Better Crops International

Vol. 11, Issue 2, November 1997

In This Issue:

Helping Extension Workers Assess Soil Fertility in the Tropical Uplands

Long-term Effects of Phosphorus Fertilization

Extraction of Potassium and Phosphorus by Mexican Yam Bean

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Vol. 11, Issue 2,
November 1997

Better Crops International

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Our Cover: A farmer carries freshly-harvested peanuts from the field in West Sumatra, Indonesia.
Photo: Dr. Thomas H. Fairhurst.

BETTER CROPS INTERNATIONAL (BCI) is published two times each year by the Potash & Phosphate Institute (PPI) and Potash & Phosphate Institute of Canada (PPIC). The publication 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). Address inquiries to: Potash & Phosphate Institute, 655 Engineering Drive, Suite 110, Norcross, GA 30092-2837 USA. Phone (770) 447-0335. Fax (770) 448-0439.

This publication is made possible in part through resource tax funding provided by the Government of Saskatchewan. We thank them for their support in this important educational effort.

Extraction of Potassium and Phosphorus by Mexican Yam Bean

By J.Z. Castellanos, V. Badillo and A. Sosa

A tuberous legume crop with high nitrogen (N) fixing capacity, Mexican yam bean (also called jícama) has great potential as a high protein food crop. It contributes N for subsequent crops, provided adequate phosphorus (P) and potassium (K) are supplied.

The Mexican yam bean (*Pachyrhizus ahipa* and *Pachyrhizus erosus*) is a tuberous legume crop cultivated in South America and Mexico. It has high yield potential (Heredia-Garcia, 1994), high nutritional value (Evans et al, 1977), as well as low N fertilizer requirement (Tamez, 1987) and pesticide requirements (Clausen, 1944). It has worldwide potential as a cultivated crop (Sorensen, 1994).

One significant advantage of these two crop species is their ability to produce high biomass through biological N fixation, thereby negating the need for N fertilizer applications (Kjaer, 1992). However, no studies have been conducted to measure N_2 fixation or the uptake of K and P. Our first objective was to measure both the percent N derived from the atmosphere (Ndfa) and the actual amount of N that was fixed by each species. The second objective was to measure the amount of K and P uptake by each species.

The plants were flower-pruned, as is normally practiced in Latin America. Harvesting was done 180 to 200 days after planting. Tuber fresh weight and moisture content and the dry *(continued on page 4)*

Nodulation is compared in two species of Mexican yam bean at 122 days after planting.

More About Our Cover Photo

The scene on our cover is in Tanah Datar, West Sumatra, Indonesia. Stover and pods of freshly harvested peanuts have been brought from the field to the house, where shelling takes place. The plant material will probably not be returned to the field.

The traditional fallow system is often not practiced in the region, so soils have become depleted of phosphorus (P). Farming is on steep slopes so erosion control, using simple contour strips, is part of the P capitalization approach.

PPI/PPIC programs are encouraging recapitalization of P in acid upland soils of Southeast Asia and other regions. Phosphorus fertilization is usually required before any response to potassium (K) is noted in these conditions. The article beginning on page 14 of this issue tells more about work with soil fertility in tropical uplands. BCI

weight of straw were determined after harvest. Samples of both roots and shoots were analyzed for total P and K content.

Tuber Yield and Nitrogen Fixation Capability of Mexican Yam Bean

Percent of Ndfa ranged from 55 to 70 for the *P. ahipa* cultivars and from 70 to 77 for the *P. erosus* cultivars (Table 1). The percentage Ndfa for the latter equals the best N_2 fixation capability of cultivated grain legumes (Peoples and Craswell, 1992; Castellanos et al, 1995). Fifty percent of the harvested N, the equivalent of 300 to 800 kg protein per hectare, accumulates in the tuber. This amount of protein is equivalent to...and in some cases higher than...the values of harvested protein reported for common grain legumes (Jensen and Castellanos, 1994).

Table 1. Tuber yield, nitrogen fixation and partitioning by yam bean cultivars.

Species/Cultivar	Tuber yield, t/ha	Nitrogen yield, kg/ha	Nitrogen fixed, kg/ha	N in crop residue, kg/ha	N content in crop residue, %	Net N[1] balance, kg/ha
P. ahipa/cv AC-102	38	137	95	55	3.24	18
P. ahipa/cv AC-521	41	133	74	63	3.49	12
P. erosus/cv San Miguelito	103	247	175	150	3.45	73
P. erosus/cv San Juan	101	248	190	130	3.51	81
LSD (0.05)	11	37	30	21	NS	16
CV	10	12	14	13	9	22

[1]Net N balance = N fixed minus N exported in the tuber.

Nitrogen content in the crop residue ranged from 130 to 150 kg/ha in *P. erosus* cultivars, more than twice that found in both *P. ahipa* cultivars. The concentration of N in the residue was very high, ranging from 3.24 to 3.51 percent N. High quality residue is a unique feature of Mexican yam bean, contributing significant quantities to the N nutrition of subsequent crops. The amounts of N fixed ranged from 74 to 95 kg N/ha and from 175 to 190 kg N/ha for *P. ahipa* and *P. erosus*, respectively. Positive net N balances ranged from 12 to 18 kg N/ha for *P. ahipa* and 73 to 81 kg N/ha for *P. erosus*...higher than those values found for most legume crops (Peoples and Craswell, 1992).

Potassium Removal by Mexican Yam Bean

The K content of tubers was 50 percent higher in *P. erosus* than in *P. ahipa*, a proportional difference similar to that for N between the two species. Potassium uptake ranged from 125 to 266 kg/ha and is high compared to other field crops, including potatoes (Table 2).

Table 2. Potassium content and uptake by yam bean.

Species/Cultivar	Tuber[1] yield, t/ha	K content, %[2]		K uptake, kg K_2O/ha		
		Tuber	Straw	Tuber	Straw	Total
P. ahipa/cv AC-102	38	0.96	1.54	94	31	125
P. ahipa/cv AC-521	41	0.99	1.56	92	34	126
P. erosus/cv San Miguelito	103	1.55	1.59	180	86	266
P. erosus/cv San Juan	101	1.56	1.80	161	80	241

[1]Fresh weight.
[2]Dry weight basis.

Since farmers do not traditionally apply K to the yam bean crop, it is important to study the crop's response to fertilizer K inputs.

Mexican yam bean has potential as a cultivated crop in many areas of the world.

Phosphorus Removal by Mexican Yam Bean

The amounts of P in the tuber and straw components were relatively low, although P content was much higher in the above ground portion of the plant. The total P_2O_5 uptake by *P. erosus* was approximately 40 kg/ha, indicating a high demand for P (Table 3).

Table 3. Phosphorus content and uptake by yam bean.

Species/Cultivar	Tuber[1] yield, t/ha	P content, %[2]		P uptake, kg P_2O_5/ha		
		Tuber	Straw	Tuber	Straw	Total
P. ahipa/cv AC-102	38	0.09	0.20	22	7	29
P. ahipa/cv AC-521	41	0.09	0.17	16	7	23
P. erosus/cv San Miguelito	103	0.11	0.16	23	16	39
P. erosus/cv San Juan	101	0.13	0.20	25	16	41

[1]Fresh weight.
[2]Dry weight basis.

The results of this study indicate that these tuberous legume species have excellent potential as a high protein food crop and supplier of N to subsequent crops for agricultural systems used in tropical and semitropical regions, provided adequate P and K are supplied. BCI

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This research project was funded in part by the PPI/PPIC Program in Mexico and Northern Central America (INPOFOS).

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Balanced Fertilization for China's Cotton Production

By Jason Wang, Jin Ji-yun and Sam Portch

In 1984, China's cotton production reached its peak of 6.25 million tonnes (Lin, 1995). Since then, production has fluctuated between 3.54 and 4.50 million tonnes, with the exception of 1991 when it reached 5.68 million. Most production goes to the domestic textile industry, which annually consumes between 4.82 and 4.95 million tonnes of cotton. Any shortfall is made up with imports. In 1995, cotton imports cost China US$13.74 billion. Large scale imports not only dampen China's foreign exchange reserves, but also have significant negative impact on local economies in major cotton producing provinces.

Imbalanced nutrient supply has been identified in China by PPI/PPIC as one of the most important factors limiting cotton yields and quality. Among the essential plant nutrients required in high-yielding cotton production systems, potassium (K) is most often found deficient in almost all areas. The brown colored leaf rust symptom, a sign of K deficiency, is commonly seen during mid and late growing season.

Cotton plots in a demonstration field at Siyang, north Jiangsu province, contrast cotton fertilized with and without K in 1996. Cotton at left received N-P_2O_5-K_2O rates of 210-54-180 kg/ha (yield = 1,700 kg/ha). Cotton at right received 210-54-0 kg/ha (yield = 987 kg/ha).

In support of China's efforts to implement scientific farming technologies and to reduce foreign exchange expenditures on imported cotton, PPI/PPIC and cooperating Chinese scientists initiated a project in six provinces. The fundamental concept was to use soil test based balanced fertilization practices to obtain higher yields of high quality cotton with greater fertilizer use efficiency. This would provide larger profits for farmers and stimulate local economies. Six of the largest traditional cotton producing provinces...Anhui, Hebei, Henan, Hubei, Jiangsu, and Shandong...were included in this special project. In 1994, the total area planted to cotton among these provinces was 3.89 million ha, accounting for 70.44 percent of the national total. Lint yield was 2.74 million tonnes or 63.2 percent of the total, (*China Agriculture Yearbook*, 1995). While Xinjiang province is an important cotton producer, it was not included in this study since it is in the early stages of cotton expansion and native soil nutrient levels are higher than in traditional cotton producing provinces where nutrients have been depleted.

Table 1. Relative crop yield in absence of K.

Crop	Relative yield, %
Cotton	45
Corn	81
Soybean	73
Wheat	93

Source: Auburn University, Alabama, U.S.A.

Table 2. General treatment design for cotton trials in China 1995-96.

	Fertilizer rate, kg/ha			
Treatment	N	P_2O_5	K_2O	Other nutrients
1	150-300	60-180	0	added
2	150-300	60-180	low	added
3	150-300	60-180	high	added
4	150-300	60-180	highest	added
5[1]	150-300	40-135	high	added
Farmer[2]	N+ manure	low or none	low or none	–

[1]Different P rate and high K rate.

[2]Farmer practice: Up to 1.5 tonnes organic manure and low K were applied in the provinces of Jiangsu, Anhui, Hubei; no K was applied in the provinces of Henan, Hebei and Shandong.

Justification

With recent, rapid development in farming technology and management skills in China, cotton yields have continuously increased. This has resulted in greater plant nutrient removal from the soil. Results of China's National Soil Survey II (1990) indicate soil K levels have decreased considerably since 1980 in all major agricultural regions. In addition to K, phosphorus (P), sulphur (S), calcium (Ca), magnesium (Mg), and some micronutrients were also found deficient because of the implementation of intensive cultivation and high yield production systems.

The amount of plant nutrient removal by 1,000 kg/ha of cotton lint is calculated as N, 120; P_2O_5, 45; K_2O, 90; MgO, 40; and S, 20 kg/ha (PPI, 1993). To maintain soil productivity, these nutrients must be replenished. Cotton is a K sensitive crop, making it highly responsive to K fertilizer additions. Table 1 indicates relative crop yields without K.

When K supply is inadequate, lint yield and quality are affected because the cotton plant is likely to suffer a greater severity of leaf diseases and premature defoliation. Adequate supplies of K increase seed weight, percent lint, and lint yield. Fiber micronaire and its uniformity of strength and length are improved, as is the plant's resistance to wilt and nematodes.

Research in the 1950s and 1960s in the U.S.A. demonstrated both lint yield and quality improvements with K fertilization. Research in China, India, and other countries also shows significant yield increases with K fertilization (*Better Crops International*, 1993, 1989).

Table 3. Cotton yield response to K fertilizer rates in major cotton producing provinces of China.

Province	Year	K_2O rate	Lint yield	Yield increase[1]	Percent increase	Province average yield,
			kg/ha		%	kg/ha
Anhui	1995	270	1,517	160	11.8	562
	1996	300	1,411	388	37.9	679
Hubei	1995	165	1,231	196	19.0	904
	1996	180	1,302	99	8.2	1,167
Jiangsu, South	1995	225	1,123	161	16.6	855
	1996	270	1,061	98	10.1	994
Jiangsu, North	1995	270	1,517	621	69.4	855
	1996	270	1,157	617	114.2	994
Hebei	1995	113	1,256	83	10.2	569
	1996	135	1,290	130	11.2	528
Henan	1995	135	1,519	201	15.0	649
	1996	135	1,432	197	16.0	769
Shandong	1995	180	1,548	233	17.0	705
	1996	180	1,088	259	31.0	706

[1]Lint yield compared to the yield of local farmers.

PPI/PPIC publications state that K deficiency of cotton is a widespread production problem. Both mid-season K deficiency on older leaves and late season deficiency on young leaves reduce cotton yield and lint quality (*Better Crops International*, 1989). University research and grower experience show that higher yields can be produced with K fertilizer, giving economic returns of US$4 to $9 for each $1 invested in K fertilizer. This was true for fields already producing high lint yields in Arkansas and Mississippi, U.S.A.

Experimental Design

Experimental trials (30 m^2 plots, four replications) and demonstration plots (300 to 600 m^2) were established in two or more counties of each of the six provinces. Recommended fertilizer rates for all nutrients other than K were based according to soil test results, yield targets and local soil characteristics. In 1995 and 1996, four levels of K were used to test yield response to applied fertilizer. These rates were slightly adjusted in 1996 based on 1995 results. Two additional treatments were: (1) a lower rate of fertilizer P to evaluate possible response to P, and (2) the local farmers' practice (which varied at each location). The range in treatments is described in Table 2.

Results

Lint yields greater than 1,000 kg/ha were obtained at all locations when soil test based fertilizer recommendations were applied. When other essential plant nutrients were adequate, based on a scientifically derived recommendation, cotton yields increased sharply with high K rates in both 1995 and 1996 (Table 3). Yield increases were calculated as the differences between yield obtained from the recommended fertilizer treatment and local farmer practice.

Table 4. Estimation of yield increase potentials and economic analysis when soil test based fertilizer rates are applied to cotton in China.

Province	Year	Yield increase by K, kg/ha	Total yield increase estimated, tonnes	Cost of K, million yuan	Net return for K, million yuan[1]	VCR
Anhui	1995	160	42,600	133	630	4.7
	1996	388	103,000	122	1,519	12.5
Hubei	1995	196	39,000	50	577	11.5
	1996	99	19,800	55	293	5.3
Jiangsu, South	1995	160	25,600	72	379	5.3
	1996	98	16,600	76	246	3.2
Jiangsu, North	1995	621	99,400	54	1,471	27.2
	1996	616	104,400	85	1,539	18.1
Hebei	1995	116	27,800	68	411	6.0
	1996	130	31,800	83	471	5.7
Henan	1995	201	68,000	114	1,006	8.8
	1996	197	69,000	118	1,021	8.6
Shandong	1995	233	73,900	143	1,094	7.6
	1996	259	68,900	120	1,020	8.5

[1]Market prices in 1995 and 1996: MOP (KCl) fertilizer, RMB1,500/tonne; lint cotton, RMB14,800/tonne (14.8/kg).

Average yield increase over the six provinces was 27.7 percent, with all being above 10 percent, except for Hubei province in 1996. Flooding in Hubei and the higher use of inputs by the farmer in south Jiangsu contributed to relatively small yield increases in 1996. In north Jiangsu, a combination of high K rates and split K application was necessary to obtain high yields on these sandy soils, showing potential to increase yields is very high when scientific farming methods are applied. Serious rust symptoms resulting from K deficiency were commonly seen in mid and late season if K was not properly managed on these low cation exchange capacity soils.

Dr. Jason Wang compares cotton with balanced fertilization including 300 kg K_2O/ha (at left) and with 75 kg K_2O or less (at right). Field is in Siyang, north Jiangsu province.

Among these six provinces, soil test K levels are relatively higher in Hebei and Henan [74 to 90 parts per million (ppm)] and lowest in Anhui and Jiangsu (35 to 70 ppm), with Hubei and Shandong in between. It is reasonable to assume that similar yield responses to recommended K rates used in these trials would occur on 35 percent of the cotton growing soils in Henan and Hebei, 40 percent in Hubei and Shandong, and 60 percent in Anhui and Jiangsu. Thus, the potential economic benefit from adequate and balanced fertilization can be determined for each province (Table 4). These data are conservative estimates. Higher yields may be obtained as farmers continue to improve nutrient input and management practices.

Based on data from these six provinces, it is estimated that a total lint yield increase of 413,500 tonnes would result when soil test based recommendations are used. To achieve this potential yield, an additional 403,000 tonnes of potassium chloride (KCl) along with small amounts of some micronutrients would be needed. Estimated economic return and VCR to K fertilization indicate an enormous economic benefit at reasonable risk. Total economic return from cotton lint yield increases would be nearly 10-fold the cost invested in KCl, assuming market prices of RMB 1,500/tonne for KCl and 14,800/tonne for cotton lint (US$1 = 8.2 RMB).

Statistics from the General Administration of Customs indicated that 743,217 tonnes cotton were imported in 1995 at a value of US$13.77 billion (*China Agricultural Yearbook*, 1996). With adequate use of K in a balanced fertilization program, cotton imports could be

Table 5. Cotton lint yields respond to P fertilizer rates in major cotton producing provinces of China.

Province	Year	P rate, kg/ha	Lint yield, kg/ha	1.5 P rate, kg/ha	Lint yield, kg/ha	Yield increase kg/ha	Yield increase %
Anhui	1995	60	1,336	90	1,423	87	6.5
	1996	90	1,143	135	1,166	23	2.0
Hubei	1996	60	1,396	75	1,276	–	–
Jiangsu	1996	120	1,020	180	1,061	41	4.0
Hebei	1995	75	1,216	113	1,256	40	3.3
	1996	90	1,275	135	1,288	13	1.0
Henan	1995	75	1,404	113	1,432	31	2.2
	1996	90	1,370	120	1,432	62	4.5
Shandong	1995	135	1,253	180	1,315	62	4.9
	1996	135	907	180	928	21	2.3

reduced by 54 percent. This would save US$7.39 billion on imports, when cost of K is deducted. These funds would then be available for investment in other needy agricultural sectors.

Furthermore, while only a few participating provinces made measurements on the effect of K on cotton quality, it is well understood from the world literature that cotton quality would be higher where K fertilization was adequate.

Raising the P fertilizer rate to 1.5 times recommended levels resulted in small increases in cotton yields (Table 5). These results indicate that current recommended P levels are economically adequate for cotton production. However, data suggest that recommended P levels for cotton must be closely watched because they are not agronomically adequate. Future studies to determine the economic benefits of the residual effects of both P and K on the subsequent crop, a result of higher P and K fertilization of cotton, are likely to show additional economic benefits from application of these two nutrients.

Conclusions

Cotton yield is sensitive to K nutrition. Lint production could be increased by 413,500 tonnes by supplying an additional 403,000 tonnes of KCl in six of China's major cotton producing provinces. This would provide a net benefit of 13.3 RMB for each kg of lint produced ...or an annual saving of US$7.39 billion in foreign exchange after subtracting US$0.054 billion for cost of additional KCl. In other words, an investment in 403,000 tonnes KCl, for application on cotton would save China US$7.39 billion to spend on agricultural development and improvements in other areas.

The cotton produced would be of higher quality. As well, there would be an added benefit of residual K in the soil for the subsequent crop...two advantages not calculated in the net benefit of using additional K on cotton in these trials.

Higher than presently recommended P rates gave only marginally higher yields. Although not economically advantageous based on cotton yields alone, the residual effect resulting from additional P may be beneficial to following crops. This should be measured since current P recommendations are not biologically sufficient. BCI

Dr. Wang and Dr. Jin are Deputy Directors, PPI/PPIC China Program. Dr. Portch is Director, PPI/PPIC China Program, Hong Kong.

Acknowledgement: The authors wish to acknowledge the support given by the Soil and Fertilizer Institutes of the provincial academies of agricultural sciences of Anhui, Hebei, Henan, Hubei, Jiangsu and Shandong and the Institute of Soil Science, Chinese Academy of Sciences, for conducting the research reported in this paper.

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Balanced Fertilization Research and Demonstration on High Yield Cotton in Henan Province

By Li Guibao, Sun Kegang, Wang Ying and Jiao You

Research experiments and field demonstrations are showing farmers and leaders the positive effects of potassium (K) fertilization in balance with other nutrients for increased cotton production.

Cotton is an important cash crop in Henan, grown on more than one million hectares in the province. In recent years, to meet demand of the growing population, yield per unit area has been increased by using high-yielding varieties, heavier rates of nitrogen (N) and phosphorus (P), and an increased cropping index. However, through this process, the status of plant nutrients in the soil has changed, and K depletion (deficiency) has become a significant cotton yield and quality limiting factor. It was also found that with an increasing incidence of K deficiency, some diseases are becoming prevalent in cotton. Therefore, a study on balanced fertilization was developed to demonstrate to farmers the need for adequate inputs of all limiting nutrients, especially K.

Materials and Methods

The three locations selected were: Yanjing, Fuguo and Nanyang counties in northern, eastern and southern Henan. Soil types represented were a fluvo-aquic soil in Yanjing and Fuguo counties and a yellow cinnamon soil in Nanyang county. There were three replications with 20 to 30 m^2 plot sizes. The rates of N, P and K application to the summer cotton crop at Yanjing were lower than rates applied to the spring cotton sites at Fuguo and Nanyang counties (Table 1).

Large field demonstration plots were also established at all three sites. Treatments included a typical farmer fertilization practice as check, and balanced fertilization with K.

A high-yielding variety was selected for all trials. Other management practices such as pest control and irrigation were done to maximize yield. Cotton was picked from individual plots and yield calculated on the spot for the benefit of local leaders and farmers organized to inspect the experiments and demonstrations. This approach showed them the positive effect of K use on cotton and provided technology transfer by immediately expanding the influence of the results.

Table 1. Experimental treatments, rates as kg/ha.

Fuguo and Nanyang			Yanjing		
N	P_2O_5	K_2O	N	P_2O_5	K_2O
180	112	0	135	90	0
180	112	90	135	90	75
180	112	135	135	90	112
180	112	180	135	90	150
180	75	90	135	60	75
180[1]	75	0	135	60	0

[1]Farmer practice for fertilization. Other nutrients were applied to a sufficient level.

Experimental Results and Effect of Demonstrations

Yield effect: Cotton yield in Yanjing was lowest among the three sites (Tables 2 and 3). With adequate supply of N and P, cotton yields increased gradually with increasing rates of K application up to a maximum, then decreased. The best K rate for spring cotton was 135 kg K_2O/ha while for summer cotton it was 112 kg K_2O/ha. The K effect on summer cotton yield was much higher than on spring cotton. The reason postulated is that spring cotton absorbs more K from the soil due to its longer growing period (135 days). The effect of K application on yield between the Fuguo and Nanyang site was similar.

Table 2. Spring cotton lint yield from different P and K treatments.

Fertilizer, kg/ha			Fuguo		Nanyang	
N	P_2O_5	K_2O	Yield, kg/ha	Increase, %	Yield, kg/ha	Increase, %
180	112	0	1,318	–	1,353	–
180	112	90	1,432	8.6	1,470	8.6
180	112	135	1,520	15.2	1,550	14.6
180	112	180	1,450	10.0	1,483	9.6
180	75	90	1,401	6.3	1,467	8.4
180	75	0	1,306	-0.9	1,338	-1.1

Table 3. Summer cotton lint yields (kg/ha) at Yanjing.

Fertilizer, kg/ha				
N	P_2O_5	K_2O	Yield	Increase, %
135	90	0	777	–
135	90	75	944	21.4
135	90	112	974	25.3
135	90	150	967	24.4
135	60	75	838	11.2
135	60	0	724	-0.07

The lowest yield of cotton was obtained with the farmer's fertilization practice and was due to the absence of applied K and lower P use. It appears that the main effect benefitting cotton yield was from additions of K. With the same rate of N and K (180 and 90 as N and K_2O), there was no obvious difference between the two levels of P application on spring cotton at both locations. This could be due to the fact that the P application levels were tested at less than optimum levels of K (90 rather than 135). On the other hand, with summer cotton, lint yield at the lower rate of P was significantly lower than that of the higher dose, indicating the need for K and an increase in the recommended rates of P. In this case, P application rates were tested at an adequate level of K. Results may also be due to the fact that summer cotton absorbed less available P from the soil due to the shorter growing period.

Yield Component Effect

With increased rates of applied K at Fuguo, both the boll weight and number of bolls per plant increased. There was no obvious difference with the number of fruit branches per plant among treatments. Fiber length also increased when K was applied.

Economic Analysis

Maximum net profit (Tables 4 and 5) resulted with the same treatment that gave the highest yield (135 kg K_2O/ha for spring cotton and 112 kg K_2O/ha for summer cotton). Net profits for the farmer fertilization treatment and the one without K were much lower, although each had higher VCRs compared with other treatments. This serves as a good example that VCR should not be the factor that determines the rate of fertilizer to recommend unless it is extremely low (VCR less than 2). Otherwise, net profit should be used for determining rates of fertilizer to recommend.

Results and Impact of Field Demonstrations

Simple field demonstrations were established near the experimental sites. The application of 150 kg K_2O/ha increased lint yield by 8.9 percent and 9.6 percent at Nanyang and

Table 4. Spring cotton economic analysis (RMB yuan/ha).

Fertilizer, kg/ha			Fuguo			Nanyang		
N	P_2O_5	K_2O	Cost	Net profit	VCR	Cost	Net profit	VCR
180	112	0	1,213	30,431	25.1	1,213	31,259	25.8
180	112	90	1,411	32,969	23.4	1,411	33,869	24.0
180	112	135	1,510	34,958	23.2	1,510	35,714	23.6
180	112	180	1,609	32,203	20.6	1,609	33,995	21.1
180	75	90	1,294	32,329	24.9	1,294	33,914	26.2
180	75	0	1,096	30,259	27.6	1,096	31,016	28.3

Note: Price (yuan/kg) N = 4.8, P_2O_5 = 3.1, K_2O = 2.2, cotton = 24. US$1 = 8.2 RMB.

Table 5. Summer cotton economic analysis (RMB yuan/ha).

Fertilizer, kg/ha			Yanjing		
N	P_2O_5	K_2O	Cost	Net profit	VCR
135	90	0	927	17,721	19.1
135	90	75	1,092	21,552	19.7
135	90	112	1,175	22,189	18.9
135	90	150	1,257	21,944	17.5
135	60	75	999	19,106	19.1
135	60	0	834	16,554	19.8

Table 6. The effect of K application on lint yield in field demonstrations.

	Fuguo		Nanyang		Yanjing	
Treatment	Yield, kg/ha	Increase %	Yield, kg/ha	Increase %	Yield, kg/ha	Increase %
Check	1,360	–	1,381	–	867	–
K_2O150[1]	1,491	9.6	1,504	8.9	952	9.8
K_2O225	1,547	13.8	–	–	–	–

[1]Rate at Yanjing site, 120 kg/ha.

Fuguo, respectively. At Fuguo, an additional 4 percent yield increase was obtained with the application of 225 kg K_2O/ha. At the Yanjing summer cotton site, the application of 120 kg K_2O/ha increased lint yield by 9.8 percent (Table 6).

Local leaders and farmers were organized to inspect the demonstrations. At the Fuguo spring cotton site, the Fuguo county Commission of Science and Technology, one of the cooperating units in the demonstrations, persuaded local leaders and more than 60 farmers to visit both the research and demonstrations at Gaohetao village and the Guaiwang farm demonstration site in Dalizhuang township. These organized field days made a good impression on both the leaders and farmers, demonstrating the agronomic and economic benefits of balanced fertilization. This approach helps get research results put into practice on farmers' fields quickly.

From a practical point of view, it was essential to combine research trials with demonstrations. This brought together researchers, local leaders and farmers to see the benefits of balanced fertilization and the fruits of research as well as convey research results to the mass media. BCI

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When There Is No Soil Test... Helping Extension Workers Assess Soil Fertility in the Tropical Uplands

By Thomas S. Dierolf, Ellen Kramer and Thomas Fairhurst

Alternative approaches are needed to assess soil fertility in many areas of the world where on-farm soil testing and the supporting correlation and calibration information required for precise fertilizer recommendations are not available. The approach described in this article is an on-going process of developing, implementing, and modifying tools and methods for farmers and extensionists in Indonesia's uplands. This straightforward and strictly participatory method aims for general guidelines in simple soil fertility assessment and fertilizer management applicable in the tropical uplands of Southeast Asia.

While precision agriculture is gaining prominence in some developed countries, most upland farmers in Indonesia have no access to common soil testing because they lack the financial resources to pay for simple soil tests or facilities are not locally available. Likewise, soil test correlations and calibration information are not usually available for upland soils and crops. Yet, fertilizer consumption is increasing in Indonesia and farmers need advice on fertilizer use and soil fertility management.

A low cost Pehameter (Hellige) provides a quick pH test in the field.

The lack of accurate soil test data and fertilizer recommendations reflects the local-specific information vacuum that extension workers face when advising farmers in the uplands of Indonesia and other developing countries. Agricultural extension and the supporting technical information base have historically focused on wetland rice areas, but increasing demand has been placed on intensifying agricultural production on the rainfed uplands.

An approach is being developed by the Area Development for the Rehabilitation of Critical Land and the Protection of Natural Resources and Environment (ProRLK) in West Sumatra to provide extension workers with the information and skills required to advise farmers on proper soil fertility management for the rainfed uplands.

The Approach

The approach involves two major steps.

1. A general soil fertility assessment of an area is carried out through a participatory soil survey.
2. Tools and methods are developed to help extension workers make specific farm-level diagnoses and to provide farmers with recommendations which are then tested in farmers' fields.

In this approach, the five elements of the environmental education learning process ... *awareness*, *knowledge*, *attitudes*, *skills*, and *participation* ... are applied. Table 1 shows how these steps correspond with soil fertility assessment at different scales (e.g. from a large region, possibly several villages, down to farm-specific soil fertility assessment).

Table 1. The tools and methods used to move from general to specific soil fertility assessment and the corresponding learning process elements experienced by extension workers.

Learning process element	Geographical focus	Tool/method
Awareness	Several villages	Participatory soil survey
Knowledge and attitudes	⋮	Dissemination of results (e.g., soil handbook, workshops, etc.)
Skills	↓	Training on diagnosis and recommendation (using indicator plants, nutrient deficiency symptoms, etc.)
Participation	Single farm	Participatory technology development

Awareness - *Participatory Soil Survey*

The participatory soil survey involves extension workers, farmers, and scientists as they share their individual expertise to identify the potentials and limitations of agriculturally important soils. Extension workers are included in the process to increase their awareness of the properties of local soils, which will eventually help them to assist farmers in their soil fertility management. The major steps involved in the approach are shown in Table 2.

Table 2. The major steps involved in the participatory soil survey.

1. Scientists review secondary soil data.
2. Farmers, assisted by extension workers and scientists, sketch simple land use and soil maps. Farmers identify soils by color, texture, presence of indicator plants.
3. Based on the information from steps 1 and 2, farmers and scientists select representative sites to dig soil pits.
4. Scientists, in the presence of extension workers, farmers, and village officials, characterize the soil pit profiles and obtain soil samples for basic chemical and physical analyses.
5. Scientists process the results.
6. Feedback through discussion in the village and visits to soil pits.

Although additional soil fertility information (particularly where pronounced soil spatial variability exists) can be gathered by means of auger-hole sampling, the soil pit is an important vehicle for increasing awareness among participants. Besides having a good look at the subsoil (e.g., clayey and deep, shallow and stony), participants can easily recall the location of a soil pit and the soil's characteristics, which is less likely to occur for auger-hole sampling. The entire process of characterizing a soil profile in the field stimulates ample discussion about the soil among the participants.

Knowledge and Attitudes - *Dissemination of Results*

It is critical to follow-up the awareness and expectations created by the participatory soil survey. Workshops and technical and extension publications are used to share the soil survey results with farmers. Crop suitability and general soil fertility assessment of the surveyed soils

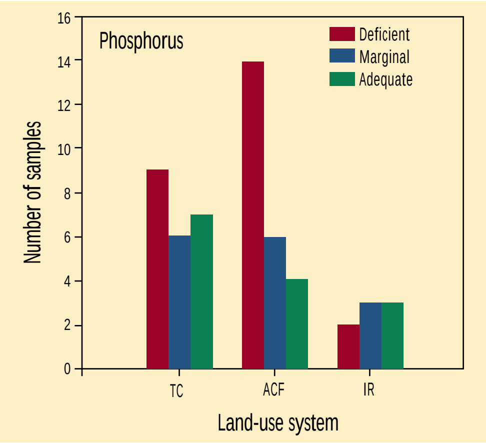

Figure 1. Number of soil samples containing deficient, marginal, and adequate P (Olsen) in tree crops (TC), annual crops with fallows (ACF), and irrigated rice (IR) land-use systems in West Sumatra.

are presented to local planning officials and extension staff in half-day workshops. Additionally, the soil surveys are published in detailed technical reports and provided to relevant agencies and organizations.

An extension handbook provides extension workers with basic soil fertility information from the participatory soil survey. The handbook also includes relevant chemical data of the topsoil, maps with profile locations, and photos of representative profiles. As mentioned earlier, precise correlation and calibration data are not available in Indonesia, so general guidelines are used in order to convey important messages to extension workers.

Figure 1 and Figure 2 show examples of data from West Sumatra. Soil available phosphorus (P) was deficient in 40 percent of the samples taken from fields planted to tree crops and 60 percent of the samples taken from fields planted to annual crops (Figure 1). In contrast, potassium (K) was only deficient in 20 percent of the tree crop fields and 5 percent of the annual crop fields (Figure 2). In tree crop and annual cropping systems, P deficiency must be corrected before there will be any response to K.

In addition to soil fertility data interpretation, a simple five step process helps extension workers to improve on-farm soil fertility management practices, without having to rely on precise soil data (Table 3). A basic principle of this approach is that extension workers should first try to improve the management of the fertilizer that the farmer is already willing to purchase, and only then focus on trying to determine the correct fertilizer dose.

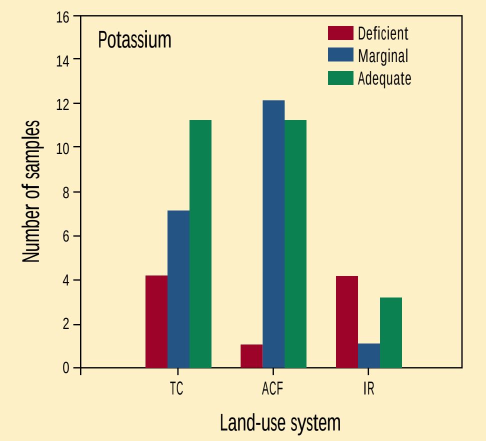

Figure 2. Number of samples containing deficient, marginal, and adequate exchangeable K in tree crops (TC), annual crops with fallows (ACF) and irrigated rice (IR) land-use systems in West Sumatra.

Skills - *Training on Diagnosis and Recommendation*

Simple tools and methods help train extension workers on how to diagnose and provide recommendations to farmers based on the results of the participatory soil survey. Geographical regions and related potential soil fertility problems are identified during the participatory soil survey. However, extension workers need to be shown how to determine whether or not these conditions exist on a particular farm.

Extension staff should be trained to identify and interpret nutrient deficiency symptoms. For example, when an extension worker enters an upland area in West Sumatra, one of the first observations in the field is to look for indicator plants that suggest P deficiency. The presence of large amounts of weed species such as *Imperata cylindrica* (cogon grass or alang-alang), *Melastoma malabathricum* (Straits rhododendron) and *Dicranopteris linearis* (tropical bracken) may indicate an acid, low P soil. Among annual crops, maize is an especially useful indicator of various nutrient deficiency symptoms, particularly of P (e.g., purpling of leaves and stem bases).

A simple worksheet can help the extension worker analyze the field cropping history with the farmer, in particular crop yields and the management of crop residues, soil amendments and fertilizers. Nutrient removal/replacement graphs provide estimates of the amounts of nutrients removed from the field under different management practices. While the total uptake of nitrogen (N) and K by a maize crop is similar, the amount of N contained in the grain is

Table 3. Five suggested steps for extension workers to help improve farmers' soil fertility management.
1. Improve the timing of fertilization.
2. Improve fertilizer application methods.
3. Improve the balance of fertilization.
4. Improve organic material management.
5. Optimize fertilizer use.

With its distinctive red flowers, Straits rhododendron is a good indicator of acid soil.

twice the amount in the stover. However, the amount of K contained in the stover is four times the amount in the grain. These two tools can be used to develop simple nutrient budgets to identify possible nutrient imbalances on the farm.

If crop yields are relatively low for the area, the amount of P fertilizer used was small, indicator weeds species are present, and P deficiency is found in maize leaves, the extension worker starts to build a case for P limitations to crop production. He/she may then recommend that the farmer increase the amount of P fertilizer applied or even propose P recapitalization of the farmer's soil. The source of P used should be related to soil pH test, using a Pehameter (after Hellige) soil pH kit. Rock phosphate is only recommended when pH is less than 5.5.

In areas where aluminum (Al) toxicity is identified as a probable limiting factor, the extension worker would have to learn the relative Al tolerance of various crops (e.g., cassava is more tolerant than soybean). If an Al-sensitive crop is being grown, a simple pH test kit can be used to estimate the approximate lime requirement. A broad relationship between soil pH and Al saturation was found for the soil pits tested in the West Sumatra survey. It may be useful for the calculation of lime requirements based on soil pH. Chemists have used pH indicators for centuries with a high degree of precision and it may be possible to estimate the amount of lime required to reduce Al saturation to the required level by measuring the pH of soil-water solutions to which different amounts of lime have been added. The advantage is that the tests can be carried out in the field using the pH kit and some plastic containers.

Field meetings allow an exchange of information among farmers and extension workers.

Participation - *Participatory Technology Development*

While farmers and extension workers participate in the process from the beginning, the last and most important phase puts focus on how the extension workers could test their tentative recommendations with the farmer. Although the process also requires skill training, this step is seen more as a working relationship put to practice. The extension worker must be taught how to work with a farmer to test, monitor and evaluate the new recommendations against the current farmer practice. BCI

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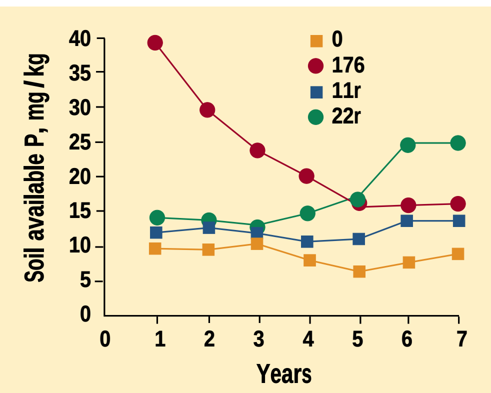
Long-term Effects of Phosphorus Fertilization on Wheat Yields, Efficiency and Soil Test Levels

By Angel Berardo, Fernando Grattone, Roberto Rizzalli, and Fernando Garcia

Several years of phosphorus (P) fertilization studies are now providing a basis to evaluate long-term effects on wheat yields, nutrient efficiency and soil test levels in the Pampas of Argentina.

The Pampas region of east central Argentina has extensive plains, mainly dedicated to grain and beef cattle production. Soils under cereal crop production are Mollisols, generally Argiudolls. The surface horizon is usually moderately acid with organic matter levels from 2 percent in the west to 6 percent in the east. Annual precipitation ranges from 1,100 mm in the northeast to 500 mm in the southwest.

Figure 1. Evolution of soil available P (Ps) with P application only in the initial year (Pi) and with two annual rates of P (Pr) in the CW rotation.



Soil P levels are usually deficient for grain production in the central and east area of the Pampas. Several field experiments in the last 30 years have shown the need for P fertilization for maximum economic yield (MEY). Many farmers have adopted P fertilization as a regular practice for wheat, corn and forage production. Annual P fertilization has resulted in the buildup of soil P levels in several cases, but the agronomic value of this increased soil P has not been evaluated for annual crops. Residual P is especially important for cropping systems in which the cost of fertilizer is high, because it might allow adjustments in the rate of fertilizer, improving the economic results.

The objective of this research was to evaluate the long-term effects of P fertilization on wheat yields, P recovery in grain, and soil P levels (Bray P-1).

Materials and Methods

Two field experiments were begun in 1988 at the Balcarce Agricultural Experimental Station, Buenos Aires Province, Argentina (37° 45‘ S, 58° 18‘ W; altitude 130 m). The soil is a loamy, illitic, thermic, typic Argiudoll. Soil organic matter was 6.2 percent, pH 5.8, and soil P 10.2 mg/kg at the initial soil sampling of the surface horizon (0 to 18 cm) in the experimental areas.

The effects of residual P were evaluated on a continuous wheat (CW) rotation (Experiment 1), and in a wheat-sunflower (WS) rotation (Experiment 2). A randomized complete block design with three replications was used for each experiment. Treatments included six rates (0, 11, 22, 44, 88, and 176 kg/ha) of P applied only in the first year (1988), and

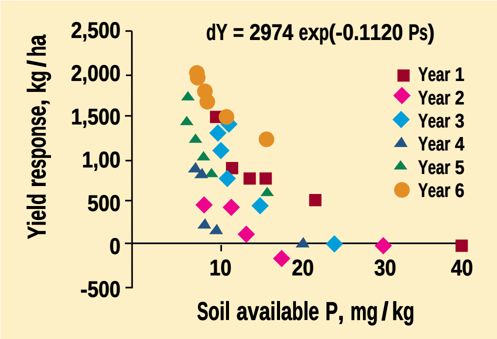


Figure 2. Relationship between soil available P (Ps) and yield response (dY), for the CW rotation.

two rates (11 and 22 kg/ha) P annually applied.

Fertilizer was applied annually in the CW rotation, but only to wheat in the WS rotation. Phosphorus fertilizer was applied with the seed at the 11 and 22 kg/ha rates. The remainder was broadcast and incorporated with a disk before planting. Urea was applied annually at a rate of 120 kg N/A to all treatments to avoid N deficiencies.

Sixty subsamples at 0 to 18 cm depth were taken from each plot before wheat planting to determine soil P levels. Aboveground biomass at physiological maturity of wheat, grain yield and recovery of P in grain were determined. Data from seven years (1988-1994) for the CW rotation, and from four years (1988, 1990, 1992, and 1994) for the WS rotation were analyzed.

Results and Discussion

Table 1 shows grain yields, grain yield responses and P fertilizer efficiency in the CW and WS rotations, from 1988 to 1994. Average yield for the highest rate of P applied in 1988 (176 kg/ha) was 4,321 kg/ha for the CW and 5,076 kg/ha for the WS rotations, respectively. Yield response for the same treatment was 1,090 and 968 kg/ha, or 34 percent and 24 percent above check yields for the CW and WS rotations, respectively.

Residual P effect for the rate of 176 kg/ha P was significant in the seven years, but it was not enough to reach maximum yields in the last two years. There were significant residual effects through the fourth and seventh year for the rates of 11 and 22 kg/ha P, respectively (data not shown).

Phosphorus fertilizer efficiency for the CW rotation, considering the accumulated yield response for the seven years, was approximately 160 kg of grain per kg of P for rates of 11 and 22 kg/ha P. Phosphorus fertilizer efficiency decreased to 44 kg of grain per kg of P for higher rate of initial P fertilization. The same trend was observed for the WS rotation, but with lower efficiency because of the lower number of years (four) under wheat.

Table 1. Accumulated grain yield (Yac), accumulated grain yield response (dYac), accumulated P fertilizer efficiency (dYac/P), and accumulated grain P (Pgac) for the seven years (1988-1994) of the CW and WS rotations.

Treatment	Continuous Wheat				Wheat – Sunflower			
P, kg/ha	Yac kg/ha	dYac kg/ha	dYac/P kg/kg P	Pgac P, kg/ha	Yac kg/ha	dYac kg/ha	dYac/P kg/kg P	Pgac P, kg/ha
0	22,605	–	–	57	16,435	–	–	43
11	24,333	1,728	159	66	17,070	635	58	47
22	26,188	3,583	164	73	18,249	1,814	83	51
44	27,492	4,887	112	78	19,032	2,597	59	55
88	28,685	6,080	70	82	19,347	2,912	33	58
176	30,249	7,644	44	98	20,305	3,870	22	68
11r	28,065	5,460	72	84	19,142	2,707	35	57
22r	31,822	9,217	60	98	20,521	4,086	27	65

r = annually fertilized

Annual fertilization with 22 kg/ha P resulted in the highest accumulated grain yield for the seven years in both rotations, although it did not result in maximum yields in the first years. Average annual response and P fertilizer efficiency for this rate were 1,317 and 1,021 kg/ha and 60 and 27 kg grain per kg P for the CW and WS rotations, respectively.

Average annual grain P removal was 14 to 17 kg/ha for the initial rate of 176 kg/ha P and the annual rate of 22 kg/ha P, depending upon rotation. Grain P removal averaged 8 to 11 kg/ha for the check treatments (data not shown).

Figure 1 shows the dynamics of soil P over years for some of the treatments of the CW rotation. For the P rate of 176 kg/ha, there was a progressive decline in soil P until it reached 16 mg/kg in the fifth year. Annual fertilization with 22 kg/ha increased soil P up to 25 mg/kg in the sixth year. Soil P variations for the check and the annual rate of 11 kg/ha were much lower.

It has been estimated that to increase soil P by 1 mg/kg in the CW rotation, it was necessary to apply 6 kg P/ha in the previous year or 20.8 kg P/ha seven years before.

Figure 2 shows the relationship between grain yield response and soil P for the CW rotation. The adjusted equation estimates grain yield responses of 1,700, 1,000, 550 and 300 kg/ha for the soil P of 5, 10, 15 and 20 mg/kg, respectively. Soil P for the 90 percent maximum yield was estimated at 17.2 mg/kg. Variations among years are mainly attributed to water availability.

Conclusions

Residual P in Typic Argiudolls of southeastern Buenos Aires Province (Argentina) was high considering the effects on wheat yield and soil P.

Phosphorus use efficiencies for initial rates of 22 and 44 kg P/ha were 164 to 112 kg grain per kg P for the seven years under consideration.

The changes in soil P through the years were highly associated with the initial P rates and yield responses, indicating that the extraction method is accurate enough to evaluate residual P under the conditions of the experiments.

Applications of 6 kg P/ha in the previous year or 20.8 kg P/ha seven years before increased soil P by 1 mg/kg. BCI

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Evaluation of Residual Soil Phosphorus in Pastures and Alfalfa

By Angel Berardo and Fernando Grattone

Growth with no P (P-0) is very limited compared to plots with rates of 50 or 100 kg P/ha.

Phosphorus (P) fertilization studies were initiated in 1994 in mixed pastures (grasses + legumes) and alfalfa. Both studies were established in an Argiudoll soil with Bray P of 9 parts per million (ppm), pH of 6.1, and organic matter content of 6.4 percent. A randomized complete block design with three replications was used for each experiment. Treatments included five rates (0, 25, 50, 100, and 200 kg/ha) of P applied only in the first year, and two rates (25 and 50 kg/ha) of P applied annually.

The objective of these studies is to evaluate the long-term effects of P fertilization on pasture and alfalfa yields, and on soil P levels (Bray P-1). Parallel research includes the study of organic and inorganic P dynamics. The studies will be carried out for at least four years.

Figure 1 shows dry matter production for both studies. In the alfalfa study, dry matter production doubled with the application of 100 kg P/ha, indicating the potential for alfalfa production in Mollisolls of the Pampas with adequate P fertilization. In the pasture study, the lower P response has been explained by a shortage of nitrogen (N) that could be solved with periodical applications of fertilizer N. BCI

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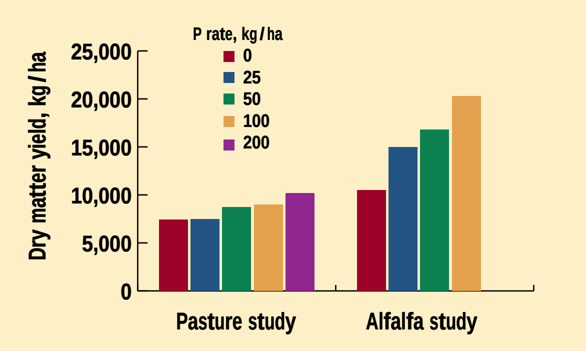

Figure 1. Dry matter production in the first year of the pasture and alfalfa experiments. Balcarce 1995.

Improvement of Root Nodule Nitrogen Fixation and Soil Fertility by Balanced Fertilization of Broad Beans

By Su Fan, Hong Lifang, Hu Jin and Zhong Li

Balanced fertilizer application is the foundation for higher yields of broad beans, and can also improve soil fertility.

In the traditional agricultural practices of Yunnan province, no fertilizer is applied to broad beans. Even in the more advanced agricultural areas, farmers generally apply only phosphorus (P) fertilizer, while potassium (K) is almost always neglected. To increase broad bean yields in large areas where deficiencies of soil nitrogen (N), P and K occur, agricultural researchers in Yunnan conducted experiments to demonstrate to local farmers the benefits of P and K. Balanced fertilization could also improve the fertility of their soils.

Application of both P and K is needed for high yields of broad bean.

Field experiment treatments were established on the basis of soil analyses. Seven NPK treatments were used. Broad bean varieties and plant populations followed local practices. Trials were conducted at Qujing in 1993 and Jinning in 1994.

It is well established by experimental results that N, P and K are important for obtaining high broad bean yields.Results indicate that in most cases, the N required by broad beans can be supplied through N fixation, provided P and K supplies to the plant are adequate (Table 1).

Table 1. Broad bean yield at the two locations in Yunnan.

	Treatments, kg/ha			Yield, kg/ha	
	N	P_2O_5	K_2O	Qujing	Jinning
	0	135	135	3,022	3,444
	39	135	135	3,044	3,491
	54	135	135	3,050	3,275
	0	0	135	1,925	1,877
	0	75	135	2,403	2,495
	0	135	0	2,302	2,106
	0	135	75	2,639	2,812
F-Test	Treatment			5.34 **	8.59 **
	Replication			2.88	3.1

In cases where N is extremely deficient in the soil, a small starter dose of N fertilizer may be needed. Excessive use of N will normally inhibit the effectiveness of N fixing bacteria.

Data also show that application of rational amounts of P and K to broad beans is the foundation for obtaining high yields. Application of 135 kg/ha P_2O_5 increased yields by 57 and 84 percent, respectively, at the Qujing and Jinning test sites. Potassium applied at 135 kg/ha K_2O increased yields from 2.30 to 3.02 t/ha (31 percent) at Qujing and from 2.11 to 3.44 t/ha (63 percent) at Jinning. Thus, as demonstrated at these locations, application of both P and K is essential for high yields of broad beans.

Measurements of nodule dry weight per hectare (based on 2 m^2 sampling area) were made when the crop was in full-bloom (Table 2). Also, the N-fixing capacity of nodules was calculated according to initial and final soil-N analysis and the N content of broad bean plant parts. These data clearly demonstrate that application of P and K increased nodule weight and N-fixing capacity dramatically. While supplemental N gave a slightly higher nodule weight, it did not increase the amount of N fixed. The greatest amount of fixed N resulted with high P and K inputs and no supplemental N. In fact, with 54 kg N/ha, a decline in total N fixation resulted.

Table 2. Effect of N, P and K on nodule weight and biological N fixation of broad bean in Yunnan province.

Fertilizer, kg/ha			Dry weight of nodules, kg/ha		N fixed by nodules, kg/ha	
N	P_2O_5	K_2O	Qujing	Jinning	Qujing	Jinning
0	135	135	130.45	147.56	220.81	247.47
39	135	135	136.67	150.39	187.04	214.16
54	135	135	131.11	151.41	147.71	179.92
0	0	135	95.20	109.27	131.21	112.80
0	75	135	100.78	120.38	181.18	177.03
0	135	0	97.89	105.43	156.90	130.16
0	135	75	122.38	132.98	183.45	196.10

Notes: Plant population 238,095 plants/ha. Nitrogen fixing capacity by root nodule = N1 (removed in pots, seeds, stems, leaves and roots) plus N2 (final soil analysis) minus N3 (added in fertilizer) minus N4 (initial soil analysis).

A study of the input to output ratio was made for N, P and K at both locations. Considering that only the pods and seeds were removed from the field and that the leaves, stems and roots were returned to the soil, calculations were made to measure the effect treatments had on soil fertility. Similar results were obtained for both locations.

As would be expected, there were negative balances (more removal than input) for P and K when the plant nutrients were not applied. When only N applied as fertilizer was considered, the balance was also negative. However, in all cases, the application of P and K showed positive balances, indicating that these plant nutrients could be built up in the soil with repeated applications over time, and when only the pods and seeds were removed from the field at harvest. This indicates that balanced fertilizer application is not only the foundation for higher yield, but is also a prerequisite for improving soil fertility. BCI

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Effects of Potassium Fertilizers on Sugar Beet Yield and Quality

By Li Yu-ying and Liang Hong

Potassium (K) is important to sugar beet yield and quality, in balance with other essential plant nutrients. Two sources of K fertilizer were included in this study.

Sugar beet production is important for edible sugar supply in northern China. The crop is grown on approximately 300,000 ha in Heilongjiang province. Located in the northeastern region of China, the 100 to 140 day frost-free period and large day- and night-time temperature differences make it favorable for sugar beet production.

With K application, sugar beets grew more vigorously.

The crop is a heavy K feeder but the importance of K for improving sugar beet yield and sugar content is still unknown to most growers in the province. The reasons for this relate to (1) limited supply because nearly all K fertilizers are imported, resulting in higher prices, especially for sulphate of potash (K_2SO_4), and (2) many scientists and some farmers have the opinion that chloride (Cl) reduces sugar beet quality. In the final analysis, neither muriate of potash (KCl) nor K_2SO_4 is used. This experiment determined the positive effects of K fertilizers, regardless of source, on sugar beet yield and quality.

The experiment was conducted by pot culture (12 kg air dried soil/treatment) in a screenhouse at the Soil and Fertilizer Institute of Heilongjiang Academy of Agricultural Sciences. The black soil with thin layer used in this experiment is characterized as having 2.9 percent organic matter content and total nitrogen (N), phosphorus (P), and K contents of 0.139, 0.109 and 2.78 percent, respectively. Available N, P and K contents (mg/kg) were determined to be 109.6, 139.0, and 212.0, respectively. Potassium fertilizer was added as either KCl or K_2SO_4 at rates of 50, 100, 150, 200 and 500

Table 1. Effect of K rate and source on sugar beet leaf growth and chlorophyll content.

	Rate, mg K_2O/kg soil	No. of leaves June 23	No. of leaves July 30	Length of leaves, cm June 23	Length of leaves, cm July 30	Chlorophyll content, mg/dm^2 July 5
KCl	50	13.1	27.1	15.2	38.4	7.52
	100	12.5	27.6	14.6	38.9	7.78
	150	14.2	28.9	16.6	39.0	8.41
	200	13.9	26.9	15.3	39.2	6.34
	500	12.3	26.5	14.8	37.7	7.65
K_2SO_4	50	12.4	24.8	14.1	35.8	7.67
	100	13.2	26.7	13.6	36.4	7.75
	150	12.9	25.0	14.9	37.8	7.82
	200	13.5	27.4	15.6	39.1	8.88
	500	13.1	26.3	14.5	38.0	7.70
Ck (NP)		12.8	25.8	13.7	32.6	7.20

mg K_2O/kg soil. Treatment NP was the control (Ck), and rates of N and P fertilizers were equal for each treatment. Where KCl was applied, the N source was ammonium sulphate (12 g/pot) although the soil tested adequate in sulphur (S). The source of P was triple superphosphate (2.6 g/pot).

There was no significant difference between KCl and K_2SO_4 application on sugar beet root yield. Either source increased beet and sugar yield and sugar content.

Effect of Potassium Application on Sugar Beet Growth and Development

Time to seedling emergence as well as its uniformity was consistently good for all treatments, indicating that neither K source had a 'salt' effect on germination.

Data indicate that K fertilizers increase both leaf number and length as well as chlorophyll content compared to the NP control (Table 1). No significant difference between KCl and K_2SO_4 was noted, with the exception that the best application rate for KCl was 150 mg K_2O/kg compared to 200 mg K_2O/kg soil for K_2SO_4. Both sources had a positive effect on sugar beet growth and development.

As a result of improved top growth with the application of K, there was an increase in sugar beet root yield, sugar content, and sugar yield (Table 2). The 150 mg K_2O soil dose from KCl was optimal, increasing sugar beet root yield by 29 percent, sugar content by 2.0 percent and sugar yield by 26.4 percent. Again, the best treatment with K_2SO_4 was 200 mg K_2O/kg soil. In comparison with the control, it increased root yield by 29 percent, sugar content by 0.3 percent and sugar yield by 17.1 percent. However, when considering only sugar content, the best K_2SO_4 treatment was 150 mg K_2O/kg soil, while the best KCl treatment was 100 mg K_2O/kg soil. With KCl, average sugar beet yield was 454 g/pot and sugar yield was 68.9 g/pot. With K_2SO_4, these measurements were 456 and 67.0 g/pot, respectively.

Table 2. Effect of K rate and source on sugar beet yield and quality.

	K_2O rate, mg/kg soil	Root yield, g/pot	Increase over CK, %	Sugar content, %	Sugar yield, g/pot	Water content in the root, %
KCl	50	425	7	16.0	68.2	73.4
	100	411	4	16.5	67.8	69.6
	150	513	29*	15.7	80.6	72.0
	200	439	11	15.0	65.7	71.6
	500	481	21	12.9	62.1	71.4
K_2SO_4	50	438	10	14.7	64.2	73.9
	100	409	3	13.7	56.0	73.6
	150	471	19	16.1	75.9	73.4
	200	511	29*	14.0	71.3	73.0
	500	451	14	14.9	67.2	71.0
Ck (NP)		397	100	13.7	54.2	70.0

Note: $LSD_{0.05}$ = 9.7 (g/pot), $LSD_{0.01}$ = 46.2 (g/pot). *Significant at 5% level.

These results clearly show the positive effect K has on sugar beet growth and development. It increased beet yield, sugar content and sugar yield partly because of increased leaf area and chlorophyll content. With proper rates and placement (broadcast and incorporated) there was no significant difference between KCl and K_2SO_4 on sugar beet yield and quality on this soil with sufficient S. BCI

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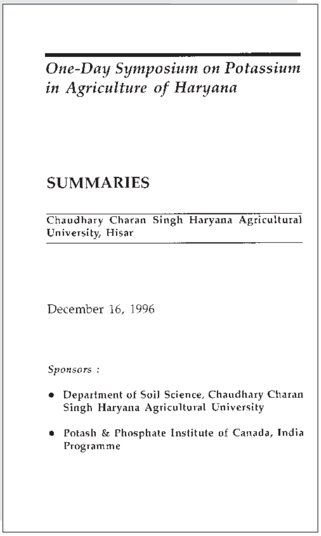
Use of Potassium in Haryana Agriculture Featured in One-Day Workshop



One-Day Symposium on Potassium in Agriculture of Haryana

SUMMARIES

Chaudhary Charan Singh Haryana Agricultural University, Hisar

December 16, 1996

Sponsors :

- Department of Soil Science, Chaudhary Charan Singh Haryana Agricultural University
- Potash & Phosphate Institute of Canada, India Programme

A one-day workshop at Haryana Agricultural University, Hisar, on December 16, 1996, featured review papers by specialists discussing potassium (K) in crops and soils of Haryana State. The program was organized by Haryana Agricultural University and the PPIC-India Programme.

Dr. J.B. Chowdhury, Vice Chancellor of the University, presented the inaugural address. The keynote address, " Potassium for Sustainable Agriculture in Haryana", was given by Dr. S.S. Khanna, Ex Vice-Chancellor of N.D. University of Agriculture & Technology, Faizabad, Uttar Pradesh.

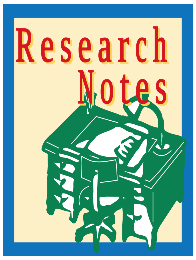
A total of 13 technical papers were presented. The topics and names of presenters follow: *Potassium-An Essential Nutrient*, G. Dev; *Potassium Use Pattern and Projections in Haryana*, H.S. Lohan and A.V. Shanwal; *Available Potassium Status of Haryana Soils*, D.K. Bhandari, J.C. Sharma, R.S. Mehla, B.K. Suneja, S. Dev and O.P. Sagwal; *Potassium Scenario in Haryana Soils*, Balwant Singh and A.V. Shanwal; *Spatial Variability of Available Potassium in Haryana Soils*, M.S. Grewal, I.S. Dahiya, Anil Kumar and M.S. Kuhad; *Potassium Exchange Equilibria in Some Haryana Soils*, S.R. Poonia and S.C. Mehta; *Critical Limits of Potassium and Its Response Under Different Cropping Sequences in Haryana Soils*, Mahendra Singh, S.C. Mehta, S.B. Mittal and Narendra Singh; *Response to Applied Potassium in Some Field Crops in Haryana*, K.S. Grewal and S.C. Mehta; *Response to Applied Potassium in Sugarcane in Haryana*, Y.P. Dang, K.S. Verma and Vijay Kumar; *Studies on Potassium Fertilization of Cotton in Haryana*, Vijay Kumar; *Depletion Pattern of Native Soil Potassium under Pearlmillet-Wheat Cropping Sequence*, Raghbir Singh, Mohinder Singh, M.L. Dixit and S.B. Mittal; *Physiological Studies on Effect of Potassium on Some Crops of Haryana under Water Stress*, M.S. Kuhad, A.S. Nandwal, Narender Singh and Anita Hooda; *Potassium for Fruit Quality*, V.P. Ahlawat, O.P. Gupta and Kartar Singh. BCI

Proceedings and Summaries of presentations for the workshop are available by contacting Dr. G. Dev, Director, PPIC-India Programme, Sector 19, Dundahera, Delhi-Gurgaon Road, Gurgaon-122016, Haryana, India.

Award to India Programme

Dr. G. Dev, Director, PPI/PPIC India Programme, received the Best Poster Award in the Resource Management session of the International Group Meeting "Wheat Research Needs Beyond 2000 A.D." The poster presentation was titled "Maximum Yield Research Shows the Way to Increase Wheat Yields." The Meeting was held at the Directorate of Wheat Research, Karnal, India. BCI

Phosphorus Soil Test Calibration for Lowland Rice on an Inceptisol

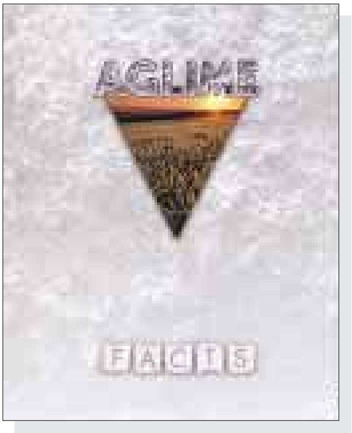


The study was conducted on two field experiments in central Brazil on Haplaquept Inceptisols. In the first year, phosphorus (P) was broadcast at rates of 0, 87, 175, 262, 350 and 437 kg/ha. In the second year band applications of 0, 22, 44 and 66 kg/ha P were made to each plot receiving broadcast P the previous year. Phosphate source was triple superphosphate.

Soil test levels of Mehlich-1 extractable P were categorized, based on relative grain yield of rice from the first year, as very low, low, medium or high. Broadcast P required to build up soil P test concentrations at very low, low, medium and high ratings was 80, 220, 292 and greater than 444 kg/ha, respectively. Rice yields were 0 to 70, 70 to 95, 95 to 100 and 100 percent of relative yield at the very low, low, medium and high soil P levels, respectively. The amount of banded P required for maximum yield at each location was 66 kg/ha for very low and low soil P levels, 44 kg/ha for the medium level, and 22 kg/ha for the high level. BCI

Source: N.K. Fageria, A.B. Santos and V.C. Baligar. 1997. Agron. J. 89:737-742.

Aglime Facts Booklet Now Available



Agricultural lime (aglime) can be a valuable part of nutrient management for profitable crop production systems. Correcting acid soil conditions and maintaining optimum soil pH range are keys to achieving best results with nitrogen (N), phosphorus (P), potassium (K) and other essential nutrients in crop and forage production.

A new booklet...prepared jointly by the Potash & Phosphate Institute (PPI), Foundation for Agronomic Research (FAR), and the National Stone Association (NSA)...offers a useful overview of considerations on aglime. While not an "in-depth" reference text, the 16-page booklet discusses several topics, including: the importance of aglime in agriculture; why soils become acid; determining aglime needs; aglime quality and types; aglime and crop production; and applying aglime. Color photos and charts help illustrate responses and benefits of aglime.

The *Aglime Facts* booklet is available at $2.50 per copy, plus shipping cost. To order or for more information, contact:

Circulation Department, PPI
655 Engineering Drive, Suite 110
Norcross, Georgia 30092-2837
Fax: (770) 448-0439
E-mail: ppi@ppi-far.com

Partners in Progress

Mr. Eldon Lautermilch (at right in photo), Minister, Energy and Mines, Government of Saskatchewan, addressed participants during the International Symposium on Fertilizer in Agricultural Development. Mr. Tommie Sutanu (at left in photo), Managing Director, Odyssey Trading, translated Mr. Lautermilch's comments at a banquet during the Symposium in Beijing, PRC, in October 1996.

To happen…that is, to become a reality…progress requires partners. From outset till fruition, each step along the road of progress is sustained by the support, encouragement, involvement and even critical comment from others. Collectively, partnerships propel people with ideas towards their ultimate goal and success. And collectively, all partners benefit.

Our Institute's International Program is a benefactor of partnering in many ways. Strategic partnering of field staff with leading scientists and agronomists throughout the world is turning their ideas into reality…into increased yields, safeguarded environments and social benefits for farmers and their countries.

Underpinning and supporting this opportunity is the 14-year partnership between Saskatchewan's potash producers and the Government of Saskatchewan, Canada. Mr. Eldon Lautermilch, Minister for Energy and Mines in the province of Saskatchewan recently stated, "The people of this province and their government recognize the inherent benefit of developing world potash markets based on sound, science-based information. It supports this effective and unique 'potash alliance' – of government and industry – because all partners benefit from it. The potash producers benefit because increasing and more stable markets are developed. The people of Saskatchewan benefit through an improving economic base of secure jobs and increased tax revenue. The people of the world benefit because balanced fertilization practices…using potash appropriately, gives rise to sustainable agricultural and economic development."

The progress we make as citizens of the world is often measured by how far down the road we have travelled in terms of producing more food efficiently while being protective of agriculture's land and water resources. As we consider our past, the progress achieved is a lesson in partnering. Future progress will demand it…and opportunity will go to those who ensure strong, strategic alliances. BCI

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

Printed on recyclable
paper with soy ink.