizer Best Management Practices

With the recent media attention directed to the fertilizer industry as a result of the food crisis and public recognition that fertilizer is part of the solution to world food security, it is incumbent on the industry to do everything practical to ensure fertilizer is used responsibly and efficiently. Fertilizer BMPs are intended to do that — to match nutrient supply with crop requirements and minimize nutrient losses from fields. The approach is simple: apply the correct nutrient in the amount needed, timed and placed to meet crop demand. Applying the 4Rs — right source (or product), right rate, right time, and right place is the foundation of fertilizer BMPs (Roberts 2007).

IPNI has developed a global framework describing how the 4Rs are applicable in managing fertilizer around the world (Bruulsema et al. 2008). Fertilizer management is broadly described by the four "rights", however, determining which practice is right for a given farm is dependent on the local soil and climatic conditions, crop, management conditions, and other site-specific factors. The purpose of IPNI's framework is to guide the application of scientific principles to development and adaptation of global BMPs to local conditions, while meeting the economic, social, and environmental goals of sustainability.

Summary

Global demand for fertilizer remains strong. A growing population with the desire and means to improve their diet will ensure fertilizer consumption will continue and will increase. Meeting the world's escalating food needs cannot be achieved without fertilizers. Without fertilizer, the world would produce only about half as much stable foods and more forested lands would have to be put into production. Inorganic fertilizer plays a critical role in the world's food security. It cannot be replaced by organic sources…although where available, organic nutrient sources should be utilized…but fertilizer must be used efficiently and effectively. The 4Rs — right source, right rate, right time, and right place — are the underpinning principles of fertilizer management and can be adapted to all cropping systems to ensure productivity is optimized. BC

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This article is adapted from a paper presented by the author at the conference "COVAPHOS 111 : Phosphate Fundamentals, Processes and Technologies in a Changing World", in Marrakech, Morocco, March 18-20, 2009.

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Applications of Soil Electrical Conductivity in Production Agriculture

By Pawel Wiatrak, Ahmad Khalilian, John Mueller, and Will Henderson

Greater understanding of soil electrical conductivity (EC) could offer useful information for crop management decisions. Several years of study at Clemson University have identified some important insights, outlined in this article.

Considerable soil variation occurs within and across production fields in the Southeastern USA. The photo below shows the typical variation in soil texture for a Coastal Plain soil. Soil texture relates to factors that have a major impact on productivity and will affect management strategies. For example, irrigation scheduling is closely related to soil type and water holding capacity of the soil. Mobile nutrients are used, lost, and stored differently as soil texture varies. Yield potential of sandy soils generally is less than clay soils; therefore, crop inputs should be based on economical returns. Variations in texture within the soil profile can also have an effect on tillage decisions.

Soil texture will also affect pest management. For example, nematodes such as Columbia lance and root knot nematodes prefer sandy soils. Spiral nematodes like heavier soils and Ring nematodes live only in sandy soils. Soil insects such as southern corn rootworm prefer poorly drained, less sandy soil with high organic matter content, while lesser cornstalk borer will have much higher population on sandy soils. Soil-applied herbicide should be matched to soil properties. Therefore, a good soil texture map could help growers make intelligent management decisions.

Soil EC is an important characteristic that can be used to map the spatial variability of soil within a production field. Basically, soil EC describes the ability of a soil to transmit an electrical current. An EC mapping system is commercially available and many farms in South Carolina and other states are already using this technology for nutrient management.

A typical production field in the Southeastern Coastal Plain, showing variation in soil texture.

Abbreviations and notes for this article: N = nitrogen.

A view of the Veris 3100 soil electrical conductivity equipment.

The Veris 3100 (see photo above) resembles a small disk-tillage implement and measures soil EC continuously (on-the-go) across the field. The implement can be operated at speeds ranging from 8 to 12 mph and measures a 40 to 60 ft. swath in most fields. This equipment allows a 100-acre field to be mapped for soil texture in about 2 hours. The operation cost in South Carolina is around $5/A for commercial operators and $1/A if leased by farmers.

Since sands have low EC, silts have medium EC, and clays have high EC, the EC map would be strongly correlated to soil particle size and texture. **Figure 1** shows an example of a soil EC map from a production field, with yellow areas having light soil and brown areas having heaver soils. In addition to texture, EC has been proven to correlate closely to other soil properties, such as organic carbon, cation exchange capacity (CEC), and depth of topsoil.

Our work during the past 12 years at Clemson University has shown that soil EC is positively correlated to percent clay, and negatively correlated to percent sand. Also, the overall EC

Figure 1. Aerial photo and EC map of a typical production field in the Southeastern Coastal Plain.

Farmers in South Carolina are finding practical benefits of information on soil electrical conductivity.

values increased with increased soil moisture, but the relative values remained consistent. The response curves were parallel for different moisture contents in all areas of the field.

Nematode management relies heavily on the use of nematicides such as Temik 15G applied at planting at a cost of about $16/A or pre-plant soil fumigation with Telone II at about $33/A. Usually, farmers apply a uniform rate of one of these nematicides across an entire field or even an entire farm. However, nematodes are not uniformly distributed within fields and therefore uniform applications result in nematicides being applied in areas with and without nematodes. Our work has showed that soil EC can be effectively used for variable-rate applications of nematicides in production fields. Nematode densities were also highly correlated to soil texture as measured by soil EC. This technology is being used by several farmers in South Carolina.

Soil compaction management in the Coastal Plain region relies heavily on the use of annual deep tillage, usually to a uniform depth throughout the field. Our work indicated that variable-depth tillage could be used to significantly reduce fuel requirements for tillage operations. Predicted tillage depths were inversely correlated to the soil EC. The soil EC data were good estimates of the topsoil thickness (**Figure 2**).

Furthermore, our work showed strong correlations between soil EC maps and water holding capacity, plant vigor, and crop yield maps. Additionally, geo-referenced soil EC maps were successfully used to match soil properties with the lowest herbicide rate needed for effective weed control. This was true only for soil-applied herbicides such as fluometuron (cotoran). For example, to achieve 80% control of pitted morningglory, the fluometuron rate in heavy soils was five times higher than in light soils.

Results from 2007 and 2008 studies showed that there is a potential to use mid-season specific plant Normalized Difference Vegetation Index (NDVI) data for variable-rate application of N fertilizer in cotton and corn production. However, the soil EC data should be included in the N-rate prediction equation

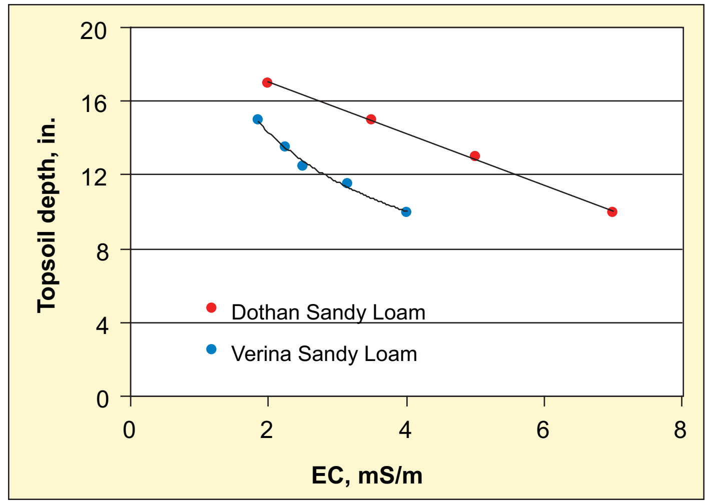

Figure 2. Soil electrical conductivity can estimate topsoil thickness. Predicted tillage depth are inversely correlated to the soil EC.

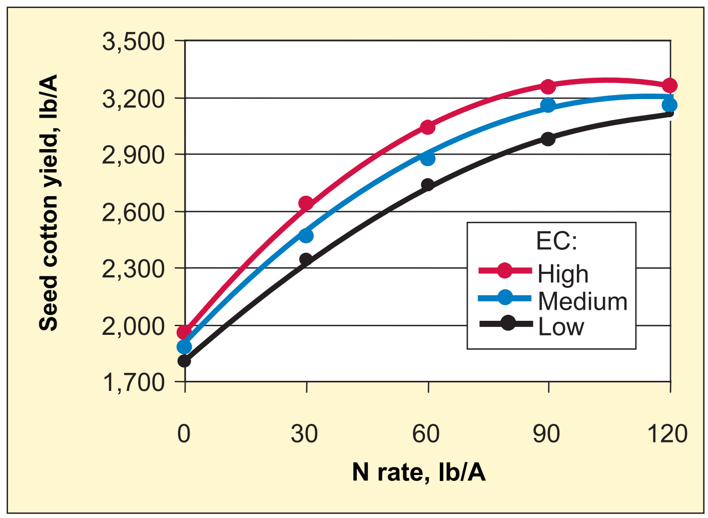

Figure 3. Seed cotton yields increased as N rates increased in low EC areas, but there was no yield response to N rates higher than 90 lb/A in medium and high EC areas.

for the Southeastern Coastal Plain region. For example, seed cotton yield increased as N rates increased in low EC areas. As shown in **Figure 3**, there was no yield response to N rates higher than 90 lb/A in medium and high EC areas. BC

IPNI/FAR Proj. No. SC-14

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Optimum Fertilization Effect on Maize Yield, Nutrient Uptake, and Utilization in Northern China

By Wei Gao, Ji-yun Jin, Ping He, Shutian Li, Jinghua Zhu, and Mingyue Li

Field experiments were conducted in northeast, northcentral, and northwest China in order to explore and compare regional yield responses, nutrient uptake, and nutrient utilization in maize. The results showed that spring maize yields in northeast and northwest China were higher than summer maize yield in northcentral China. Total macronutrient accumulation was higher in the northwest compared to other regions.

In the last 50 years, maize yields in northern China have improved rapidly. From 1961 to 1988, maize mean yield increased from 1,180 kg/ha to 5,000 kg/ha with a mean annual growth rate of 5.3% (Zhen et al., 2006). This rapid increase in productivity has been mainly dependent on chemical fertilizer application, especially N. However, lack of science-based fertilization has prevented farmers from obtaining their attainable yields and profits. Cases of over use or unbalanced fertilization have resulted in low nutrient use efficiency and increased risk of environmental harm. The area presently planted to maize in the northern regions now represents about 20 million (M) ha or about 70% of China's total maize area. Rational nutrient management is needed to increase the sustainability of maize-based crop production systems in northern China and enhance the environmental protection of the surrounding areas.

This study included field experiments in the northeast (Heilongjiang, Jilin, and Liaoning), northcentral (Hebei, Henan, and Shanxi), and northwest (Xinjiang; Zhenyuan, Gansu; and Wuwei, Gansu) regions of China in 2006 to explore and compare yield responses, nutrient uptake, and nutrient utilization. All sites used the same maize cultivar (Zhengdan 958), but the northeast and northwest sites conducted spring maize trials (April to October) while the northcentral sites grew during the summer maize season (June to October).

Prior to each sowing, soil samples (0 to 20 cm) were collected and analyzed (**Table 1**) following National Laboratory of Soil Testing and Fertilizer Recommendations as described by Portch and Hunter (2002). This procedure generated a soil test-based balanced "optimum" nutrient application (OPT) that was compared against farmer practice (FP), and a series of nutrient omission treatments including: OPT-N, OPT-P, and OPT-K. **Table 2** shows the OPT and FP rates used at each experiment site. Each experiment was designed in a randomized complete block with three replications. Urea, single superphosphate, and potassium chloride were used as sources for N, P, and K, respectively. Plots received all the P and K, plus half of the N fertilizer as a basal broadcast application, while the remaining N was topdressed at V6 stage.

Abreviations and notes: N = nitrogen; P = phosphorus; K = potassium.

Experimental site in Henan Province.

Table 1. Soil pH, organic matter, and available N, P, and K of test soils.

Experiment sites	Soil type	pH	OM, %	NH_4^+-N	NO_3^--N	P	K
				----------- mg/L			-----------
Heilongjiang	Black soil	5.6	2.4	22.5	32.4	2.5	93.9
Jilin	Aeolian soil	5.3	2.4	9.0	16.9	11.9	86.0
Liaoning	Meadow soil	5.8	1.0	16.6	38.2	16.5	97.8
Hebei	Fluvo aquic soil	8.2	0.6	20.6	40.8	26.8	77.5
Henan	Fluvo aquic soil	7.8	0.7	7.6	12.6	91.9	215.0
Shanxi	Fluvo aquic soil	8.4	0.6	12.7	28.2	25.1	126.9
Xinjiang	Gray desert soil	8.3	0.8	18.8	47.9	23.3	136.9
Gansu (Wuwei)	Irrigated desert soil	7.9	0.9	10.2	23.1	34.3	96.8
Gansu (Zhenyuan)	Yellow mien soil	8.1	0.9	10.5	13.4	7.6	90.2

The general critical values for soil fertility evaluation are 12 mg/L for P, 78 mg/L for K, and 20 kg/L for NH_4-N + NO_3-N. Detailed N, P_2O_5, and K_2O recommendations also considered a yield goal as well as local soil and climatic conditions.

Table 2. Fertilization rates of the optimum (OPT) and farmer practice (FP) treatments used at each experiment site.

	Rate of fertilizer application (N - P_2O_5 - K_2O), kg/ha	
Experiment sites	OPT	FP
Heilongjiang	160-68-90	175-45-45
Jilin	150-75-75	180-100-100
Liaoning	180-30-135	180-90-90
Hebei	240-75-150	300-0-75
Henan	225-90-180	180-0-0
Shanxi	225-90-120	345-0-0
Xinjiang	233-71-35	275-138-0
Gansu (Wuwei)	210-45-75	350-120-0
Gansu (Zhenyuan)	225-150-150	225-150-0

Table 3. Maize yield and yield response to OPT fertilization at different experiments sites.

Region/Season	Site	Grain yield, kg/ha		Yield response to each nutrient, kg/ha		
		OPT	FP	N (OPT-N)	P (OPT-P)	K (OPT-K)
Northeast/ Spring	Heilongjiang	11,672 a	11,098 a	2,161	443	1,783
	Jilin	10,474 a	9,009 b	4,065	1,508	1,273
	Liaoning	10,372 a	9,425 b	1,850	1,595	2,193
Northcentral/ Summer	Hebei	8,625 a	7,980 b	1,594	996	1,337
	Henan	9,221 a	6,125 b	3,606	2,218	1,162
	Shanxi	8,299 a	7,408 b	2,012	378	74
Northwest/ Spring	Xinjiang	12,381 a	12,251 a	950	2,000	900
	Gansu (Wuwei)	14,533 a	12,727 b	5,158	2,485	900
	Gansu (Zhenyuan)	14,720 a	12,940 b	5,333	2,513	1,133

Means within a row followed by the same letter are not significantly different at p = 0.05

Yield and Nutrient Uptake

Across regions, grain yields under OPT treatments tended to be highest in the spring maize trials conducted in the northwest, followed by spring maize sites in the northeast, and then the summer maize trials in northcentral China (**Table 3**). The OPT treatment generated significantly higher grain yield compared to the FP treatment at all sites except Heilongjiang and Xinjiang.

The OPT treatment achieved higher N, P, and K uptake compared to FP at 4, 2, and 3 sites, respectively, out of all 9 sites (**Table 4**). Thus, any yield benefit attributed to balanced fertilization over FP could not be consistently linked to improved nutrient uptake. The cultivar expressed higher N and P uptake potential in the northwest, as a spring maize crop, compared to the other two regions. The effective growing period for the spring season at the northeast and northwest sites is known to be much longer compared to summer conditions in northcentral China and this has a significant effect on grain yield. The high cumulative degree days and great differences in diurnal temperature in the northwest contributed greatly to the highest yields and nutrient accumulations across sites. Total K accumulation at northeast sites was lowest among the three regions, which likely reflects low available soil K and historically low non-exchangeable soil K contents in the northeast (Huang et al, 1999). Significant differences in crop K uptake were observed between the OPT and FP at sites located in the northcentral and northwest regions.

Nutrient Use Efficiency

Nutrient use efficiency can be expressed as agronomic efficiency (AE) and crop recovery efficiency (RE) (Fixen, 2007). Here we use AE and RE to evaluate the effect of balanced fertilization on N utilization, where AE refers to the crop yield increase per unit N applied, and RE refers to the increase in plant nutrient uptake per unit N applied (**Table 5**).

The highest AE values for N were found in the northeast and the northwest at the two spring maize sites in Jilin (27.1 kg grain/kg N) and Gansu, Zhenyuan (24.6 kg grain/kg N). The lowest AE values (6.6 to 16.0 kg grain/kg N) were in the northcentral summer maize sites. Higher AE values for N were more commonly found with OPT than FP.

The measurements for RE of N for the group of spring maize sites in the northeast (range = 31 to 50%), were distinctly higher than those obtained from the summer maize sites (range = 15 to 28%). Recovery of N from the northwest spring maize sites was similar or slightly lower than that determined for the northcentral sites.

As compared with developed countries, N use efficiency in China is still very low. Dobermann et al. (2007) reported that AE of N and RE of N in cereals varied between 10 to 30 kg grain/kg N and 30 to 50%, respectively, and could exceed 25 kg/kg and 50 to 80% in a well-managed system, with low levels of N use, or with low soil N supply.

In this study, some AE values for N in the northeast and northwest sites were between 20 to 30 kg grain/kg N, but were often lower in the northcentral region. In regard to RE of N, values were lower than 35% (with the exception of Jilin) because of continuous high N input in recent years, especially in northcentral China (He et al., 2008; Cui, 2005). Excessive N use, and imbalanced N, P, and K practices lead to low N use and recovery efficiency in these maize growing regions.

The low N use efficiency in this study means that additional in-season N management strategies are needed. Designing a N management strategy that involves a combination of anticipatory (N applied as a basal dressing at the beginning of the growing season based on available soil information and an expected target yield) and reactive (N topdressing during the growing season guided by a chlorophyll meter or leaf color chart) decisions may improve the performance of SSNM by accounting for seasonal variation and therefore matching crop need with nutrient supply.

It should also be noted that yield potential in maize is, to a large degree, determined by factors such as solar radiation, temperature, moisture, and nutrient supply during grain filling, long after most of the N has been applied. Hence, for optimal

Maize was most limited by N at some sites (foreground), but analysis of soil test -based OPT treatments (background) found lower than optimum N use efficiency.

Table 4. Nutrient accumulation for maize at different experimental sites in northern China.

		Total N uptake, kg/ha		
Region	Site	OPT	FP	OPT-N
Northeast	Heilongjiang	172 a	153 b	116 c
	Jilin	144 a	137 a	68 b
	Liaoning	149 a	169 a	121 b
Northcentral	Hebei	189 a	163 a	163 a
	Henan	174 a	150 b	119 c
	Shanxi	165 a	146 b	102 c
Northwest	Xinjiang	217 a	197 ab	190 b
	Gansu (Wuwei)	238 a	219 b	190 b
	Gansu (Zhenyuan)	196 a	178 a	155 a
		Total P uptake, kg/ha		
Region	Site	OPT	FP	OPT-P
Northeast	Heilongjiang	22 a	16 a	14 a
	Jilin	35 a	31 a	24 b
	Liaoning	40 a	33 a	34 a
Northcentral	Hebei	51 a	40 a	43 a
	Henan	46 a	38 b	33 c
	Shanxi	47 a	37 b	31 c
Northwest	Xinjiang	56 a	55 a	40 b
	Gansu (Wuwei)	53 a	50 a	50 a
	Gansu (Zhenyuan)	47 a	36 a	42 a
		Total K uptake, kg/ha		
Region	Site	OPT	FP	OPT-K
Northeast	Heilongjiang	120 a	108 a	109 a
	Jilin	98 a	80 ab	62 b
	Liaoning	122 a	114 a	84 b
Northcentral	Hebei	278 a	248 b	271 a
	Henan	296 a	259 ab	273 b
	Shanxi	249 a	226 b	197 b
Northwest	Xinjiang	277 a	235 b	226 b
	Gansu (Wuwei)	276 a	251 a	243 a
	Gansu (Zhenyuan)	316 a	245 a	260 a

Means within a row followed by the same letter are not significantly different at p = 0.05

Table 5. Agronomic efficiency (AE) and recovery efficiency (RE) for N fertilizer applied in maize grown in northern China.

		AE-N, kg grain increase/kg N		RE-N, %	
Region	Experiment sites	OPT	FP	OPT	FP
Northeast	Heilongjiang	23.0 a	12.8 b	34 a	18 b
	Jilin	27.1 a	15.2 b	50 a	39 a
	Liaoning	10.3 a	7.8 a	31 a	24 a
Northcentral	Hebei	6.6 a	2.7 b	15 a	7 a
	Henan	16.0 a	8.3 b	26 a	21 a
	Shanxi	7.9 a	3.9 b	28 a	16 b
Northwest	Xinjiang	4.1 a	7.7 a	15 a	14 a
	Gansu (Zhenyuan)	24.6 a	11.4 b	27 a	6 b
	Gansu (Wuwei)	23.7 a	17.9 a	24 a	21 a

Means within a row followed by the same letter are not significantly different at p = 0.05

performance, reactive N management should be integrated with predictive algorithms that aim at preventing deficiencies, or excess, of N at the critical stages for yield component formation.

Research on improving N conservation and efficiency should be strengthened for this highly intensified cropping system in China. In addition, improvements in best management practices, by alleviating other crop management constraints, should be integrated to improve fertilizer (especially N) use efficiency. BC

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Dr. Jin is Director, IPNI China Program. Dr. He and Dr. Li are Deputy Directors of the IPNI China Program.

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InfoAg 2009 Conference Set for July 14-16 in Illinois

Individuals interested in precision agriculture should mark their calendars for the next edition of the popular Information Agriculture Conference, set for July 14-16, 2009, at the Crowne Plaza in Springfield, Illinois. This is the same location as InfoAg 2007 and InfoAg 2005.

InfoAg 2009 will continue the tradition of bringing together the latest in precision farming, information management, and communication technologies, providing a forum for discussion and demonstration of what is working, what is new, and what is needed. It is an excellent forum for networking with others who are involved in implementing these systems in the field. The event is organized by IPNI and the Foundation for Agronomic Research (FAR), with exhibits coordinated by CropLife Media Group.

InfoAg 2009 will present a wide range of educational and networking opportunities for manufacturers, consultants, practitioners, input suppliers, producers, Extension and NRCS personnel, and anyone interested in site-specific techniques and technology.

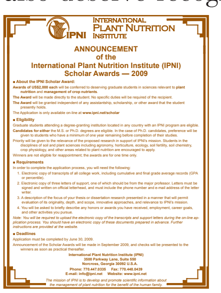
"Since the first conference in 1995, InfoAg has been a leading event in precision agriculture," said Dr. Harold F. Reetz, Jr., Director of External Support and FAR. He is located at Monticello, Illinois, and may be contacted by telephone at (217) 762-2074.

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

IPNI Awards Available to Graduate Students and Scientists

Each year, the International Plant Nutrition Institute (IPNI) offers the Scholar Award to honor and encourage deserving graduate students, and also the IPNI Science Award to recognize and promote distinguished contributions by scientists.

"We believe both of these awards are unique and have many positive benefits," said IPNI President Dr. Terry Roberts. "It is important to encourage talented young people in their studies of agronomic and soil sciences, while established scientists also deserve recognition for career accomplishments. These awards are made possible by our member companies and are evidence of their respect for science."


INTERNATIONAL PLANT NUTRITION INSTITUTE

ANNOUNCEMENT
of the
International Plant Nutrition Institute (IPNI)
Scholar Awards — 2009

■ 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, 2009.

Announcement of the Scholar Awards will be made in September 2009, and checks will be presented to the winners as soon as practical thereafter.

International Plant Nutrition Institute (IPNI)
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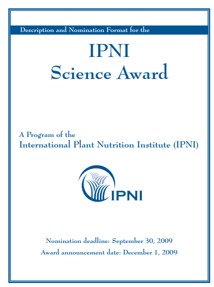
The mission of IPNI is to develop and promote scientific information about the management of plant nutrition for the benefit of the human family.

The Scholar Award 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 graduate students in any country where an IPNI program exists are eligible. Only a limited number of recipients are selected for the award, worth US$2,000 each. The application process is available on-line only. Recipients are announced in September.


Description and Nomination Format for the

IPNI
Science Award

A Program of the
International Plant Nutrition Institute (IPNI)

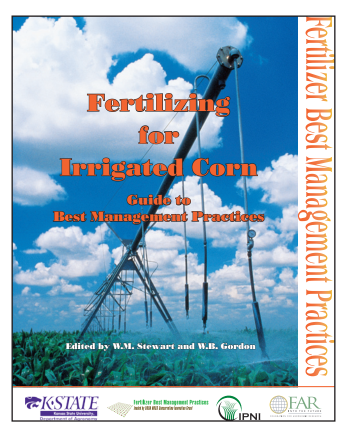
IPNI

Nomination deadline: September 30, 2009
Award announcement date: December 1, 2009

The Science Award goes to one individual each year, based on outstanding achievements in research, extension, or education which focus on efficient and effective management of plant nutrients and their positive interaction in fully integrated crop production, enhancing yield potential. It requires that a nomination form (no self-nomination) and supporting letters be submitted by mail before September 30. The Award announcement is December 1. It includes a monetary prize of US$5,000.

More information about past winners of these awards, plus details on qualifications and requirements for both awards can be found at the IPNI website: >**www.ipni.net/awards**<. BC

Fertilizing for Irrigated Corn—Guide to Best Management Practices Publication Available from IPNI



Irrigated corn production is an important component of agricultural systems in some parts of the central and southern Great Plains of the USA. This 52-page color manual was designed and authored by industry, university, and government soil fertility experts to address fundamental irrigated corn fertility questions.

The publication (Item #30-3240) is available for US$6.00 per copy, with discounts for quantities. To order or for more information, call (770) 825-8082 or visit the IPNI website at: >**www.ipni.net/bmp**< BC

IPNI Crop Nutrient Deficiency Photo Contest—2009

Once again, IPNI opens our crop nutrient deficiency photo contest as part of a continuing effort to encourage the art of field observation and increase understanding of the physical appearance of crop nutrient deficiencies and the varying conditions in which they may appear in the field.

"This competition continues to appeal to a wide range of practitioners involved in all phases of crop production," said IPNI President Dr. Terry L. Roberts. "Researchers working under controlled plot conditions are also welcome to submit entries. We encourage crop advisers, farmers, students, and others to photograph and document deficiencies in crops."

Some specific supporting information is required for all entries, including:

- The entrant's name, affiliation, and contact information.
- The crop and growth stage, location, and date of the photo.
- Supporting and verification information related to plant tissue analysis, soil test, management factors, and additional details that may be related to the deficiency.

There are four categories in the competition: **Nitrogen (N), Phosphorus (P), Potassium (K), and Other**. Entrants are limited to one entry per category (one individual could have an entry in each of four categories). Cash prizes are offered in each of the four categories as follows:

- First place = US $150
- Second place = US $75
- A Grand Prize of US $200 will be awarded to the entry with the best combination of photographic quality and supporting evidence across all categories.

Photos and supporting information can be submitted until December 15, 2009, and winners will be announced in January of 2010. Winners will be notified and results will be announced at the IPNI website and in this publication.

Entries are encouraged from all regions of the world. However, entries can only be submitted electronically as high resolution digital files to: >**www.ipni.net/photocontest**<.

For questions or additional information, please contact:

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Shown at right are examples of past winners of the contest. BC

Nitrogen Category...N-Deficient Lettuce

Phosphorus Category...P-Deficient Corn

Potassium Category...K-Deficient Soybeans

Other Category...Zn-Deficient Cassava

International Plant Nutrition Colloquium Set for August 2009

The 16th International Plant Nutrition Colloquium (XVI IPNC) will take place August 26-30, 2009 at the Sacramento Convention Center in California, sponsored by the University of California-Davis (UC-Davis). Since its inception in the 1950s, the IPNC has grown to become one of the most important international meetings on fundamental and applied plant nutrition, from both an agricultural and environmental context.

The theme for the 2009 Colloquium, "Plant Nutrition for Sustainable Development and Global Health", aims to highlight the importance of plant nutrition as a foundation science with impact on all aspects of cropping system and environmental sustainability, human health, and well being. Dr. Patrick Brown of the UC-Davis Department of Plant Sciences serves as President of the IPNC. Additional information is available at the website: >**http://ipnc.ucdavis.edu**.< BC

Armando Tasistro Joins IPNI Staff as Communications Specialist


Dr. Tasistro

Dr. Armando S. Tasistro has joined the staff of the International Plant Nutrition Institute (IPNI) as Communications Specialist, effective April 1, 2009. He will be based at the IPNI headquarters office in Norcross, Georgia.

"This key addition to our staff further strengthens IPNI capabilities in communicating science-based information related to plant nutrition," said IPNI President Dr. Terry Roberts. "With his unique and diverse background and skills, Dr. Tasistro will be involved in furthering our agronomic research and education programs around the globe."

A native of Uruguay, Dr. Tasistro was most recently Research Scientist at the University of Georgia-Athens, Agricultural and Environmental Services Laboratories. His work there included study of phosphorus dynamics and analysis in poultry wastes, with focus on bioavailable forms. He studied development of alternatives to abate ammonia emissions from poultry production facilities and wastes, including the use of chars derived from the pyrolysis of agricultural wastes. Another focus was on calibrating Near-Infrared Reflectance Spectoscopy for the quicker determination of water and potentially mineralizable nitrogen in poultry litter. He is also Adjunct Assistant Research Scientist with the Department of Crop and Soil Sciences.

Dr. Tasistro received his B.Sc. in agronomy at the University of Uruguay at Montevideo in 1976. In 1981, he completed his M.Sc. in weed science at the University of Wisconsin-Madison, and later received his Ph.D. in soil fertility in 1993 at the University of Georgia.

From 1993 to 2001, Dr. Tasistro worked as an independent agricultural consultant and successfully advised more than 30 clients (mostly in Latin America) on soil and crop management and crop protection. He also assisted agribusiness companies and project management firms in research and development. He emphasized hands-on training programs for agronomists and growers in field diagnostic techniques for corn, conservation tillage systems, and soil and weed management.

Earlier, Dr. Tasistro was with the International Maize and Wheat Improvement Center (CIMMYT) in Mexico from 1984 to 1992 as Assistant Head/Agronomist/Training Officer, Experiment Stations. He was involved in planning, budgeting, and field and administrative operations for CIMMYT's four experiment stations in Mexico, plus other off-station sites. His responsibilities included training and advising in agronomic and experiment station management at headquarters and internationally. BC

Conversion Factors for U.S. System and Metric Units

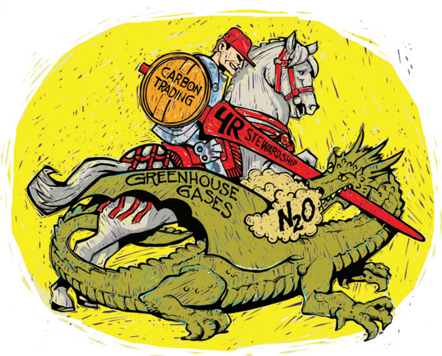
Because of the diverse readership of *Better Crops with Plant Food*, units of measure are given in U.S. system standards in some articles and in metric units in others…depending on the method commonly used in the region where the information originates. For example, an article reporting on corn yields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

Fertilizing for Credit



Agricultural organizations have been seeking opportunities for recognition of farmer contributions toward mitigating greenhouse gas emissions. For this to happen, regulatory programs need to allow offsets. Offsets are defined as emission reduction credits traded from regulated to non-regulated industries. Governments plan to regulate emissions from large factories, but not those from farms. Farm emissions are diffuse, sporadic, and difficult to measure directly. Nonetheless, science is elucidating the effects of crop management practices in terms of probability and magnitude of mitigation. This provides a potential opportunity for farmers to receive carbon credits.

Nitrous oxide is one of the greenhouse gases considered responsible for the warming trend in the climate. Pound for pound, it is deemed about 300 times more effective in trapping heat than carbon dioxide. Experts recently agreed on a new approach to fertilizer stewardship to limit its emission.

Farmers can achieve better management though implementation of the 4R nutrient stewardship approach, applying the right source at the right rate, right time, and right place. This approach starts with the definition of economic, social, and environmental sustainability goals. The 4Rs describe site-specific practices— based on sound agronomic principles and supported by objective research results—that contribute to the defined goals.

Including nitrous oxide emission reduction as one of the goals leads to the selection of practices that are "right" for reducing nitrous oxide without neglecting the remaining goals. Farmers may need to spend or invest more to implement such practices. However, the environmental benefit for the "public good" should be recognized as a carbon credit or offset in protocols for reduction of greenhouse gas emissions.

Recent studies by USDA Agricultural Research Service with irrigated no-till corn in Colorado documented reductions of 25 to 50% in nitrous oxide emissions through use of enhanced-efficiency N fertilizer sources. Similar reductions have been reported in other studies, and may be witnessed in on-going research in the USA and Canada.

Investment in and implementation of the 4R fertilizer management strategy would seem attractive not only to farmers and society, but also to carbon credit and offset trading programs. New and exciting technologies are being explored, and better crop management skills are being honed by professional agronomists, crop advisers, and farmers. As science-based protocols are developed, there may be potential for farmers to receive carbon credits to help optimize the performance of their cropping systems.

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