Better Crops International

Vol. 17, No. 2
November 2003

In This Issue:

Corn Response to Potassium on Black Soil in Heilongjiang (China)

Nutrient Management for a No-Till Rotation in the Pampas (Argentina)

Phosphorus Management for Fish Ponds in Red and Lateritic Soil Zones (India)

and much more…

Vol. 17, No. 2
November 2003

Better Crops International

Table of Contents

PPI/PPIC on the Web: www.ppi-ppic.org

Learn more about PPI/PPIC programs, research support, publications, and links by visiting the website at www.ppi-ppic.org. From the central website, visitors may reach the various individual regional sites where PPI/PPIC programs are at work. BCI

Our Cover: Wheat field in Argentina.
Photo Source: PPI/PPIC staff.

Editor: Donald L. Armstrong
Assistant Editor: Katherine P. Griffin
Circulation Manager: Carol Mees
Design: Kathy Hefner

BETTER CROPS INTERNATIONAL (BCI) is published two times each year by the Potash & Phosphate Institute of Canada (PPIC) and the Potash & Phosphate Institute (PPI). PPIC office is located at Suite 704, CN Tower, Midtown Plaza, Saskatoon, Saskatchewan, Canada S7K 1J5. Address inquiries to PPI office at 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837 U.S.A. Phone (770) 447-0335; Fax (770) 448-0439. URL:www.ppi-ppic.org.
BCI is intended primarily for agricultural leaders and scientists working in agronomy and related sciences outside North America. Subscription price is (U.S.) $5.00 (five dollars) per year (free on request to qualified individuals).

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.

Corn Response to Potassium on Black Soil in Heilongjiang

By Li Yuying

A 7-year study demonstrates the potential yield and profit gains from annual additions of potassium (K) fertilizer in a region traditionally considered to have 'no need'.

The northeastern province of Heilongjiang occupies 453,900 square kilometers, with more than 10 million hectares (M ha) of cultivated land. Main soil types are Black, Meadow, and Chernozem, which respectively cover 3.6, 3.0 and 1.6 M ha. Heilongjiang is the leading grain producing province in China and the main crops are corn, soybean, rice, and wheat. Corn covers about 2.5 M ha annually or nearly 25% of the total cultivated land in the province. Annual production is about 11.9 million tonnes (M t), which represents about half of all cereals produced in the province.

Farmers in Heilongjiang are accustomed to using only nitrogen (N) and phosphorus (P) fertilizers. In fact, at the initiation of this experiment, farmers had little experience with K fertilizer.

Tradition suggests that these soils are 'rich' in K, thus the lack of emphasis on K application. As a result, little was known about how corn responds to K application and what effect successive K applications would have on soil fertility. This experiment was established to specifically answer these two questions.

Plots with 112 kg K_2O/ha (right) and with no K (left) near Shuangcheng City, Heilongjiang.

The site was located at the Extension Center of Agricultural Technology in Shuangcheng City, Heilongjiang. Shuangcheng is the main region for corn production and has a higher average yield than other regions in the province. Soil at the field site was Black with 1.14% organic matter (OM). Available N, P, and K were measured at 11.6, 5.0, and 66.5 mg/kg, suggesting a K responsive soil.

Potassium fertilizer was applied each year over a 7-year period. There were three treatments with four replications (**Table 1**). Plots were 30 m^2 in size and were arranged in a randomized block design. Soil and plant samples were collected after each harvest. The NPK fertilizers used were urea, diammonium phosphate (DAP), and potassium chloride (KCl).

Table 1. Fertilizer rates (kg/ha) applied at Shuangcheng City, Heilongjiang.

Treatment	N	P_2O_5	K_2O	$ZnSO_4$
NP	172	120	0	20
NPK_1	172	120	112	20
NPK_2	172	120	225	20

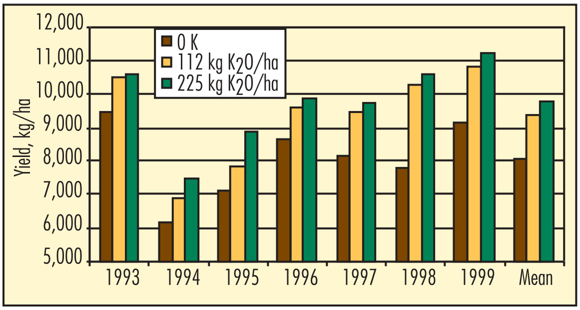


Figure 1. Corn yield response to K for seven successive years in Black soil, Heilongjiang Province.

Effect of K Fertilizer on Corn Yield and Profit

The site's low available soil K content correctly predicted a response to K as yield was consistently higher with K fertilizer application (**Figure 1**, **Table 2**). Compared to zero K, application of 112 kg K_2O/ha increased the 7-year average yield and net benefit by 1,280 kg/ha (15.8%) and US$95/ha, respectively. Similarly, the 225 kg K_2O/ha rate increased average yield and net benefit by 1,689 kg/ha (20.9%) and US$102/ha. Interestingly, the largest differences in yield between the two K supplying treatments were 560 and 1,040 kg/ha, occurring in 1994 and 1995, the two poorest years of the seven studied.

Table 2. Yearly and average yield effects of 7 years K application to corn, Shuangcheng City, Heilongjiang.

Year	Treatment	Yield, kg/ha	Increase kg/ha	Increase kg/kg K_2O	Increase %	Benefit, US$/ha[1]
1993	K_0	9,470	–	–	–	–
	K_1	10,500	1,030	9.2	10.9	73.5
	K_2	10,600	1,130	5.0	11.9	48.7
1994	K_0	6,180	-	-	-	-
	K_1	6,910	730	6.5	11.8	39.7
	K_2	7,470	1,290	5.7	20.9	61.4
1995	K_0	7,130	–	–	–	–
	K_1	7,830	700	6.2	9.8	36.2
	K_2	8,870	1,740	7.7	24.4	106.4
1996	K_0	8,660	–	–	–	–
	K_1	9,610	950	8.4	11.0	61.1
	K_2	9,870	1,210	5.4	14.0	52.5
1997	K_0	8,180	–	–	–	–
	K_1	9,500	1,320	11.7	16.1	100
	K_2	9,740	1,560	6.9	19.1	88.5
1998	K_0	7,780	–	–	–	–
	K_1	10,300	2,520	22.4	32.4	218.6
	K_2	10,600	2,820	12.5	36.2	214.2
1999	K_0	9,160	–	–	–	–
	K_1	10,800	1,640	14.6	17.9	136
	K_2	11,200	2,040	9.1	22.3	141.9
Cumulative	K_0	56,560	–	–	–	–
	K_1	65,450	8,890	–	–	–
	K_2	68,350	11,790	–	–	–
Mean	K_0	8,080	–	–	–	–
	K_1	9,360	1,280	11.4	15.8	95
	K_2	9,770	1,690	7.5	20.9	101.9

[1]The average price of corn was US$0.10 /kg. The average cost of KCl was US$187/t. K_0 = zero K; K_1 = 112 kg/ha; K_2 = 225 kg/ha

Soil K Balance

Potassium removal by corn was higher in plots supplied with K than in plots without K (**Table 3**). Corn removed larger quantities of soil K when supplied with the high rate versus the low rate of K fertilizer. Over 7 years, the balance coefficient for the lower rate was 0.96, indicating that slightly more K was removed than was applied as fertilizer. At the higher rate, the average balance coefficient was 1.4, indicating soil K status was likely improved over the 7 years.

Potassium Fertilizer and Corn Grain Quality

Potassium fertilizer application showed a positive effect on the quality of harvested grain (**Table 4**). As K application rates increased, protein, cystine, and methionine contents increased, while percent starch content decreased. Cystine and methionine are sulfur (S)-containing amino acids important for

In addition to improved yield and profit potential, K fertilization also improved nutritional value of harvested grain.

animal and human health.

Conclusions

Results from this 7-year, fixed-site trial found rapid soil K depletion and unsustainable grain yields if no K fertilizer was applied. Application of 112 and 225 kg K_2O/ha contributed to successively better soil K balance and supplying capacity, which translated into higher yields and farmer profit.

Potassium fertilization also improved the nutritional value of harvested grain by elevating the protein content, and more specifically, the content of S-containing amino acids. Further studies on whether these improvements to animal feed might translate into more efficient livestock production would prove interesting.

It is apparent that K fertilizer is necessary to maintain or improve soil K status on these soils, which contradicts longstanding attitudes of farmers. More study is required in order to determine the optimal rate capable of providing the highest benefit to farmers while maintaining good soil K supply capacity. BCI

Table 3. Estimate of soil K output (kg/ha) and balance coefficients, Shuangcheng City, Heilongjiang.

	Treatment	1994	1995	1996	1997	1998	1999	Mean
K output	K_0	71.7	68.5	73.5	81.8	43.9	83.9	70.6
	K_1	99.5	122	113	118.6	114	142.7	118.3
	K_2	160.6	167	181.5	174.6	144.2	189.4	169.6
Balance coefficient	K_0	–	–	–	–	–	–	–
	K_1	1.1	0.92	1	0.95	0.99	0.79	0.96
	K_2	1.4	1.34	1.24	1.28	1.97	1.19	1.4

K_0 = zero K; K_1 = 112 kg/ha; K_2 = 225 kg/ha

Table 4. Analysis of corn grain quality grown on plots treated with different rates of K, Shuangcheng City, Heilongjiang.

Treatment	Protein	Starch	Cystine	Methionine	S content (amino acids)
	---	---	%	---	---
NPK_0	8.23	73.32	0.134	0.139	0.273
NPK_1	10.50	70.71	0.140	0.172	0.312
NPK_2	9.55	71.80	0.170	0.195	0.365

Li Yuying is a staff member at the Soil and Fertilizer Institute of the Heilongjiang Academy of Agricultural Sciences, Harbin, People's Republic of China.

Nutrient Management for a No-Till Rotation in the Pampas: Three Years of Field Trials

By Agustín Bianchini, Martín Ambrogio, Santiago Lorenzatti, and Fernando García

Crop economics can be improved by high yield crop management. Advantages include reduced impact of fixed costs and increased profit margins. Adequate crop nutrition optimizes the use efficiency of all resources and inputs involved in crop production. Knowledge of the extent of nutrient deficiencies pinpoints one set of the barriers to maximum economic yields.

No-tillage is a best management practice that has expanded rapidly in the last 10 years in Argentina. With approximately 12 million hectares (M ha) in the 2000/01 growing season under the no-till production system, it has allowed higher and more stable crop yields than conventional tillage systems due to improved soil organic matter content, greater soil water retention, and better soil structure. As Argentina's farmers develop high-yielding production systems including use of improved technologies such as no-tillage, crop nutrient requirements increase and new nutrient limitations may develop.

Figure 1. Location of the experimental sites in the Pampean region of Argentina (Provinces of Buenos Aires, Santa Fe, Córdoba, Entre Ríos, and La Pampa). Black dots indicate the sites started in 1999 under wheat, and red dots represent sites started in 2000 under corn. Map generated with ArcView© from INTA-Aeroterra (1995).

In 1999, AAPRESID (a farmer organization dedicated to innovative conservation tillage methods) initiated a study on nutrient management of field crops under no-tillage rotations in the Pampas region. The main objectives were to: evaluate deficiencies and responses to nitrogen (N), phosphorus (P), sulfur (S), potassium (K), magnesium (Mg), boron (B), copper (Cu), and zinc (Zn), under a wheat/double crop soybean-corn-soybean rotation; and to determine maximum grain yields without nutrient limitations. This article summarizes results of grain yields of the first three years of the project, that includes a complete rotation with the four crops.

Thirteen trials on farm fields having stabilized no-tillage systems were established in the provinces of Buenos Aires, Córdoba, Santa Fe, and Entre Ríos (**Figure 1**, **Table 1**). Nine of the experiments were established in 1999/00 under wheat/soybeans, and four were established in 2000/01 under corn. Soils

Table 1. Experimental sites, years under no-tillage (NT), and previous crop at the beginning of the study.

Site	Province	Farmer	Years under NT	Previous crop
Bragado [1]	Buenos Aires	Spelanzón	8	Corn
Cafferata [1]	Santa Fe	Ambrogio	4	Soybeans
Corral de Bustos [1]	Córdoba	Ghio	8	Corn
Leones [1]	Córdoba	Fogante	10	Soybeans
Los Surgentes [1]	Córdoba	Pellizón	1	Soybeans
Maciel [1]	Santa Fe	Berra	2	Corn
Monte Buey [1]	Córdoba	Romagnoli	11	Soybeans
San Carlos [1]	Santa Fe	Colussi	3	Corn
San Justo [1]	Santa Fe	Fabbro	2	Soybeans
Noetinger [2]	Córdoba	Fogante	2	Wheat/soybeans
Paraná [2]	Entre Ríos	A. Protestante	5	Soybeans
Pilar [2]	Córdoba	Borletto-Barrilli	5	Wheat/soybeans
Tandil [2]	Buenos Aires	El Hervidero	3	Wheat

[1]Sites started in 1999 (wheat/soybeans). [2]Sites started in 2000 (corn).

were Argiudolls, except at Bragado and Pilar, which were Hapludolls. Crop management was similar to that provided to the whole field site by farmers. Wheat, soybean, and corn cultivars at each trial were selected according to their adaptation to the area and yield potential.

The fertilizer treatments—varying nutrient combinations plus an unfertilized check—are listed in **Table 2**. Treatment strips were 5 to 15 m wide and 50 to 300 m long, and were arranged in randomized complete block design within a complete block. Fertilizer application rates were determined from grain removal data for expected yield. Treatment 6 was omitted at San Carlos and San Justo. Rates of N were reduced for full season soybeans (2001), which were treated with a double rate of *Bradyrhizobium* inoculant. Fertilizer treatments were applied annually before planting by banding below and to the side of the seed row for wheat (1999), corn (2000), and soybeans (2001).

Soil sampling to a 20 cm depth was carried out prior to wheat planting, and at selected sites and years, prior to corn and soybean planting. Leaf analysis was performed for selected sites and treatments by collecting flag leaves of wheat at anthesis, and ear leaves of corn at silking. Grain was harvested by farm-scale equipment and yields are reported at commercial grain moisture contents, (i.e., 13.5% moisture for wheat and soybean and 14.5% for corn). Analysis of variance and means separation by the Least Significant Difference (LSD) test were performed for each crop data set when appropriate.

Soil analysis for the nine wheat sites (1999), and four corn sites (2000) are provided (**Table 3**). Soil organic matter (SOM) content ranged from 2.4 to 5.7%, and soil pH from 5.5 to 6.7.

Soil nitrate-N (NO_3-N) and sulfate-S availability

Table 2. Fertilization treatments applied to trials.

Treatment	Application rates, kg/ha
Check	—
NP	150 kg N [1] + 30 kg P
NPS	150 kg N [1] + 30 kg P + 22 kg S
NPSK	150 kg N [1] + 30 kg P + 22 kg S + 50 kg K
NPSKMg	150 kg N [1] + 30 kg P + 22 kg S + 50 kg K + 11 kg Mg
Complete	150 kg N [1] + 30 kg P + 44 kg S + 36 kg K + 22 kg Mg + 2 kg B + 2kg Cu + 4 kg Zn

[1]For soybeans (2001), the amount of N applied was 34 kg/ha.

Table 3. Soil analysis at the 13 experimental sites, 0 to 20 cm depth.

Site	SOM	P	NO_3-N	SO_4-S	pH	Ca	Mg	K	B	Cu	Fe	Mn	Zn
	%	- - - ppm - - -				- - meq/100 g - -			- - - - - - - ppm - - - - - - -				
Cafferata[1]	3.3	12	26	5	5.7	9.8	2.4	1.6	0.7	2.0	93	118	1.6
Maciel[1]	2.4	20	12	7	6.1	7.1	1.8	1.2	1.1	1.9	85	154	1.0
San Carlos[1]	2.6	19	14	5	5.7	8.2	2.0	1.0	0.6	2.2	97	155	1.1
San Justo[1]	2.6	14	32	5	5.5	7.4	1.6	1.0	0.7	1.7	102	160	1.5
Leones[1]	2.6	19	18	6	5.8	11.5	3.1	1.9	0.8	2.4	69	122	1.1
Corral de Bustos[1]	3.4	22	21	5	5.8	10.8	2.5	1.9	1.0	2.2	82	122	1.5
Los Surgentes[1]	3	28	16	5	5.6	11.3	2.7	1.8	0.6	2.6	86	117	1.5
Monte Buey[1]	2.8	19	17	6	5.7	10.9	2.8	1.9	0.6	2.0	75	77	1.2
Bragado[1]	4.2	7	17	6	5.6	9	2.1	1.4	0.7	1.9	111	90	2.6
Noetinger[2]	3.0	20	14	7	6.1	10	2.7	2.0	0.9	1.7	56	87	1.0
Paraná[2]	4.0	11	13	–	6.6	–	–	–	–	–	–	–	–
Pilar[2]	2.3	26	16	7	6.7	11	2.5	2.7	1.2	1.5	36	78	0.7
Tandil[2]	5.7	33	8	7	5.9	14	1.9	1.9	1.0	1.4	85	28	2.9

[1]Sites started in 1999 (wheat/soybeans). [2]Sites started in 2000 (corn).

were both low at wheat and corn planting. Bray P-1 was low, less than 15 parts per million (ppm) at four sites, medium (15 to 20 ppm) at six sites, and high (more than 20 ppm P) at four sites. Exchangeable calcium (Ca), Mg, and K were above those considered critical for grain production as were soil test Cu, iron (Fe), and manganese (Mn). Boron availability was medium at nine sites and adequate at four sites. Soil Zn content was low at one site, adequate at 10 sites, and high at two sites.

Soil analysis in the second year of experimentation failed to show residual effects from year-1 fertilization for N, K, Mg, S, B, Cu, or Zn fertilization (data not shown). Bray P-1 was extremely variable among treatments and years (data not shown).

Average grain yields for wheat, doublecrop soybeans, corn, and full season soybeans are provided (Table 4). Total grain production, the sum of all four crop yields, and a relative production index, a comparison of the check (100) is also given.

Wheat yields varied from 2,000 to 4,120 kg/ha for the check treatment, and between 2,610 and 5,420 kg/ha for the various fertilizer treatments. A significant difference between the check and the fertilized treatments was determined, but no difference existed among fertilized treatments. The average response to NP fertilization was 1,120 kg/ha (+36%). This response was associated with low NO_3-N availability at planting, and for the Bragado, Cafferata, and San Justo sites, low Bray P-1 levels. Higher yields were observed at Cafferata, because of S application (i.e., NPS treatment), and at Bragado because of application of potassium chloride (KCl) and sulfate of potash magnesia.

Doublecrop soybean yields were affected by drought as rainfall during the months of December 1999 and January 2000 averaged only 226 mm for all seven sites. There were no significant differences between treatments as check yields varied between 1,810 and 3,240 kg/ha, while fertilized plots averaged between 1,580 and 3,260 kg/ha. Yields of the NP treatments tended to be lower than check yields, but application of S raised yield to the same level of the check (**Table 4**). A tendency for lower yields in doublecropped soybeans following NP fertilized wheat

Table 4. Average grain yields for the six treatments of the four crops.

Crop	Number of sites	Check	Grain yield NP	NPS	NPSK	NPSKMg	Complete
		kg/ha					
Wheat (1999)	9	3,090 b	4,220 a	4,170 a	4,330 a	4,390 a	4,710 a
Soybeans (1999/00)	7	2,520	2,220	2,490	2,460	2,490	2,570
Corn (2000)	10	5,620 b	9,000 a	10,100 a	10,100 a	10,200 a	10,100 a
Soybeans (2001)	10	3,860	4,020	4,240	4,140	4,330	4,310
Total production		15,100	19,400	21,000	21,000	21,400	21,700
Relative index		100	129	139	139	142	144

For Wheat 1999 and Corn 2000, values for each treatment followed by the same letter are not significantly different at a probability level of 5%. LSD values of 887 and 2,538 kg/ha for wheat and corn, respectively.

was observed in this and other experiments in the northern Pampas. It is speculated to be a result of: a) greater water consumption by the fertilized wheat crop compared to the check, with less soil water available for soybeans at initial vegetative stages after wheat, and b) an "induced" S deficiency generated by greater S consumption of the previous NP fertilized wheat crop as compared to the unfertilized check.

The last hypothesis is supported by the fact that S fertilization in the previous wheat crop (NPS treatment in these trials), usually equaled or exceeded the yields of soybean check plots.

Corn yields benefited from excellent climatic conditions, with the average precipitation being 526 mm from October to February for all 10 sites. Check yields varied between 1,230 and 9,550 kg/ha, while fertilized yields ranged from 3,510 to 12,200 kg/ha. There were significant differences between the check and the fertilized treatments, but no difference amongst fertilized treatments. Response to NP averaged 3,370 kg/ha, a 60% grain yield increase over the check yield, which was related to low soil NO_3-N and/or Bray P-1 at planting. Sites at Cafferata, San Justo, Corral de Bustos, Los Surgentes, and Paraná also showed yield increases due to S fertilization (data not shown).

Full season soybean yields varied between 2,370 and 5,160 kg/ha for the check treatments, and between 2,850 and 6,120 kg/ha for the fertilized treatments. There were no significant differences between treatments in the overall analysis. Observations at individual sites showed that P application increased yields by 480 and 1,080 kg/ha at San Justo and Cafferata, respectively, according to their low Bray P levels. Sites at Cafferata, San Justo, Los Surgentes, and San Carlos showed increases of 330 to 760 kg/ha because of S fertilization.

Nitrogen and P concentrations for ear leaves of corn for checks were lower than the critical levels suggested by international references. Fertilization with N and P increased these concentrations above critical levels (**Table 5**). Similarly, NP concentrations for wheat were lower in the checks compared to fertilized plots. Concentrations of B and Cu for wheat, and B and Mg for corn were below international standards, while Mg concentrations for wheat, and K and S concentrations for corn were close to standard international critical levels. All other nutrients were at concentrations well above critical levels. Significant relationships were found between corn yield and leaf N and P

Table 5. Average nutrient concentration of flag leaves of wheat (1999) at anthesis, and ear leaves of corn (2000) at silking for the six treatments evaluated.

Treatment	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	%						ppm				
Wheat 1999											
Check	2.9	0.25	1.7	0.40	0.13	0.24	4	3	146	33	14
NP	3.4	0.27	1.8	0.52	0.14	0.29	4	3	140	53	15
NPS	3.2	0.26	1.8	0.46	0.13	0.30	4	2	139	48	14
NPSKCl	3.5	0.27	1.8	0.50	0.13	0.32	4	2	135	48	14
NPSKMg	3.5	0.27	1.9	0.50	0.13	0.33	4	2	124	53	14
NPSMgK micros	3.4	0.27	1.9	0.49	0.13	0.35	7	2	134	52	15
Corn 2000											
Check	1.9	0.21	1.6	0.55	0.16	0.18	12	8	158	40	28
NP	3.0	0.33	1.7	0.59	0.19	0.20	13	13	166	88	35
NPS	3.0	0.32	1.6	0.60	0.22	0.23	13	14	190	81	30
NPSKCl	3.1	0.32	1.7	0.60	0.21	0.24	12	14	187	80	28
NPSKMg	3.2	0.35	1.7	0.62	0.21	0.22	13	15	187	79	29
NPSMgK micros	3.1	0.34	1.7	0.61	0.21	0.25	14	14	192	84	29

concentrations considering all sites and treatments (**Figure 2**). Corn grain yields of 11,000 kg/ha could be reached with N and P concentrations of 3.4 and 0.36%, respectively.

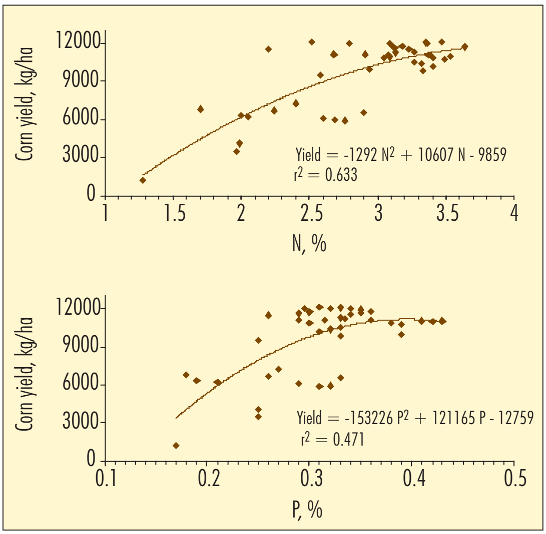


Figure 2. Relationship between corn yield and N and P concentration in the ear leaf at silking. Data include all sites and treatments (n = 42).

Conclusions

Fertilization with N and P increased the total average grain production of the four crop, 3-year rotation by 29%. The NP effect was significant for wheat and corn, but not for doublecropped or full season soybeans. Application of S increased total grain production over NP fertilization alone by an average of 10%; however, this increase was not statistically significant (p=0.05) in any of the four crops. Responses to other nutrients were not significant, although some crop-specific tendencies were occasionally observed at some sites.

Analysis of this 3-year rotation shows the importance of a fertilization management strategy for the complete rotation and not just for a particular crop. A new cycle of the 3-year rotation started in 2002/03 and will provide more information on long-term fertilization management for high-yields under no-tillage in the Pampas, particularly improvement of NPS fertilization management. **BCI**

Ing. (M.Sc.) Agustín Bianchini (e-mail: abianchini@arnet.com.ar), Ing. Ambrogio, and Ing. Lorenzatti are with AAPRESID, Paraguay 777, 8th floor, Room 4, (2000) Rosario, Argentina. Dr. García is Regional Director, PPI/PPIC (INPOFOS) Cono Sur.

Acknowledgments: *To all farmers who conducted the trials and to the companies that generously supported this study: ASP, Hydro Agri, and PASA.*

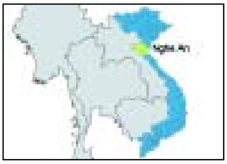
References

INTA-Aeroterra. 1995. Atlas de suelos de la República Argentina. CD. ISBN 987-95542-0-5. Buenos Aires, Argentina.

Phosphorus Fertilization Strategies for Groundnut Grown on Upland Acid Soils in Nghe An Province

By Nguyen Cong Vinh

Sustained cash crop production in the acid uplands of North Vietnam can be seriously hampered by the strong phosphate (P) adsorption capabilities of the region's soils. Insight into the nutrient demand of groundnut (peanut) is gained through this series of laboratory and field studies.



Groundnut is an important cash crop for Nghe An Province in North Vietnam, which has a total land area of 1.6 million hectares (M ha) and 180,000 ha agricultural land. Groundnut area in Nghe An is about 29,000 ha and total production was 32,000 tonnes (t) in 1999. It is expected to increase to about 40,000 t by 2010 (Vu Nang Dung, 2001). Groundnuts are cultivated as a monocrop, intercropped with perennial crops, and in peanut-bean-maize rotations. Low soil P status is the main production constraint because of strong P sorption in Ferralsols, the predominant soil type.

This study examined P sorption characteristics of the predominant soil type, groundnut response to applied P, and compares P management strategies for locally available nutrient sources.

Materials and Methods

In a soil P sorption study, potassium phosphate (KH_2PO_4) in 0.01M calcium chloride ($CaCl_2$) was added to soil samples at rates of 0, 25, 50, 100, 200, 400, 2,000, and 4,000 µm P/g soil. The soils were shaken, centrifuged, and the P content in solution was measured colorimetrically. Adsorption was determined by the difference between the amount of P added and the amount remaining in solution.

Field experiments were carried out in the spring seasons in 1997 and 1998 at Nghia Dan District, (19°00-19°32'N and 104°10'-105°34'34''E) on a Ferralsol derived from basaltic rock (Hyperdystric rhodic Ferralsol, FAO-UNESCO; Typic Paleustult, USDA Soil Taxonomy, see **Table 1**). These clay soils are strongly acidic and

Table 1. Soil properties at the experimental site, Nghe An Province.

	Depth, cm		
Parameter	0 - 9	9 - 28	28 - 120
pH_{H_2O} (1:5)	4.10	4.30	4.10
Total C, %	1.48	0.87	0.45
Total N, %	0.137	0.129	0.095
Total P, mg/kg	2.8	2.8	2.8
Total K, mg/kg	1.0	0.9	1.0
Available P, mg/kg (Bray II)	3.8	2.0	2.7
K, cmol/kg	0.11	0.08	0.08
Ca, cmol/kg	2.77	2.15	2.15
Mg, cmol/kg	2.15	2.38	1.61

Table 2. Characteristics of local P-containing sources, Nghe An Province.								
		Concentration of nutrients in fertilizer, %						Moisture,
Source	Year	pH	N	P_2O_5	K_2O	CaO	MgO	%
SSP	–	2.7	–	16.0	–	21.8	1.35	–
FMP	–	7.3	–	15.0	–	24.4	15.9	–
FYM	1997	–	0.31	0.27	0.18	0.22	0.12	37.5
FYM	1998	–	0.42	0.31	0.10	0.42	0.26	30.5

contain small amounts of organic matter, plant available nitrogen (N), P, potassium (K), magnesium (Mg), and calcium (Ca).

The goals in the field study were to: (a) determine the potential response of groundnut to P fertilizer and (b) compare locally available P sources [i.e., single superphosphate (SSP) and fused magnesium phosphate (FMP), and farmyard manure (FYM)] (**Table 2**).

In the P rate study, six rates (0, 30, 60, 90,120, and 150 kg P_2O_5/ha) were tested with SSP as the source.

Table 3. Outline of treatments used in the P source comparison study, Nghe An Province.					
		P fertilizer			
Treatment	FYM, t/ha	FMP	SSP	N	K_2O
1. Control	0	0	0	0	0
2. FMP	0	90	0	20	60
3. SSP	0	0	90	20	60
4. FYM	10	0	0	20	60
5. FYM + FMP	10	90	0	20	60
6. FYM + SSP	10	0	90	20	60

For the P source comparison, an outline of the fertilizer treatments is provided in **Table 3**. Treatments with FYM first had the manures spread along shallow ditches created in the field. Those treatments with FYM and P fertilizer had both products added to the ditches which were then covered with fine soil at planting time. All treatments, except the control, also received 20 kg N, 60 kg K_2O, in the form of urea and potassium chloride (KCl), as well as 500 kg lime/ha. The lime was broadcast and incorporated during initial land preparation before planting.

A local groundnut variety (var. Sen Lai) was planted in rows 30 cm apart with 15 cm between hills. A randomized complete block design with four replications was used. Plot size was 20 m^2. Two to three seeds were sown per hill and plants were thinned to one or two plants after establishment. Aboveground portions were recycled for the next crop and below ground portions were removed and separated from the pods.

Air temperature ranged from 18 to 29°C in 1997 and from 19 to 30 in 1998. Air humidity ranged between 80 to 90% in 1997 and between 73 to 90% in 1998 (**Figure 1**). Total rainfall was 1,778 mm in 1997 and 1,137 mm in 1998. During the wet season (late April to October) air temperature was also high, increasing the rate of evaporation. Total

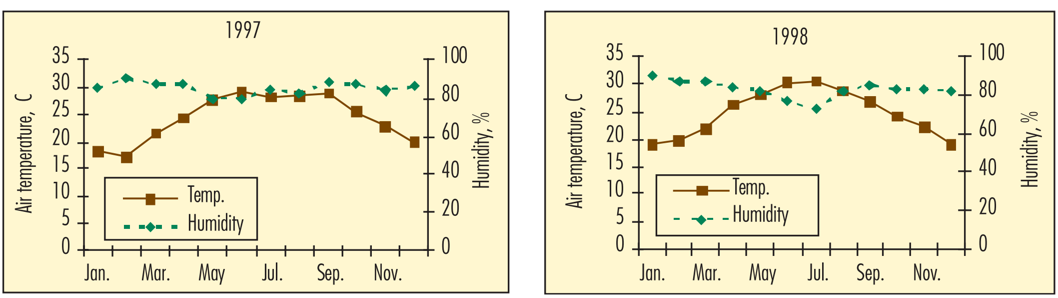
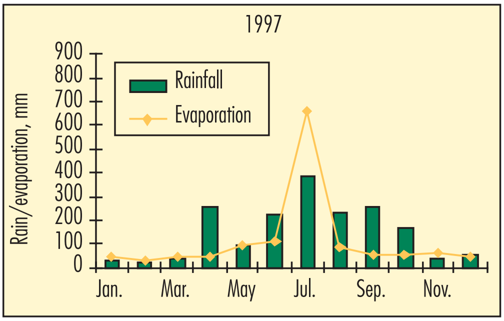


Figure 1. Seasonal changes in air humidity and temperature in Nghia Dan, Nghe An Province.



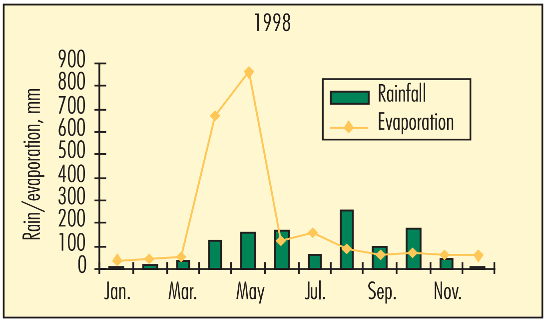


Figure 2. Seasonal changes in rainfall and evaporation in Nghia Dan, Nghe An Province.

evaporation was 1,321 and 2,262 mm in 1997 and 1998, respectively (**Figure 2**). As a result, precipitation was greater than evaporation in 1997 and the opposite was true for 1998.

Results

The P sorption model, represents the test soil's ability to 'fix' applied P and highlights the high P requirement for crops grown on this soil type (**Figure 3**). At low concentrations of applied P (25 to 100 mg/kg), 99.8% was adsorbed, while at high concentrations (4,000 mg/kg) 46.5% was adsorbed. High clay content, most likely kaolinitic clay, and the presence of iron (Fe) and aluminum (Al) oxides are responsible for this high affinity for P (Fairhurst and Warren, 1992; Le Van Can, 1979; Hoang Van Huay, 1979).

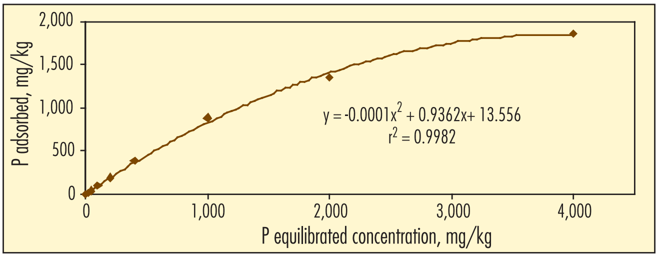


Figure 3. Phosphorus absorption of the Ferralsol test soil located at Nghia Dan, Nghe An Province.

There was a large response to P, applied as SSP. Pod yield was significantly correlated with P fertilizer application rate (**Figure 4**). The relationship between yield and the amount of P applied was fitted to a Mitscherlich equation:

$$y=a-b^{\exp(-cx)}$$

where y is seed yield (t/ha), x is P_2O_5 rate (kg/ha), and a, b, and c are coefficients. Coefficient a estimates the asymptote or maximum yield plateau (t/ha), coefficient b estimates the maximum yield increase to added P (t/ha), and coefficient c describes the shape of the response curve. Fitting the relationship between spring peanut yield and P rate resulted in the following functions:

$$(1997)\ y = 0.993(1-0.303^{\exp(-0.021 \times \text{P rate})})$$

$$(1998)\ y = 0.823(1-0.271^{\exp(-0.028 \times \text{P rate})})$$

The maximum yield increase to added P (coefficient b) was 0.303 t/ha (1997) and 0.271 t/ha (1998) indicating that yield potential in 1998 was lower than in 1997, which is likely due to the relative amounts of rainfall during the two growing conditions.

Over the two seasons, both pod and seed yield reached their

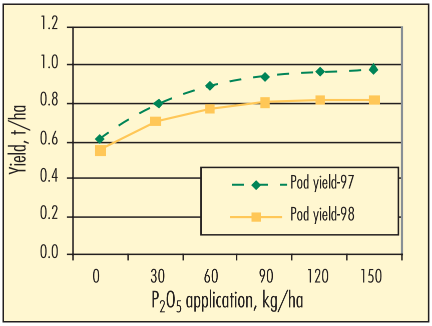


Figure 4. Groundnut pod yield response to SSP application, Nghe An Province.

maximum at 90 kg P_2O_5/ha (**Table 4**). Seed out-turn seemed to be positively affected by application rates of 60 kg or higher and agronomic efficiency for P fertilizer also reached its maximum at the 90 kg application rate.

Groundnut showed a strong response to P fertilizer regardless of source. Depending on the crop year, application of fertilizer P alone increased pod yield by 26 to 66% and seed yield by 24 to 102% (**Table 5**). Application of SSP along with 500 kg lime/ha gave a higher pod and seed yield than FMP plus lime. It is reasoned that the higher pH of the FMP source, which is already rich in Ca oxide (CaO) and Mg oxide (MgO), may be a less plant available P source, especially when it is combined with 500 kg lime/ha.

The FYM treatment performed well and this was likely a result of additional nutrient supply. FYM nutrient content was estimated at 20 kg N/ha, 11 kg K_2O, 14 kg CaO, and 8 kg MgO in 1997. For 1998, it was 29 kg N/ha, 7 kg K_2O, 29 kg CaO, and 18 kg MgO. Yield increased from 0.86 and 0.71 t/ha in the control to 1.57 and 1.44 t/ha with the FYM treatment for the 2 years. Application of organic manures on these soil types could also be responsible for reduced P adsorption as evidenced by research on coffee soils in Nigh Dan (Nguyen Khan Hoa, 1994). In that pot study, P adsorption in the control soil was measured at 99.7%, but addition of FYM decreased it to 87.2%.

The highest seed and pod yields were obtained by combining fertilizer P and FYM, where FYM + FMP appeared to have a slight advantage over FYM + SSP, particularly for increasing pod yield. Groundnut seed out-turn was

Table 4. Mean groundnut (var. Sen Lai) yield (1997, 1998) at six rates of SSP fertilizer, Nghe An Province.

P_2O_5 rate, kg/ha	Relative yield, % Pods	Relative yield, % Seed	Yield, t/ha Pods	Yield, t/ha Seed	Out-turn[1]	Agronomic efficiency[2] for P
0	100	100	0.60	0.47	0.78	–
30	118	113	0.71	0.53	0.75	2.0
60	138	143	0.83	0.67	0.81	3.3
90	160	166	0.96	0.78	0.81	3.4
120	150	153	0.90	0.72	0.80	2.1
150	142	145	0.85	0.68	0.80	1.4
LSD (p = 0.05)			0.03	0.03		

[1]Ratio of seed yield to pod yield.
[2]kg seed yield increase per kg nutrient added.

Table 5. Effect of five fertilizer treatments supplying 90 kg P_2O_5/ha and the zero P control on the groundnut seed and pod yield as well as percent of filled pods, Nghe An Province.

Treatment	Seed yield (t/ha) 1997	Seed yield (t/ha) 1998	Pod yield (t/ha) 1997	Pod yield (t/ha) 1998	Out-turn[1] 1997	Out-turn[1] 1998	Filled pods (%) 1997	Filled pods (%) 1998
1. Control	0.37	0.34	0.86	0.71	0.43	0.48	60.8	60.2
2. FMP	0.46	0.41	1.08	0.95	0.42	0.43	73.1	74.5
3. SSP	0.59	0.51	1.39	1.18	0.42	0.43	66.9	73.6
4. FYM	0.85	0.82	1.57	1.44	0.54	0.57	76.4	74.3
5. FYM + FMP	0.90	0.87	1.78	1.70	0.50	0.51	75.3	72.1
6. FYM + SSP	0.90	0.84	1.64	1.57	0.55	0.54	75.0	67.4
LSD (p = 0.05)	0.03	0.04	0.05	0.17	0.03	0.03	1.9	1.8

[1]Ratio of seed yield to pod yield.

positively influenced by FYM application, while the percentage of filled pods increased with either fertilizer P or FYM addition.

Groundnut showed a positive response to P in Vietnam studies on upland acid soils.

Conclusions

Hyperdystri-Rhodic Ferralsols in Nghia Dan are characterized by low pH, organic matter, and available P and K. Groundnut grown on these soils have a strong response to inorganic P as well as nutrients supplied by FYM. In hot, dry weather as in 1997 and 1998, application of FYM had the biggest impact on yield compared with SSP and FMP products. **However, the combination of P fertilizer (90 kg P_2O_5/ha) and FYM gave the highest yields and should be recommended to farmers.** BCI

The author is Head, Department of Land Use Research, National Institute for Soils & Fertilizers, Tu Liem Chem, Hanoi, Vietnam. Tel + 84 4 8 385 635; fax + 84 4 8 389 924; e-mail: ncvinh-nisf@fpt.vn

References and Bibliography

Fairhurst, T.H. and G.P. Warren. 1992. Fertilizer phosphorus: Sorption and residual value in tropical African soils, (Bulletin 37), Natural Resources Institute, Chatham, p. 91.

Le Van Can. 1979. Using P32 for studying on the phosphorus fixation of soil in the Northern Vietnam, Soil and Fertilizer Journal, Vol. VI, Scientific and Technology Publishing House, p. 123-148.

Le Dinh Dinh, Nguyen Tu Siem, Thai Phien, Nguyen Cong Vinh. 1998. Effect of fertilization for upland crops on acid upland soils in Nghia Dan, Nghe An, Journal of Agricultural and Food Industry, p. 258-272.

Vu Nang Dung. 2001. Agriculture of Vietnam, 61 provinces and towns. Agricultural Publishing House. Hanoi.

Nguyen Khan Hoa. 1994. Role of phosphorus to coffee plantation (*Coffea arabica L*), Agricultural Publishing House.

Hoang Van Huay. 1979. Phosphate anion absorption on ferraltic soils derived from Basaltic rock in Lam Dong Province, Soil and Fertilizer Research, Volume IV, Scientific and Technology Publishing House, Hanoi, p. 22-33.

Thai Phien, Nguyen Cong Vinh. 1993. The management of acid upland soils for sustainable agriculture in Vietnam. Progress in network research on the management of acid soils, IBSRAM/ASIA Land, Network Document, No 6 April 1993, p. 201-216.

Thai Phien, Nguyen Cong Vinh. 1996. Affect of leguminous intercropping and organic manure to the crop yields on acid upland soils in Vietnam. Journal of Agricultural and Food Industry, 10/1996, p. 400-402.

Effect of Phosphorus Fertilizer on Groundnut Yield in Poor Alluvial and Sandy Soils of Thua Thien Hue

By Tran Thi Thu Ha

Although groundnut (peanut) yield in Thua Thien Hue Province is improving, current productivity levels are still low. Phosphorus (P) fertilization of groundnut is considered as one limiting yield factor common to several soil types in this province. This research helps to identify the appropriate application rates for sustained, high-yielding groundnut in poor alluvial and sandy soils.

Groundnut is one of the main annual crops of Thua Thien Hue Province. The cultivated area of this crop occupies about 4,200 hectares (ha). The crop's adaptability to different soil types allows it to be grown on a large area covering all districts of the province having acid upland soil, sandy coastal soil, and poor alluvial soil. Also, groundnut's adaptability enables production in low yielding and rainfed situations. Although cultivated area of this crop increases year by year, groundnut yield in Thua Thien Hue is still low (1.43 t/ha) compared with the country's average (1.58 t/ha). Inadequate fertilizer use is one of the main factors limiting yield in the province. The amount of fertilizer applied to the crop depends on farmer experience and capital. For these reasons, the role of P fertilizer receives little attention.

This study evaluated the effect of P fertilization on groundnut yield in the poor alluvial and sandy soils and identified the most appropriate P fertilizer rate for good dry nut yield and farmer profit.

Field experiments were established in each of the three spring seasons from 2000 to 2002. Groundnut was grown with 33,000 plants per ha. At sowing, the soils (pH <5.0) contained 1.85% (poor alluvial soil) and 1.67% organic matter (sandy soil), respectively. Total nitrogen (N), P, and potassium (K), available P, and exchangeable K in these soils were all low.

Treatments included five P rates: 30, 60, 90, 120 and 150 kg P_2O_5/ha, based

Table 1. Groundnut yield (t/ha) response to P fertilization, Thua Thien Hue Province.

Treatment,	Poor alluvial soil				Sandy soil			
kg P_2O_5/ha	2000	2001	2002	Mean	2000	2001	2002	Mean
0	1.40	1.38	1.40	1.39	1.64	1.60	1.52	1.59
30	1.90	1.82	1.71	1.81	1.86	1.83	1.71	1.80
60	2.58	2.53	2.54	2.55	2.15	2.10	2.14	2.13
90	2.62	2.56	2.60	2.59	2.48	2.50	2.60	2.53
120	2.65	2.58	2.60	2.61	2.52	2.54	2.65	2.57
150	2.60	2.60	2.57	2.59	2.54	2.54	2.60	2.56
LSD ($p = 0.05$)	0.17	0.21	0.25		0.16	0.16	0.25	
CV (%)	26.8	27.1	8.6		18.5	19.6	8.8	

Table 2. Agronomic efficiency and profit resulting from various rates of P fertilization, Thua Thien Hue Province.

Treatment,	Poor alluvial soil						Sandy soil					
	2000		2001		2002		2000		2001		2002	
kg P_2O_5/ha	AE_P[1]	Profit[2]	AE_P	Profit	AE_P	Profit	AE_P	Profit	AE_P	Profit	AE_P	Profit
0	-	50	-	60	-	40	-	58	-	44	-	18
30	16.7	136	14.6	114	10.3	77	7.33	120	7.66	110	6.30	103
60	22.7	356	23.7	351	27.6	343	9.7	209	9.00	188	14.3	202
90	1.33	355	1.0	338	2.0	332	11.0	311	13.3	311	15.3	344
120	1.03	353	0.6	330	-	330	1.33	306	1.33	273	1.67	336
150	-	330		329	-	296	0.6	302	1.33	302	-	322

[1]AE_P Agronomic efficiency for P fertilizer (kg dry nut/kg P_2O_5); [2]US$/ha

on 8t of farm yard manure (FYM), 40 kg N, 60 kg K_2O, and 500 kg lime/ha (poor alluvial soil); and 30 kg N, 60 kg K_2O, and 300 kg lime/ha (sandy soil). The experiment used plots 20 m^2 in randomized complete block design with three replications. Phosphorus was applied as single superphosphate, N as urea, K as potassium chloride, and lime as calcium oxide.

Groundnut Yield, Agronomic Efficiency, and Profit Response to P

Phosphorus fertilizer significantly increased groundnut yield in both poor alluvial and sandy soils (**Table 1**). The set of test treatments delivered a similar yield maximum at both sites. However, the two soil types did respond differently to P fertilization. In poor alluvial soil, yield was significantly higher than the control with 60 kg P_2O_5/ha while the sandy soil required 90 kg P_2O_5/ha to produce a significantly higher yield. Agronomic efficiency for P showed a similar trend and was maximized at 60 and 90 kg P_2O_5/ha, in the poor alluvial and sandy soils, respectively (**Table 2**). Net profit margins for the different P fertilizer rates were calculated using local input prices and results agreed with yield and agronomic efficiency data.

Conclusion

This study has shown that the most appropriate P application rate for groundnut is 60 kg P_2O_5/ha for poor alluvial soil and 90 kg P_2O_5/ha for sandy soil (based on 8 t of FYM, 30 kg N, 60 kg K_2O, and 500 kg of lime per ha). These recommendations provide for a new yield plateau, which is much higher than the current country average, as well as vastly improved profit margins that can provide a sustained income stream from these resource poor soils. **BCI**

The author is Head, Department of Soil Science, Hue University of Agriculture and Forestry, Vietnam; e-mail: knhdhnlh@dng.vnn.vn

Phosphorus Management for Fish Ponds Located in Red and Lateritic Soil Zones

By G.N. Chattopadhyay, Rajarshi Mukherjee, and Abira Banerjee

Fish ponds in red and lateritic soil zones exhibit low availability of phosphorus (P), resulting in restricted accumulation of various fish food organisms and, thereby, lesser fish production. This study indicated that fish yields in such ponds can be improved substantially through adoption of adequate P management practices. In view of high P-fixing capacity of such pond soils, a higher dose of P…split as smaller, more frequent applications along with adequate potassium (K), manure, and lime…was found effective.

The importance of bottom soils in influencing productivity of fish ponds is well documented. Not only does this phase help in gradual release of different nutrient elements to plant or bio-available forms for the benefit of the fish food organisms, but it also controls many of the significant bio-chemical reactions occurring in aquatic eco-systems (Mandal and Chattopadhyay, 1992; Boyd, 1995).

Yields of fish in ponds under red and lateritic soil zones are generally low due to adverse soil properties which appear to somewhat restrict the production of primary fish food organisms. A survey revealed that among different soil properties, primary productivity of fish ponds of red and lateritic soil zones is governed significantly by pH and availability of P and K (Neogy et al., 1994). Since P availability is usually very low in these soils, owing to substantial fixation as insoluble iron (Fe) and aluminum (Al) compounds, a series of studies was conducted to develop an efficient P management programme for fish ponds located in these soil zones.

Supply of adequate P nutrition to primary food organisms in fish ponds can be greatly improved with proper management.

Material and Methods

The investigation was carried out in three different phases. During the initial phase of the study, P fixing capacity of 10 fish pond soils collected from typical red and lateritic soil zones of West Bengal, India, was determined (Waugh and Fitts, 1966). During the second phase of the study, yard experiments were used to study the effects of splitting P fertilizer application, the combined use of lime and organic matter, and also use of K along with P on use efficiency of P fertilizers with relation to production of primary fish food organisms. In the last phase of the study, an on-farm trial was carried out to assess efficiency of the developed P management technology compared to the conventional fertilization practice with regard to yield of fish in ponds of red and lateritic soil zones. Three typical fish ponds of similar nature were selected in West Bengal. One pond was treated conventionally with 100-50 kg N-P_2O_5/ha/year split in monthly doses. The second pond was treated with 100-100-30 kg N-P_2O_5-K_2O/ha/year distributed in equal monthly doses. In this pond, lime was applied at 100% of the recommended dose. In the third pond, treatments were similar to the second pond. However, P application was split in 2-week intervals along with cow dung slurry, with lime added at 50% of the recommended dose.

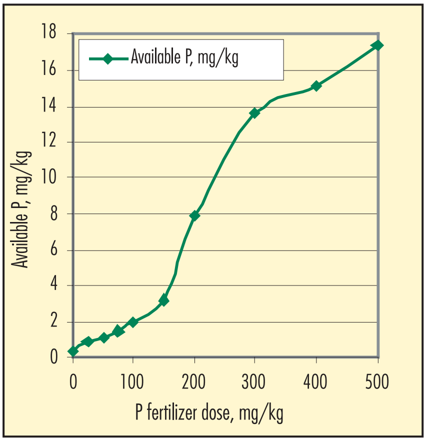


Figure 1. Phosphorus fixing capacity of fish pond soils under red and lateritic soil zones, West Bengal.

Results and Discussion

The study on P-fixing capacity of these soils showed that the conventionally recommended dose (about 50 kg P_2O_5/ha) did not have any practical impact on raising the available P status of these pond soils above the critical level of 13 parts per million (ppm). Much higher doses are required for this purpose (**Figure 1**). Since it is not practicable to increase the rate of P fertilization to very high levels in these resource poor soil zones, it would be a better proposition to increase the dose to some extent and, at the same time, improve the efficiency of any added P.

In view of high P-fixing capacity of the pond soils of red and lateritic soil zones, it was considered worthwhile to restrict the added P fertilizer from coming into contact with the bottom soil to increase P availability to primary fish food organisms in water. For this purpose, splitting the dose of P fertilizer was considered to be an effective measure. As a general norm, fertilizers are applied in fish ponds at equal monthly installments. In the present study, splitting the dose of P fertilizer to weekly or fortnightly (bi-weekly) doses helped to increase the production of organic carbon (C)...i.e. primary productivity levels of water (**Figure 2**). This increased efficiency of P fertilizers was attributed to maintaining a higher amount of P in the water phase due to smaller, more frequent applications.

Figure 2. Average gross production of organic C (mg C/m³/hr) due to photosynthesis under different treatments. Notes: P 0, 12.5, 25 = P application rate, mg P/kg soil. M, F, and W = Monthly, Fortnightly, and Weekly applications, respectively.

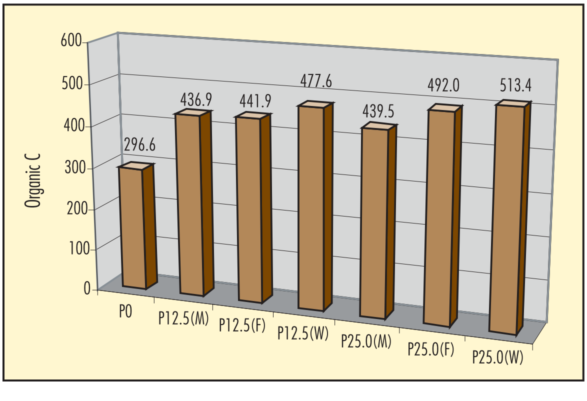


Table 1. Average effects of manure and lime application on gross primary productivity (mg C/m³/hr) of studied soil:water systems.			
	P_0 [1]	$P_{12.5}$	P_{25}
M_0 [2]	71.1	100.9	122.5
$M_{5,000}$	114.4	136.6	149.9
$M_{5,000}$ plus ½ lime[3]	155.2	180.2	197.6

[1] P_0, $P_{12.5}$, $P_{25.0}$: Dose of P fertilizer, mg/kg
[2] M_0, $M_{5,000}$: Dose of manure, mg/kg
[3] 50% of state recommendation for lime

Table 2. Average gross primary production (mg C/m³/hr) under different treatments applied to fish pond soil-water systems.				
	P_0 [1]	$P_{12.5}$	P_{25}	$P_{37.5}$
K_0 [1]	75.0	118.7	133.2	153.7
$K_{7.5}$	83.5	110.8	145.8	187.4
K_{15}	88.5	126.0	162.3	191.0

[1] P_0, $P_{12.5}$, $P_{25.0}$ and $P_{37.5}$, K_0, $K_{7.5}$ and K_{15} indicate doses (mg/kg) of P and K fertilizers.

Organic matter is known to increase the availability of applied P in submerged latosolic soils by restricting fixation of added P into Fe and Al phosphate forms due to reduction reactions and also chelating effects which inhibit the transformation of P into insoluble forms. Use of lime may supplement this benefit further by increasing the pH level of such pond soils which are predominantly acidic in nature. Under the present work programme, an attempt was made to study the effects of organic matter and lime application on the behavior of applied P in a simulated fish pond soil-water system with relation to the primary productivity of pond water. Since the pH levels of pond soils tend to increase moderately under submerged conditions, 50% of the recommended dose of lime was used for this study, which was calculated based on texture and pH of air dried soils. Results showed an improvement in gross primary productivity (GPP) levels of water owing to application of P fertilizer (**Table 1**). Values of GPP increased further with use of manure and lime.

In addition to P, K has also been observed to be a significant factor limiting fish pond productivity under red and lateritic soil zones (Neogy et al., 1994). Hence the effects of different combinations of P and K fertilizers on primary productivity of such pond water were assessed in the next phase of the study. Average GPP under these fertilizer treatments are presented in **Table 2**. Inclusion of K with each P fertilization dose increased GPP of fish food organisms in this soil-water system. Results indicated that with an increase in applied P the already K deficient soil likely became more limited and prevented primary producers from growing satisfactorily. Thus, while higher doses of P fertilizer tended to be beneficial for these ponds, inclusion of K in the fertilization schedule appeared to extract a higher benefit from added P.

Fish yield values obtained under the three systems of pond fertilization are shown in **Figure 3**. Higher GPP levels of pond water resulting from the improved nutrient management schedule were responsible for better growth of fishes in the pond. Fish ponds treated with common practice (NP only) produced 1,550 kg/ha of fish. Use of the

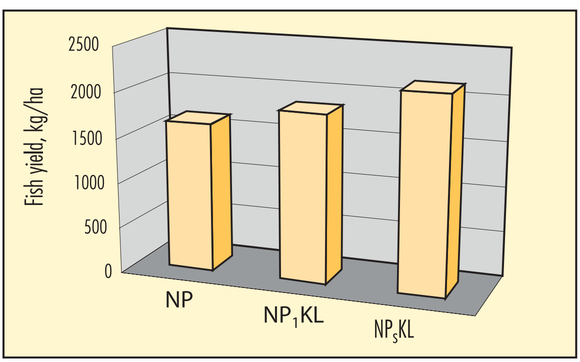


Figure 3. Fish yield levels under different P fertilization programmes, West Bengal. Notes: NP = 100-50 kg N-P_2O_5/ha/year split into monthly doses. NP_1KL = 100-100-30 kg N-P_2O_5-K_2O/ha/year split into monthly doses plus 100% of the state recommendation for lime application. $NP_SKL_{1/2}$ = 100-100-30 kg N-P_2O_5-K_2O/ha/year with P split into fortnightly doses plus 50% of state recommendation for lime application.

higher, monthly split P dose with K and the state recommended dose of lime (NP_1 KL) produced 1,850 kg/ha (19.4% increment over common practice). The third option, which implemented smaller, more frequent split applications of P and K along with manure and 50% of the recommended dose of lime ($NP_sKL_{½}$), produced 2,080 kg/ha (34.2% increment over common practice).

Conclusion

Supply of adequate P nutrition to primary food organisms in fish ponds is a global problem owing to predominantly low availability of nutrients and rapid rates for fixation of applied P into insoluble forms. Knowledge generated in this study with regard to fish ponds of red and lateritic soil zones will be helpful in developing efficient P management practices for fish ponds located in other soil regions. BCI

The authors are with Soil Testing Laboratory, Institute of Agriculture, Visva-Bharati, Sriniketan- 731236, West Bengal, India.

Acknowledgment

The authors are thankful to PPIC-India Programme for sponsoring the research effort.

References

Boyd, C.E. 1995. Bottom Soils, Sediment and Pond Aquaculture, Chapman and Hall, New York, p. 366.

Mandal, L.N. and G.N. Chattopadhyay. 1992. Nutrient management in fish ponds. *In*: (Ed. H.L.S. Tandon) Non-Traditional Sectors of Fertiliser Use. Fertilizer Development and Consultation Organization, New Delhi, p. 1-17.

Neogy, S., G.N. Chattopadhyay, and P.K. Bandopadhyay. 1994. Soil Factors Associated with Productivity of Fish Ponds of Red and Lateritic Soil Zones, J. Inland Fish. Soc. of India, 26: p.72-76.

Waugh, D.L. and J.W. Fitts. 1966. Soil Test Interpretation Studies: Laboratory and Plotted, Plant. Tech. Bull, North Carolina State Agricultural Experiment Station, (ISTP Series) No. 3.

Bud Rot in Oil Palm Plantations: Link to Soil Physical Properties and Nutrient Status

By Alvaro Acosta and Fernando Munévar

Bud rot disease (BRD) is caused by a complex of fungal organisms and its development is regulated by interactions between the plant, pathogens, and the environment. Cases of BRD in Latin America have been documented in Colombia, Ecuador, Surinam, and Brazil. In oil palm plantations in Colombia, BRD is one of the main limitations affecting fresh fruit bunch (FFB) yield as well as quality of the extracted oil, which lowers the overall profitability of the plantation.

The majority of BRD cases are not lethal to oil palm. Affected plants, however, may require four months to three years to recuperate. During this time, plant production drastically declines. The typical symptom is yellowing of young leaves during the months of high rainfall and high relative humidity. Affected leaf tissue eventually becomes necrotic and dies as the disease progresses. The disease is most serious when growing meristematic palm tips are infected and the fungal pathogen is allowed to extend deep into plant tissues. Palms can recover from BRD if the infection is superficial. However, if enough plant tissue is affected, even implementation of drastic control measures such as heavy pruning usually fail to save the tree.

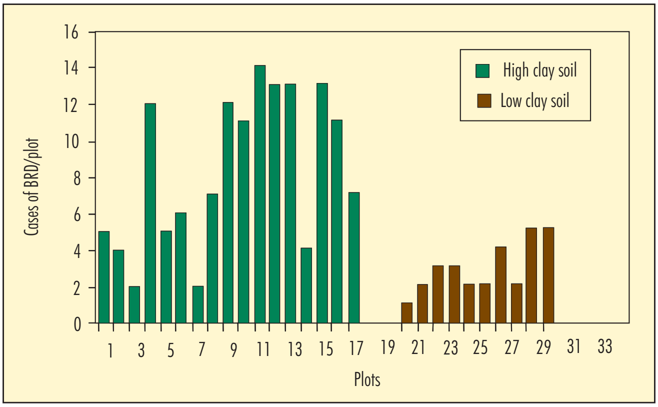
Soil Physical Properties

Research conducted by the Colombian Oil Palm Research Center (CENIPALMA) has shown that disease prevalence is higher where soil physical conditions are limited by:

Chlorosis of the youngest leaves, and drying and necrosis of the spear are initial symptoms of BRD in young palms.

Spears and young leaves become necrotic as the disease progresses. Young leaves look abnormally pale.

Figure 1. Cases of BRD infection in oil palm plantations located on soils with high and low clay content, Colombia.



- Clayey soils...plots with significant amounts of clay within the surface horizon (0 to 40 cm) often had double the incidence of BRD infection (**Figure 1**).
- Compaction...higher disease pressure is found in plantations with greater soil resistance to penetration (**Table 1**).
- Hydraulic conductivity...in-situ measurements of saturated hydraulic conductivity and total porosity in areas of contrasting disease pressure in Eastern Llanos demonstrate the negative relationship between BRD incidence, hydraulic conductivity, and soil porosity (**Table 2**).

Table 1. Soil compaction increases incidence of BRD in Colombian plantations.

Plantation	Soil resistance, kg/cm^2 High incidence	Low incidence
Palmas de Casanare	17.8	8.7
Inipalma–Parcela 1	16.1	11.8
Inipalma–Parcela 2	14.2	8.0
Manavire	18.5	16.3
Manuelita	14.0	10.0

Four plots at the Cumaral Plantation displaying early disease symptoms were selected to investigate the affect soil water drainage has on BRD. Treatments included improved drainage for two of the four plots and disease pressure was monitored in all plots for 22 months. There was significantly lower frequency of BRD in plots with improved drainage (**Figure 2**). Fifteen months after the study was initiated, researchers decided to

Table 2. Frequency of BRD decreases with increasing hydraulic conductivity and total porosity, Cumaral Plantation, Meta.

Site	Incidence of BRD, %	Hydraulic conductivity, cm/hr	Total porosity, %
1	70	0.55	44.8
2	38	0.56	46.9
3	5	3.85	72.2
4	3	4.21	47.8

Several spears and young leaves are affected in the same palm.

Palms can recover, but productivity is often reduced drastically.

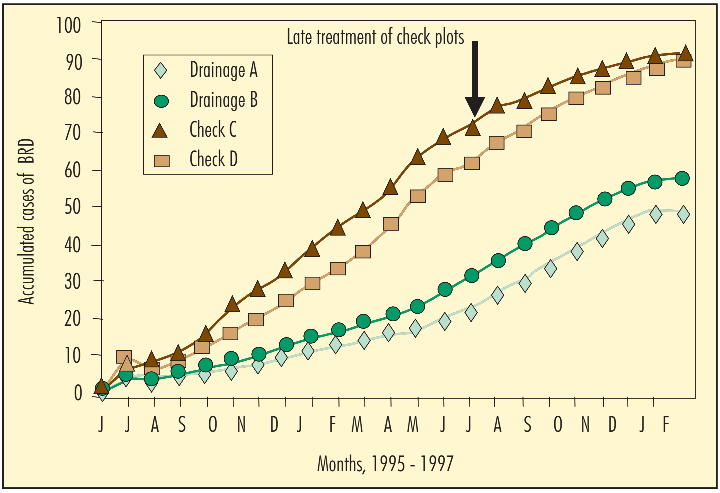


Figure 2. Effect of drainage on the BRD incidence, Santa Barbara, Cumaral Plantation, Meta.

improve the drainage in the previously non-treated plots—which consequently reduced the incidence of BRD. This recuperation is indicated by the change in slope of the two check plot lines and represents the accumulated cases of BRD in the two check plots.

Field observations in a wide variety of circumstances in the oil palm-growing areas of the eastern savannas and in Tumaco on the Pacific coastal plain indicate that BRD incidence is also related to various aspects of the site's nutritional status. Research at different sites suggested a tendency for BRD when soil nitrite (NO_2^-) concentrations are high. This tendency may be related to poor site drainage, because the presence of NO_2^- accumulation in soil is a symptom of prolonged anaerobic soil conditions.

Foliar nutrient deficiencies observed over a wide variety of plantations suggest a link between BRD and the nutritional status of the palm. Young palms (less than four years old) are often deficient in boron (B) or display 'leaf white stripe' symptoms—visual indication of an overly high ratio of nitrogen (N) to potassium (K) in the plant. Foliar analysis in affected sites has confirmed relatively high N:K as well as calcium (Ca):B ratios compared to nearby palms showing no symptoms.

Table 3. Soil test results from the palm circles of plants with and without BRD incidence, Manuelita Plantation, San Carlos de Guaroa, Meta.

Parameter	Plot 1 Infected plants	Plot 1 Healthy plants	Plot 2 Healthy plants
pH*	4.2	4.3	4.5
CEC, cmol (+)/kg*	6.29	7.21	7.83
Organic matter, %	2.3	2.4	2.6
Bray II-P, ppm[1]	24	28	28
K, cmol (+)/kg	0.16	0.18	0.23
Ca, cmol (+) /kg	0.45	0.66	0.69
Mg, cmol (+)/kg	0.23	0.32	0.31
S, ppm*	4.9	6.5	8.2
B, ppm*	0.1	0.2	0.2
Fe, ppm*	28.1	30.7	47.3
Cu, ppm*	0.2	0.2	0.5
Mn, ppm	7.9	12.6	10.2
Zn, ppm	0.1	1.3	1.4
Al saturation, %*	63	55	55

*Parameters which are significantly different by orthogonal contrasts.
[1] ppm = parts per million

The relationship between nutrient status and BRD was studied in soils without the physical limitations noted above. At the Manuelita Plantation at San Carlos de Guaroa, Meta, plot 1 had a low incidence of BRD plus healthy plants, while plot 2 had only healthy plants. Soil samples taken from the palm circles of both infected and healthy plants in both plots found that soil fertility status tended to be better in soils surrounding healthy plants (**Table 3**).

Foliar tissue from leaves 9 and 17 were sampled from the same plants where soil sampling was conducted. Foliar analysis of leaf 17 found no statistically significant differences between infected and healthy plants. However, values in healthy plants appeared closer to standard critical values than infected plants (data not shown). Using leaf 9, foliar values of P, K, and copper (Cu) were statistically higher in visually healthy plants, but Ca and magnesium (Mg) were lower (**Table 4**). It was also found that ratios of N:K, Ca:K, N:P, and Ca:B were lower in healthy plants. These results suggest that an incorrect nutrient balance likely plays an important role in the incidence of BRD in oil palm. Since foliar analysis of leaf 17 could not show a clear relationship among BRD incidence and nutrient status of the plant, it is likely that symptoms of BRD initiate in the younger tissues and a better diagnosis is achieved by analyzing leaf 9.

This research demonstrates the importance of soil management in controlling bud rot disease. Good preventative management practices include establishment of adequate drainage and adequate, balanced fertility. BCI

Table 4. Foliar test results in leaf 9 of plants with and without BRD incidence, Manuelita Plantation, San Carlos de Guaroa, Meta.

	Plot 1		Plot 2
Parameter	Infected plants	Healthy plants	Healthy plants
N, %	2.52	2.61	2.50
P, %*	0.16	0.17	0.18
K, %*	1.11	1.20	1.44
Ca, %*	0.55	0.54	0.40
Mg, %*	0.35	0.32	0.26
S, %	0.17	0.18	0.17
B, ppm	13.1	12.9	13.9
Cu, ppm*	10.8	11.8	13.3
Fe, ppm	91.5	89.0	92.1
Mn, ppm	825	817	674
Zn, ppm	30.9	31.1	22.8
N/K*	2.29	2.19	1.73
Ca/K*	0.50	0.45	0.27
N/P*	15.8	13.4	14.4
Ca/B*	425	429	289

*Parameters which are significantly different by orthogonal contrasts.

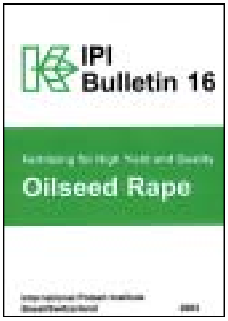
The authors are with the Colombian Center of Oil Palm Research (CENIPALMA), P.O. Box 252171, Bogota, Colombia. E-mail:fernando.munevar@cenipalma.org.

Acknowledgments

The authors are thankful to Astorga, Manavire, Manuelita, Palmas de Casanare, and Unipalma plantations for their contribution to this research.

Oilseed Rape: Fertilizing for High Yield and Quality

Publication Available as IPI Bulletin



Oilseed rape is an important commodity on the international oilseed market, ranking second in production behind soybean. The major producers are China, the European Union, India, and Canada.

A publication now available from the International Potash Institute (IPI) on oilseed rape is a very comprehensive and highly informative brochure for extension workers, students, and scientists. IPI Bulletin No. 16 discusses the botany of rapeseed, together with the use of oilseed rape and the role of plant nutrients in yield and quality management. The main part of the Bulletin is devoted to the effect of fertilizer on yield and quality. The publication, authored by K. Orlovius, has 130 pages and also includes 68 figures, 31 tables, and seven color plates, together with more than 200 references.

IPI Bulletin No. 16 is available for the price of US$12.00. For more information, contact IPI, P.O. Box 1609, CH-4001, Basel, Switzerland; tel +41 61 261 29 22, fax +41 61 261 29 25, e-mail: ipi@ipipotash.org or through the website at: www.ipipotash.org. BCI

Phosphorus Fertilization and Phosphorus-Extraction Method Calibration for Sugarcane Soils

By Ovidio Pérez, Mario Melgar, and Ignacio Lazcano-Ferrat

This article reports on calibration work for the Mehlich 1 extraction method, its usefulness to diagnose phosphorus (P) availability, and its correlation with P fertilizer recommendations in sugarcane. This study also evaluated the economic responses to P fertilization levels in different soils of the region.

Sugarcane is cultivated on the southern coast of Guatemala in an area of about 180,000 hectares (ha). Soils in this region are derived from volcanic ash with different intemperate grades (i.e., an extreme range of physiochemical properties). They are characteristically low in P content and have high P fixation capacity. Currently, fertilization in many sugarcane fields is done with little accuracy and precision. Without a doubt, adequate use of soil analyses for diagnosing P deficiency, crop requirement, and the appropriate fertilizer recommendations is very important if increased productivity and sustainability of sugarcane are to be achieved in the region. Very little work has been done to evaluate or calibrate soil nutrient extraction methods for soil P conditions in local sugarcane soils. Nor has there been much guidance provided to growers on rational fertilization based on optimum economic returns.

Methodology

Data from various field and laboratory experiments were collected and analyzed to establish a set of soil P correlations for the region (**Table 1**). These data included exploratory studies on nitrogen (N), P, potassium (K) and other assays having at least two different P levels (no P and plus P application rates). In addition, other experimental field sites were initiated in 1998/99, wherein the laboratory methods were:

1. North Carolina (Mehlich 1) 0.05 M HCl + 0.0125 M H_2SO_4 (Mehlich, 1953).
2. North Carolina (Mehlich 3) 0.2 M Acetic Acid + 0.25 M NH_4-NO_3 + 0.015 M NH_4F + 0.13 M HNO_3 + 0.001 M EDTA (Mehlich, 1984).
3. Exchange Resin P (Cooperband and Logan, 1994).

Calibration was achieved with the correlation analyses of soil P (Mehlich 1) of the experimental sites vs. the corresponding relative yields for sugarcane (RY). Categories of RY were arbitrarily selected as: low (RY <90); medium (90< RY <95); and high (RY >95). Response functions

Table 1. Summary of field experiments that evaluated soil P levels in 20 different sites of the sugarcane growing region of Guatemala.

	Site	Soil	Variety	Exper. type	Soil P, ppm	P doses, kg P_2O_5/ha	RY, %
1	Concepción	Andisol	CP 722086	P Doses	2.9	0, 40, 80, 120, 160, 200, 240	85
2	Mangalito	Andisol	CP 722086	P Doses	3.5	0, 40, 80, 120, 160, 200, 240	84
3	Camantulul	Andisol	CP 722086	P Doses	3.2	0, 40, 80, 120, 160, 200, 240	67
4	Cristóbal	Andisol	CP 722086	P Doses	3.7	0, 40, 80, 120, 160, 200, 240	89
5	Manacales	Andisol	CP 722086	P Doses	5.6	0, 40, 80, 120, 160, 200, 240	90
6	P. Castaño, Bálsamo	Inceptisol	CP 722086	P Doses	6.7	0, 40, 80, 120, 160, 200, 240	88
7	P. Antonio	Mollisol	CP 722086	P Doses	14.7	0, 40, 80, 120, 160, 200, 240	95
8	P. Grande	Mollisol	CP 722086	P Doses	43.0	0, 40, 80, 120, 160, 200, 240	96
9	Camantulul	Andisol	CP 722086	Resid. Eff.	0.6	0, 30, 60, 90, 120, 150	83
10	El Baúl (Los Sujuyes)	Andisol	CP 722086	P-Cachaza	0.8	0, 50	87
11	Los Patos	Inceptisol	CP 722086	NPK	1.0	0, 50, 100, 150	90
12	Cañaverales del S.	Andisol	CP 722086	Semi-com.	1.0	0, 40, 80	86
13	Pantaleón (El Triunfo)	Andisol	CP 722086	P-Cachaza	1.7	0, 50, 100	75
14	Camantulul (Cal)	Andisol	CP 722086	P-Ca	1.9	0, 40, 80, 120, 160	86
15	El Baúl	Andisol	CP 722086	Explor NPK	0.8	0, 50, 100, 150	86
16	Cañaverales del S.	Andisol	Mex 68P23	Explor NPK	1.0	0, 50, 100, 150	86
17	Guatalón	Andisol	Mex 68P23	Explor NPK	2.7	0, 50, 100, 150	94
18	Irlanda	Mollisol	CP 722086	Explor NPK	30.5	0, 50, 100, 150	102
19	Bougambilia	Entisol	CP 722086	Explor NPK	40.0	0, 50, 100, 150	95
20	Belén	Inceptisol	CP 722086	P-Cachaza	5.5	0, 50	88

RY was estimated based on: RY (%) = (Y_o/Ymax) * 100; where: RY = relative yield; Y_o = check yield (0 P); Ymax = maximum yield (various P rates).

to estimate optimum economic doses (OED) for P were individually created for all field assays with three or more P levels to estimate the quadratic function and the model adjustment (Pérez and Melgar, 1998; Pérez et al., 2001). The OED for P was determined from the regression model, when they had the adequate adjustment; when not, evaluated discrete levels were considered where maximum yields were obtained.

Results

High linear correlations were found between all three soil test methods. The highest correlation (r = 0.98) was found between Mehlich 1 and Exchange Resin-P. The high correlations found between all methodologies indicate that any of the methods could be used. This flexibility permits the fastest, least complicated, and most practical method. Mehlich 1 was finally chosen because it is also the most common extraction method used in Guatemala.

Sugarcane RY and the corresponding soil P levels in 20 different sites are shown (**Figure 1**). The lower RY is associated with low P levels [<8 parts per million (ppm)], but for practical purposes <10 ppm can be used to define low P soils. The middle category was associated with soil P levels between 10 to 30 ppm. Values above 30 ppm were well correlated with the highest relative yields in most fields and was selected as the level at which sufficient P is available for a good sugarcane yield for the conditions found in the region.

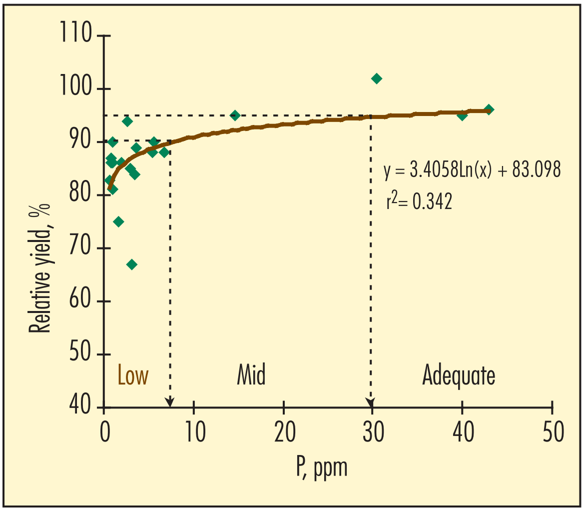


Figure 1. Extractable P (Mehlich 1) vs. relative sugarcane plant yield in 20 field experiments in Guatemala.

The optimum economic rate of P depended on the location. Optimal P levels were estimated using adjusted regression functions that were statistically significant (p=0.05). When functions were not significant, values were taken from P levels where maximum yield was reached. **Table 2** summarizes the information as a first approximation of P fertilizer recommendations for three different soil categories (i.e., soil type and depth). Blank spaces indicate few data or a lack of information for that site. Recommendations will be adjusted as more information becomes available as experimental and commercial results confirm or improve these data.

Table 2. Phosphorus recommendation (kg P_2O_5/ha) guideline according to soil P category.

Soil test category, ppm	Andisols and Inceptisols				Mollisols	
	Superficial & moderately deep soils		Deep soils			
	Plant	Ratoon	Plant	Ratoon	Plant	Ratoon
P < 10	85	50	100 to 160	50	–	–
P 10 to 30	–	–	–	–	50	40
P > 30	–	–	–	–	0/50	0

Conclusions

A common method of soil P extraction (Mehlich 1) was calibrated for sugarcane soils of Guatemala. Three categories of soil P fertility were established: 1) low: <10 ppm; 2) medium: 10 to 30 ppm; and 3) adequate: >30 ppm. Recommendations were estimated taking into consideration the Mehlich 1 categories, soil type, and crop growing conditions.

More research emphasis should be spent on including sites with medium soil P levels in order to fill a data gap. Also, the residual effects of fertilization should be studied to get a better understanding of the complete crop cycle. New field experiments are currently under way and are comparing split P applications vs. one full P application in each crop cycle. This work will help to understand the precise P needs of sugarcane and the optimum economic doses for Guatemalan soils. **BCI**

This project was partially funded by the PPI/PPIC Mexico and Northern Central America Program office (INPOFOS).

Ing. Pérez has responsibility for the Agronomy Program and Dr. Melgar is General Director, Guatemalan Center for Research and Training on Sugar Cane (CENICANA) located at Santa Lucia, Escuintla, Guatemala; e-mail cenican@concyt.gob.gt. Dr. Lazcano-Ferrat is Director, PPI/PPIC Mexico and Northern Central America Program (INPOFOS).

Literature Cited

Cooperband, L.R. and T.J. Logan. 1994. Measuring in situ changes in labile soil P with anion exchange resin-impregnated membranes. Soil Sci. Soc. Am. J. 58: 105-114.

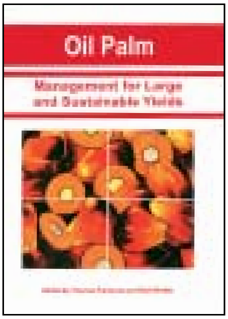
Mehlich, A. 1953. Determination of P, Ca, Mg, K, Na and NH_4. North Carolina Soil Test División, Publ. 1-53, North Carolina Dept. of Agriculture, Raleigh.

Mehlich, A. 1984. Mehlich 3 soil test extractant. A modification of the Mehlich 2 extractant. Común. Soil Sci. Plant Anal. 15: 1409-1416.

Pérez, O. and M. Melgar. 1998. Sugarcane response to nitrogen, phosphorus, and potassium application in Andisol soils. Better Crop International, Vol. 12, No. 2 (20-24).

Pérez et al. 2001. Evaluación de la respuesta a la fertilización fosforada en la zona cañera de Guatemala. Segunda soca. En Memoria de Presentación de Resultados de Investigación Zafra 2000-2001. p. 86-90.

New Publication Available: *Oil Palm—Management for Large and Sustainable Yields*



A new book on modern oil palm management was recently introduced by PPI/PPIC and the International Potash Institute (IPI). Recognized experts in the fields of oil palm management and plantation agronomy, primarily in Southeast Asia, were invited to contribute to the volume. It was edited by R. Härdter of IPI and Thomas Fairhurst, formerly with PPI/PPIC.

The 384-page book includes emphasis on important interactions between the plant's inherent capacity to convert solar radiation into palm oil and the crop's agronomic management requirements. Nutritional aspects and precision agriculture technology are also addressed. Other contents topics include: land selection, clonal oil palm, legume cover plants, fertilizing for maximum return, and utilization of field residues.

The book is available for purchase either as single copies, multiples, or in combination with other publications on oil palm management. For more information, contact:

PPI/PPIC Southeast Asia Program
126 Watten Estate Road
Singapore 287599
Tel: +65 6468 1143
Fax: +65 6467 0416
E-mail: dtan@ppi-ppic.org
Website: www.ppi-ppic.org/seasia

or

IPI
PO Box 1609, Schneidergrasse 27
CH-4001, Basel, Switzerland
Tel: +41 61 261 29 22
Fax: +41 61 261 29 25
E-mail: ipi@prolink.ch
Website: ipipotash.org

Yield and Soil Fertility Trends in a 20-Year Rice-Rice-Wheat Experiment

By A.P. Regmi, J.K. Ladha, H. Pathak, E. Pasuquin, C. Bueno, D. Dawe, P.R. Hobbs, D. Joshy, S.L. Maskey, and S.P. Pandey

Declining yields and soil nutrient balance in a long-term rice-rice-wheat study suggest depletion of soil potassium (K) and inadequate K fertilization seem to be primary reasons for limited and declining crop yields.

The rice-wheat rotation is a major cropping system in the Indo-Gangetic plains of South Asia. In Nepal, about 0.5 million ha under the rice-wheat system, mostly in the Tarai plain, meets about 75% of the country's total food demand. Productivity and profitability are quite low. A doubling of rice production in the next 25 years is needed to meet Nepal's estimated population growth. Arable land is becoming limited. Improving productivity and increasing cropping intensity is required to meet future food needs. Adequate soil fertility will be essential to improve and sustain yields.

Increased cropping intensity was evaluated using data from a 20-yr study at the Regional Agricultural Research Station, Bhairhawa, Nepal. Fertility treatments of nitrogen (N), phosphorus (P), K, and farmyard manure (FYM) in a continuous rice-rice-wheat system were analyzed to examine and explain yield trends and monitor soil nutrient status.

Rice and wheat yields were significantly influenced by NPK and FYM (**Table 1**). Yields were consistently higher in the NPK and FYM treatments than in treatments where one or more nutrients were lacking. Treatments lacking P and K in rice had the greatest rate of decline, while there was no difference in the rate of decline of yields of rice fertilized with recommended rates of NPK and FYM. Fertility treatment had no effect on rate of yield decline in wheat. Yields in the unfertilized control plots were lowest in Year 1 and declined to zero with time (data not shown). The N and NK treatments maintained high yields

Table 1. Mean yield (t/ha/yr) and yield change (t/ha/yr) in a 20-yr long-term experiment, Bhairhawa, Nepal (1978-98).

	First rice		Second rice		Wheat	
Treatment	Mean yield, t/ha	Yield[1] change, t/ha/yr	Mean yield, t/ha	Yield change, t/ha/yr	Mean yield, t/ha	Yield change, t/ha/yr
Control	0.399	-0.089a	1.066	-0.083b	0.532	-0.040a
N	0.719	-0.166b	1.330	-0.118c	0.588	-0.050a
NP	2.577	-0.073a	2.465	-0.020a	1.200	-0.070a
NK	0.630	-0.155b	1.300	-0.132c	0.611	-0.060a
NPK	2.760	-0.088a	3.082	-0.005a	2.301	-0.050a
FYM	2.797	-0.075a	3.138	-0.019a	2.202	-0.050a

[1]Slope values in a column followed by a common letter are not significantly different at p = 0.05.

Table 2. Annual N, P, and K balance in the long-term rice-rice-wheat experiment in Bhairhawa, Nepal.

	Input, kg/ha/yr					Output, kg/ha/yr		
	Manure/ fertilizer	Irrigation	Biological fixation	Rain	Seed	Crop removal	Loss[1]	Balance
				Nitrogen				
Control	0	30.6	25	3.4	8.2	33.6	30.2	3.4
NPK	300	30.6	25	3.4	8.2	138.0	200.2	29.0
FYM	240	30.6	35	3.4	8.2	137.0	83.5	96.7
				Phosphorus				
Control	0	0.5	0	0.2	1.0	5.7	0	-4.0
NPK	43.7	0.5	0	0.2	1.0	23.2	0	22.2
FYM	54.0	0.5	0	0.2	1.0	23.1	0	32.6
				Potassium				
Control	0	20.4	0	5.0	4.9	36.4	6.0	-12.1
NPK	75	20.4	0	5.0	4.9	150.3	17.3	-62.3
FYM	120	20.4	0	5.0	4.9	148.8	16.7	-15.2

[1]Includes volatilization, denitrification, and leaching from soil for N and leaching for K.

similar to the NPK and FYM treatments for the first few years, then followed trends similar to the control, eventually decreasing to zero.

The apparent N balance for the average yield over the 20 years was positive, ranging from 3.4 to 96.7 kg N/ha/yr in the NPK, FYM, and control treatments (**Table 2**). A net loss of 4.0 kg P/ha/yr was estimated for the control treatment, whereas the NPK and FYM treatments had an apparent net P gain of 22.2 and 32.6 kg P/ha/yr, respectively. The apparent K balance was negative in all plots. The control plot also had a negative balance of 12.1 kg K/ha/yr.

Insufficient application of K primarily limited yield in both NPK and FYM treatments. Crops fertilized with NPK averaged 47 kg/ha/yr more negative K balance than the FYM plots due almost entirely to lower K application. It is possible to bridge the yield gap and reverse the yield decline through appropriate nutrient management. A sustainable fertilizer management strategy must ensure high and stable overall productivity and sufficient nutrient supply for potential yield increases. The present recommendation of 100, 13, and 25 kg/ha N, P and K for rice and 100, 17.5, and 25 kg/ha for wheat is inadequate for N and K, but optimum for P.

Potassium application rates are generally low and masked by other nutrient limitations or imbalances. Hence, farmers are reluctant to take the risk to apply K. It is difficult to build up soil N, P, and K once they are depleted. Further studies are required to validate the recommendations in farmers' fields and evaluate the economic feasibility. Such a fertilizer management strategy must be revised after some years to account for the change in indigenous N, P, and K status that may have occurred because of a positive or negative N, P, and K input-output balance. **BCI**

This article is based on the paper of the authors published in Soil Sci. Am. J. 66: 857-867 (2002). Dr. Regmi, Dr. Ladha, Dr. Pathak, Dr. Pasuquin, and Dr. Bueno are with Crop, Soil and Water Sciences Division and Dr. Dawe is with the Social Sciences Division, International Rice Research Institute (IRRI), DAPO Box 7777, Metro, Manila, Philippines. Dr. Hobbs is with CIMMYT, P.O. Box 5186, Kathmandu, Nepal. Dr. Joshy, Dr. Maskey, and Dr. Pandey are with the Central Soil Science Division, NARC, Khumaltar, Nepal.

It's the Right Thing to Do— Investing in Agriculture's Development

Not much is said about those who make this investment. **Yet without them, world agriculture would be rooted in traditions and technologies unable to meet contemporary needs, either socially, environmentally, or agronomically. *BCI* is designed to acknowledge the researchers who generate new information and ideas on nutrient management in high yield agriculture, and, at times, to highlight the practitioners who develop technologies that produce higher yields and incomes through better management of the nutrient, soil, and water resources essential to agriculture.**

I thought it might be useful to the *BCI* readership to know who supports PPI/PPIC and invests in 'research' and 'education'…underpinnings of agricultural development. **If you haven't, I ask that you read the inside front cover to see the list of PPI/PPIC member companies and the special notation about the Government of Saskatchewan, Canada. Considering the seven International programs—plus the North America program—PPI/PPIC staff in collaboration with researchers and institutions in 30 countries—as well as Canada and the United States—have had remarkable success in supporting strategies that focus on developing agricultural productivity through improved nutrient management. If you doubt it, look back through the past issues of *BCI*.**

This long-term commitment to supporting agronomic research and education is focused on solving your…and each country's…problems. **It enables PPI/PPIC to encourage and focus on better understanding of nutrient management, and to explain what it means to farmers and those serving them. With improved agricultural productivity comes the promise of better nutrition for growing populations and the potential for a better standard of living. It is nearly impossible to gauge the positive dividends that can result from investing in agricultural development. Yet, by any measure, that is a generous offering. It is effective because *it's the right thing to do*.**

Supporting those who support agricultural development; *it's the right thing to do*. Take this message to your organization's leadership. Let them know.

Dr. Mark D. Stauffer
Senior Vice President,
International Programs, PPI
and President, PPIC

Better Crops International, published by the Potash & Phosphate Institute/ Potash & Phosphate Institute of Canada

Printed on recycled paper with soy ink.