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Banana Response to Potassium

By Antonio López and José Espinosa

Well-managed banana fields require a good supply of potassium (K) to replace that taken-up from the soil and removed in harvest. Research in Costa Rica continues to test response of banana to different rates and sources of K.

Due to high K accumulation in the fruit and plant tissue, K is considered the most important plant nutrient in banana production. It is the most abundant cation in the cells of the banana plant. Potassium does not play a direct role in the plant's cell structure; however, it is fundamental because it catalyzes important reactions such as respiration, photosynthesis, chlorophyll formation, and water regulation. The role of K in the transport and accumulation of sugars inside the plant is particularly important since these processes allow fruit fill and, therefore, yield accumulation.

Potassium deficiency symptoms in banana are common in less fertile soils. However, typical symptoms are difficult to find in well-managed farms, which can not afford low nutrient supplies at any point in the crop cycle. Classic symptoms of K deficiency are described below.

Photo 1. Potassium deficiency results in the development of yellow-orange coloration on the tips of the older leaves of banana plants.

Chlorosis of the leaves: The most characteristic symptom of plants lacking in K is the yellowing of the tip of the older leaves (Photo 1). As time progresses, leaves curl inward and die soon after (Photo 2).

Bunch deformation: Fruit bunches on K-deficient plants are short, slim and deformed because of poor fruit filling.

Stunted growth: It is common for K-deficient banana plants to exhibit slow growth which results in shortened internodes and a sturdy appearance (Photo 3).

The amount of K taken up from the soil and removed from the field as harvested

Table 1. Nutrient content of different banana soils (Andisols) in Costa Rica.

Site	pH (H_2O)	Al + H	K	Ca	Mg	P	O.M.,
		cmol/kg				mg/kg	%
1	4.89	1.32	0.51	4.4	2.4	13	5.9
2	4.71	1.64	0.73	5.0	3.1	18	5.1
3	4.67	1.64	0.72	3.7	2.0	17	7.3
4	4.85	1.76	0.56	5.6	2.5	4	8.9
5	4.74	1.08	0.35	2.1	1.3	5	6.9
6	4.74	1.08	0.63	3.2	2.1	8	8.6

Photo 2. *In later stages of K deficiency, the ends of the leaves turn downward and quickly die.*

bunches is very high. Estimated soil losses through fruit removal alone can be 400 kg K/ha/year with a production of 70 tonnes of fruit. For this reason, banana requires a good K supply, even in soils where K levels are considered high.

The importance of K in banana nutrition has created an abundance of research testing the response of banana to various K sources in different production areas throughout the world. Relevant results of Costa Rican research are discussed here.

Results of Banana Response to Different Potassium Sources in Costa Rica

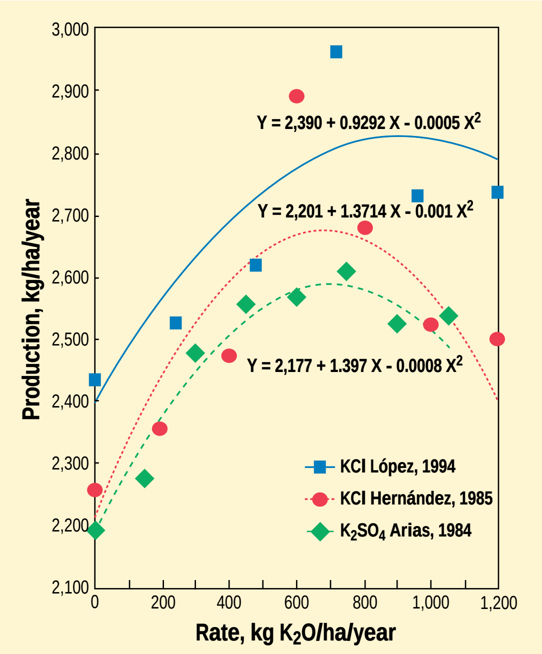

Figure 1. Response to K rates and sources in Costa Rica.

Numerous researchers in Costa Rica have tested the response of banana to different sources and rates of K in several years of field study. This work has defined K fertilizer recommendations used today in Costa Rica and in all banana-producing countries of Central and South America. Soils utilized in these studies were Andisols (volcanic), which are characterized by their relative low fertility (Table 1). Yield responses from past banana experiments on K in Costa Rica are presented in Table 2 and Figure 1.

In all years studied, the best economic responses were obtained with annual K rates ranging from 600 to 675 kg K_2O/ha (Figure 1). Consistent responses to fertilizer K in soils with relatively high K content obviously point to the high K requirement of banana and the large quantities of K being removed from the field. These prescribed levels of fertilizer K produced K concentrations greater than 3.6 percent in foliar tissues, which are considered appropriate for normal crop development. Higher K rates are not advised to avoid induced Mg deficiencies through ion competition.

It is apparent that both sources of K were equally effective in terms of yield response,

Table 2. Yield response to K sources and rates in Costa Rica.

K_2O rate kg/ha	Yield boxes/ha/year*	K_2O rate kg/ha	Yield boxes/ha/year	K_2O rate kg/ha	Yield boxes/ha/year
K_2SO_4, 1984		KCl, 1985		KCl, 1994	
0	2,195	0	2,260	0	2,435
150	2,280	200	2,360	250	2,527
300	2,460	400	2,475	500	2,620
450	2,555	600	2,890	750	2,958
600	2,570	800	2,680	1,000	2,733
750	2,610	1,000	2,530	1,250	2,738
900	2,530	1,200	2,505		
1,050	2,540				

*Exportable banana boxes = 18.14 kg

Photo 3. *The obstruction of normal leaf development is generally associated with K deficiency. However, this symptom can be due to any other factor that affects normal root development and restricts K uptake.*

but from an economic point of view, potassium chloride (KCl) continues to be the most widely used K source in banana production. Concerns have been raised regarding possible negative effects due to the high chloride (Cl) content of KCl (47 percent). However, research conducted in Costa Rica has demonstrated that although KCl application at rates over 1,000 kg K_2O/ha results in high Cl levels in leaf tissue, no negative effects on fruit yield are present.

The main advantage of KCl is the low cost per unit of the nutrient. Other K sources perform well in banana production, but are mainly used to satisfy the plant's need for secondary nutrients such as sulfur (S) or magnesium (Mg). The remaining portion of K required by the plant is subsequently met through application of KCl. BCI

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Banana has a high content of vitamins and minerals, but is known for its high K content of 370 mg/100 g of pulp.

High Fertilizer Input Can Increase the Yield of Late-Planted Wheat

By R.S. Narang, K.S. Gosal, G. Dev and B.S. Mankotia

Higher nitrogen (N) rates along with phosphorus (P) and potassium (K) and other recommended inputs can help overcome the loss in yield potential of late-planted wheat.

The northern states of Punjab, Haryana and Uttar Pradesh (western districts) represent India's granary and contribute greatly to the wheat reserves of the country (Table 1). This region, which encompasses the fertile Indo-Gangetic alluvial plain, is capable of producing above average wheat yields (Table 2).

Table 1. Northern states contribution to India's total wheat procurement (million tonnes).

State	1989-90	1992-93	1993-94	1994-95
Punjab	6.74	6.50	7.29	7.29
Haryana	2.60	3.45	3.05	3.10
Uttar Pradesh	1.58	2.13	1.41	1.30
India (Total)	11.07	12.84	11.87	12.31

Table 2. Wheat area, production and yield.

State	Area, '000 ha	Production, '000 tonnes	Yield, kg/ha
Punjab	3,282	12,724	3,877
Haryana	1,991	7,350	3,692
Uttar Pradesh	9,052	22,203	2,453
India (Total)	25,122	62,620	2,493

The generalized state fertilizer recommendation for wheat on soils with low to moderate K fertility levels is 120-60-30 kg/ha of N-P_2O_5-K_2O. Regions considered high in K fertility are commonly prescribed a reduced rate of 120-60-0 kg/ha. The recommendations for correcting deficiencies in sulfur (S) or zinc (Zn) are to apply 250 kg/ha of gypsum or 60 kg/ha of zinc sulfate ($ZnSO_4$) every two to three years. In northern India, wheat is planted between the last week of October and the second week of November. However, untimely rains and a predominance of small holder farmers commonly delay and over extend the planting period. Sowing wheat during December or early January results in reduced crop productivity and value. Recommendations for late-sown wheat include early maturing varieties and a reduction in fertilizer application rates to 90-60-30 kg/ha N-P_2O_5-K_2O, or about three-quarters of the originally recommended N rates.

This study evaluated several combinations of higher fertilizer input and other best management practices (BMPs) for the purpose of overcoming low yields in late sown wheat.

Materials and Methods

Field experiments on two varieties of wheat (cv. PBW-138 suited for late-sown conditions and cv. HD-2329, a high yielding variety also often adapted for late-sown conditions) were conducted at Punjab Agricultural University, Ludhiana, for four years. The test soil was a sandy loam Typic Ustochrept low in available N and organic carbon (0.34 percent) and medium in available P (22 kg/ha) and K (136 kg/ha). Wheat was sown late (January 6) using a row spacing of 15 cm, thereby establishing a higher plant population than obtained with the state recommended row spacing of 22.5 cm.

Late-sown wheat with normal recommended rates of fertilizer.

Maximum yield research rates of fertilizer improve growth of late-sown wheat.

Results

Grain yield was progressively increased through combination of higher fertilizer input and 50 percent higher plant densities (Table 3). The real breakthrough was obtained with 150-60-30 or 180-60-30 kg/ha N-P_2O_5-K_2O applied with 5 t/ha of poultry manure, which produced average yields of 4.4 t/ha (cv. PBW-138) and 4.0 t/ha (cv. HD-2329) over four years of study. These yields were 15.9 and 20.0 percent higher, respectively, than average yields obtained with the state recommended practice of reduced fertilizer input and lower plant population.

Poultry manure, a rich source of nutrients, contains 1.0 to 1.5 percent N, 1.4 to 1.8 percent P_2O_5 and 0.8 to 0.9 percent K_2O. Therefore, a rate of 5 t/ha supplies 50 to 75 kg N, 70 to 90 kg P_2O_5 and 40 to 45 kg K_2O/ha. As a result, the application of poultry manure along with higher fertilizer input significantly affects the supply of available nutrients to late-sown wheat. All earlier attempts to consistently boost the productivity of late-sown wheat have failed. It is evident that current state recommendations prescribing reduced fertilizer rates are not justified. Both wheat varieties had higher yields in three of the four years studied with increased inorganic fertilizer alone. The findings of this study will help farmers make better management decisions since 15 to 20 percent of total wheat planting is delayed each year. BCI

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Table 3. Grain yield (t/ha) of two wheat varieties grown under different fertilizer treatments and late-sown conditions (January 6) for four years.

Treatment	Variety PBW-138					Variety HD-2329				
N-P_2O_5-K_2O kg/ha	1993-94	1994-95	1995-96	1996-97	Mean	1993-94	1994-95	1995-96	1996-97	Mean
90-60-30	3.7	3.8	3.5	3.6	3.7	3.6	3.2	3.0	2.9	3.2
120-60-30	3.9	4.3	3.8	3.9	4.0	3.7	3.6	3.4	3.5	3.6
150-60-30	4.2	4.3	3.7	3.5	4.0	3.6	3.8	3.3	3.4	3.5
180-60-30	4.2	4.4	3.7	3.5	4.0	3.6	3.9	3.3	3.5	3.6
180-90-45	4.2	4.3	3.8	3.8	4.1	3.6	3.8	3.3	3.4	3.5
150-60-30 + Manure	4.6	4.4	4.3	4.2	4.4	4.2	4.0	3.9	3.9	4.0
180-60-30 + Manure	4.7	4.1	4.4	4.2	4.4	4.3	3.9	3.8	3.8	4.0
C.D. (0.5)	0.3	0.4	0.4	0.2	–	0.2	0.3	0.3	0.3	–

Phosphorus and Potassium Nutrient Management for Vegetable Soils in Shanghai and Guangdong

By Yao Nai-hua, Zhao Dingguo and Jason Wang

Improved nutrient management of nitrogen (N), phosphorus (P), potassium (K) and other inputs could improve yields and quality of vegetables and other crops.

The increasing rate of conversion of paddy soils into vegetable production to meet the growing demand in Shanghai is a result of economic liberalization and population expansion. The 281,600 ha of paddy account for 73.6 percent of the total cultivated land. Paddy soils can be characterized as having 1 to 3 percent organic matter, 0.1 to 0.2 percent total N, 5 to 20 parts per million (ppm) available P, and 70 to 150 ppm readily available K.

Table 1. Nutrient content of paddy (rice-wheat or rice-rapeseed rotation) and vegetable soils along the Huangpu River, Shanghai District.

Cropping History	O.M., %	Total N, %	Available P, ppm	Available K, ppm
Paddy	2.8	0.16	17	108
Vegetable	2.1	0.12	25	84

Table 2. Nutrient content in newly converted paddy and old vegetable soils (25 cm sampling depth) in Jiading County, Shanghai.

Cropping History	O.M., %	Total N, %	Available P, ppm	Available K, ppm
Newly converted	2.1	0.13	24	84
Old vegetable	2.5	0.16	43	97

Although rice yields in the area have increased in the past few years to an average of 8.5 t/ha, P and K nutrient inputs were insufficient to compensate for the amount of each nutrient being removed by each crop. Data obtained from 1991 to 1994 indicate that 1.95 kg P and 64.5 kg K per ha per year were mined from the soil (Shanghai Academy of Agricultural Sciences [SAAS] and PPI/PPIC, 1995). Long-term experiments conducted by the Soil and Fertilizer Institute of SAAS showed that both rice and rapeseed yields increased 5 to 8 percent with the addition of 60 to 120 kg/ha K_2O. In both the rice-wheat and rice-rapeseed rotations, positive yield responses to K were realized when higher rates of N were used. This indicates that crop yields could be further increased by higher fertilizer rates and by using NPK in a balanced manner.

In Guangdong province, where farmers are more economically oriented, profit is the driving force keeping farmers farming. Balanced P and K nutrient inputs applied at the proper time have been shown to improve fertilizer use efficiency and make vegetable farming more profitable.

Phosphorus and Potassium Management in Vegetable Soils

Compared to grain crops, high yielding vegetable production requires more nutrients properly balanced for efficient use as well as intensive soil nutrient supplying power. Experience has shown that after growing vegetables for several seasons on paddy soils and fertilizing them according to local practice, soil P was built up, but K levels remained deficient. The average fertilizer inputs by vegetable growers are 1,000 kg farm yard manure, 180 to 230 kg N, 60 to 90 kg P_2O_5 and 60 to 120 kg K_2O per ha per year. Significant negative changes in soil K level have occurred as a result of these fertilizer practices. Table 1 shows data for paddy compared to vegetable soils along the Huangpu River. Table 2 shows results for a newly converted paddy to vegetable soil compared to a 5 year old vegetable soil in Jiading county.

This cabbage trial is in a Shanghai suburban area.

Nutrient Uptake by Vegetables

Data collected from 1987 to 1990 show the amount of N, P, and K taken up by each tonne of tomato, bell pepper, cauliflower, or cabbage produced (Table 3). Obviously, the higher the yield the more nutrient is taken up by the crop. The $N:P_2O_5:K_2O$ uptake ratios indicate that extra K must be applied to balance both the N and P nutrient inputs required for high yields.

The economic responses when an additional 60 to 90 kg K_2O/ha was added to the local farmers' NPK rates for various vegetables resulted in substantial yield increases (Table 4) and a more marketable product by improving quality characteristics such as firmness, size and shelf life. The combination of higher yields and better quality means higher profits for the vegetable farmer.

Table 3. Nutrient uptake by various vegetables (SAAS, 1992).

Crop	kg nutrients taken up per 1,000 kg yield N	P_2O_5	K_2O	Nutrient uptake ratio $N:P_2O_5:K_2O$ as practiced
Tomato	3.82	1.06	4.65	1:0.28:1.22
Bell pepper	4.91	1.19	4.02	1:0.24:0.82
Cauliflower	15.96	4.99	12.19	1:0.31:0.76
Cabbage	3.28	0.75	2.32	1:0.23:0.71

Table 4. Yield response to K added to NPK fertilizers used by local farmers.

Crop	Duration, years	Yield, t/ha K added	Farmer practice	% yield increase	Location, county
Cabbage	1993-95	38.4	35.2	9.1	Baoshan
Tomato	1992-94	66.4	59.4	11.8	Minhang
Ground nut	1991-93	14.0	13.1	6.9	Minhang
Garlic	1989-92	15.4	13.6	13.2	Jiading
Watermelon	1989-91	30.4	26.4	15.2	Jinshan
Gourd	1987-89	10.7	9.8	9.2	Minshang

Profitable Vegetable Farming System

On a farm newly converted from paddy to vegetable production in Yuanzhou county, Guangdong province, both yield of tsaitai (a green leaf cabbage) and profit increased when the recommended fertilizer rates of 150 kg N, 50 kg P_2O_5, and 96 K_2O/kg were applied compared to rates used by local farmers (Table 5). Recommendations based on soil testing and nutrient uptake patterns were more balanced with respect to N, P and K. Lower P and K rates were suggested for this high N requiring crop, thereby reducing input costs and increasing yield and profit. In the 35 day growing period, 40 percent of the NPK bulk blend with 300 kg single super phosphate (SSP), 12 kg borax and 15 kg zinc sulfate ($ZnSO_4$) per ha was applied as a basal fertilizer. The remainder was applied in 4 split applications at later growth stages.

Although nutrient levels are higher (89 ppm P and 195 ppm K) in this Guangdong soil (Table 5) under long-term vegetable production compared to newly converted fields, adequate and balanced amounts of fertilizer inputs increased sweet corn yield by almost 15 percent, from 11.8 to 13.5 tonnes, while net profit rose by 22.5 percent (Table 6). Higher rates of N (327 kg/ha) and K_2O (404 kg/ha) and a lower rate of P_2O_5 (245 kg/ha) were recom-

Pea plots in Yuanzhou county, Guangdong province, compare balanced fertilization with local farmer practices.

mended compared to the local practice of applying 294 kg N, 288 kg P_2O_5, and 132 K_2O/kg.

Conclusions

A sound P and K fertilizer management plan should balance N, P and K as well as supply other essential nutrients according to soil test results. Balanced fertilizer application is essential for producing crops with top quality and high yields. The amounts of fertilizer applied as well as the timing and method of application are important factors and should be considered in the management plan. The results obtained from Shanghai and Guangdong indicate that local farmers can increase profitability through better plant nutrient management. BCI

Table 5. Yield, production cost and profit for tsaitai production in Yuanzhou county, Guangdong (Canpotex, 1994).

Fertilization plan	Yield, kg/ha	Fertilizer cost	Crop value	Farmer net profit	Profit increase, %	VCR[3]
		yuan/ha				
Recommended[1]	7,380	3,375	20,520	17,145	27.5	6.1
Farmers[2]	6,345	4,200	17,642	13,442	—	4.2

[1] Recommended fertilizer rates: 150 kg N, 50 kg P_2O_5, 96 kg K_2O, 0.1 kg boron (B) and 0.23 kg zinc (Zn) per ha, 4 split application.

[2] Farmer practice: 900 kg/ha compound fertilizer (15-15-15, containing N, P_2O_5 and K_2O).

[3] Value:cost ratio.

Table 6. Yield, production cost and profit for sweet corn production in Yuanzhou county, Guangdong (Canpotex, 1995).

Fertilization plan	Yield[3], t/ha	Cost[4]	Crop Value	Net profit	Profit increase, %	VCR
		yuan/ha				
Recommended[1]	13.54	12,326	32,490	20,164	22.5	2.6
Farmers[2]	11.83	11,934	28,390	16,456	—	2.4

[1] Recommended fertilizer rates: 327 kg N, 245 kg P_2O_5, 404 kg K_2O, 0.1 kg B and 0.18 kg Zn, 3 split applications.

[2] Farmer practice: 294 kg N, 288 kg P_2O_5 and 132 kg K_2O.

[3] Weight of the fresh cob.

[4] Fertilizers, pesticides, labor, and land rent.

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Potassium Supplying Capacity of Some Lowland Rice Soils in the Mekong Delta

By Nguyen My Hoa, Upendra Singh and Henry P. Samonte

The indigenous potassium (K) supplying power of most soils in the Mekong Delta is not sufficient to support the intensive cropping system there. Exchangeable K is a reliable index for measuring the amount of available K under very intensive cropping conditions.

Irrigated rice without K (left), and with K (right).

Crops growing on recent alluvial soils in the Mekong Delta generally do not respond to K fertilizer (Xuan and Hiep, 1970; Ren and Hoa, 1993). These geologically young soils are derived from mica-rich (24 to 50 percent mica) sediments (Uehara et al., 1974) and contain a large proportion of illite in the clay fraction (50 percent illite, 33 percent kaolinite, and 16 percent smectite as reported by Brinkman et al., 1985), giving them good K-supplying capacity. The practice of growing two to three crops each year for more than 25 years, coupled with large applications of nitrogen (N) and phosphorus (P) fertilizers, and the removal of crop residues have decreased the concentration of available soil K to either critical or deficient levels in many regions. No K fertilizer or only small amounts (30 kg K_2O/ha/year) are normally applied to clay textured soils where two to three crops of rice are grown annually. Rice straw removal and burning to clear the land for the succeeding rice crop are common practices. The exceptions to this are saline-intruded soils, where only one rice crop is grown annually and its crop residue is soil incorporated, and sandy soils where farmers are aware of responses to K fertilizer and commonly apply between 30 and 90 kg K_2O/ha/year. Evaluating these lowland rice soils and the K supplying power of the various fractions is essential in determining future K requirements for Vietnam's 3 million ha rice bowl in the Mekong Delta.

Table 1. Chemical properties of the soils.

Soil No.	EC mS/cm	pH H_2O (1:2.5)	OM, %	CEC, cmol/kg	Exchangeable cations Ca	Mg	K	Na
					cmol/kg			
1	0.77	4.35	3.78	20.76	5.14	6.98	0.30	1.51
2	0.35	5.07	7.80	23.40	9.53	7.41	0.31	0.82
3	0.15	5.03	3.51	17.70	8.23	2.40	0.25	0.27
4	0.46	4.78	4.20	23.97	9.66	8.35	0.20	0.85
5	0.18	5.14	2.92	16.77	8.99	2.69	0.21	0.37
6	2.26	4.74	1.79	20.13	4.29	10.14	1.11	4.35
7	0.68	3.67	11.9	15.42	2.20	1.38	0.13	0.45
8	0.22	4.46	4.40	12.99	2.63	1.31	0.08	0.49
9	0.20	6.93	1.51	6.00	2.42	0.42	0.10	0.28
10	0.38	5.72	0.48	3.06	0.72	0.20	0.04	0.10

Table 2. Total K, non-exchangeable K and exchangeable K of the soils used in the study.

Soil No.	Total K %	Non-exchangeable K	Exchangeable K
		cmol/kg	
1	1.70	0.62	0.40
2	1.72	0.41	0.45
3	1.88	0.29	0.35
4	1.49	0.55	0.30
5	1.91	0.59	0.27
6	1.88	0.97	1.24
7	1.20	0.17	0.25
8	0.77	0.21	0.16
9	0.44	0.14	0.12
10	0.57	0.39	0.03

This study had two objectives:

1. To determine the K supplying capacity of the major rice producing soils in the Mekong Delta soils using $HClO_4$-HF acid (total K), boiling 1 N HNO_3 (non-exchangeable K), and NH_4OAc pH 7 (exchangeable K) extractants.

2. To correlate K soil tests and crop response using a greenhouse experiment to exhaust the supply of K in soil.

Ten soils representing four major soil groups in the Mekong Delta were collected, analyzed, and classified according to the FAO-UNESCO classification system (Figure 1). The texture of recent alluvial soils (1-5), the saline-intruded soil (6), the acid sulfate soil (7), and the Plinthosol (8) were determined to contain up to 65 percent clay, 30 to 40 percent silt, and 2 to 11 percent sand. The Podsoluvisol (9) and the Arenosol (10) were sandy textured (89 to 93 percent). Their chemical characteristics are shown in Table 1. Table 2 describes the total K, non-exchangeable K, and available K contents of each soil.

In the greenhouse, pots were filled with one kg soil (2 mm sieve) and were planted with 50 rice plants in four successive crops. The pots were arranged in a completely randomized design with four replications. Fertilizer applications of 330 mg urea (46 percent N) and 260 mg diammonium phosphate (DAP, 18 percent N and 46 percent P_2O_5) were applied three times to each pot, but no K was added to the first three crops. In the fourth crop, 100 mg KCl (60 percent K_2O) was applied three times to all pots in addition to the N and P rates applied to the first three crops. Hoagland's micronutrient solution was applied to all pots once a week to all crops. Plants were harvested 5 weeks after sowing, and the amount of dry matter produced was recorded. Plant samples from each crop were analyzed for K concentration. Total K uptake in each crop was calculated. Soil samples were taken after the second crop for analysis of exchangeable K.

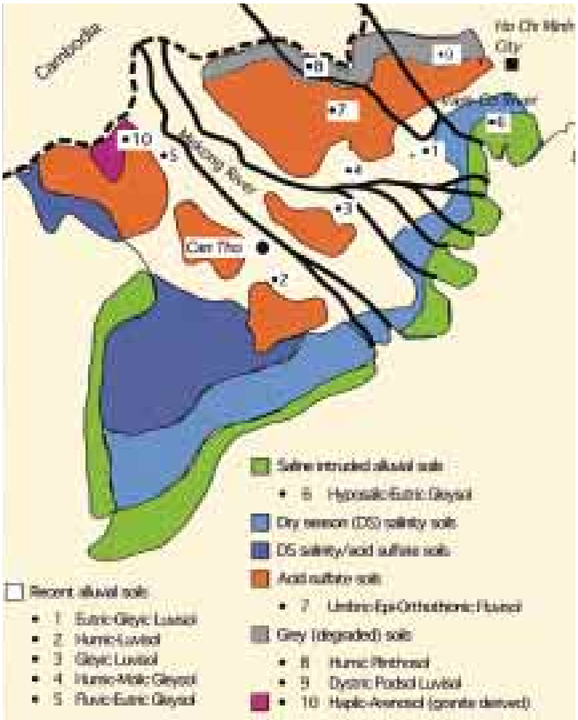
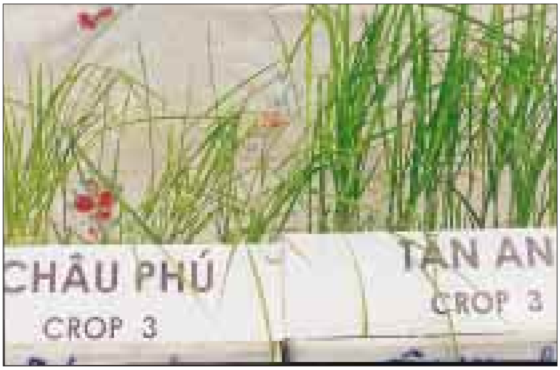


Figure 1. Major soil groups in the Mekong Delta.

Dry Matter Yield, K Concentration, and K Uptake of Rice Plants

Dry matter yields are shown in Table 3. First crop yields grown on the recent alluvial soils were the largest among the 10 soils under evaluation, and yields declined with each successive crop until K was applied to the fourth crop. Growth was severely affected by salinity in the saline-intruded soil and by acute K deficiency in the Arenosol. Plant K concentration shown in Figure 2 was above the critical level of 1 percent (De Datta, 1987) in plants grown in the saline-intruded soil and in the Humic Luvisol where K uptake and soil exchangeable K concentrations were also greatest. In plants grown on the other recent alluvial soils, leaf K concentrations ranged from 0.48 to 0.91 percent.

Differences in soil K supply growth among the alluvial soils, induced by stage of mineral weathering and amount of K supplied by irrigation water, resulted in significant differences in second crop plant growth. The highest dry matter yield among the recent alluvial soil group occurred with the Eutric-Gleyic Luvisol. The most severe K deficiency symptoms (yellowing of leaf, distal tip turned, desiccated, and folded leaves) were observed 3 weeks after sowing in the Fluvic-Eutric Gleysol. Potassium deficiencies were evident on plants grown in all soils, except the Humic Luvisol and saline-intruded soils, which have the greatest K supplying power.



Plant growth during the second exhaustive crop in the Fluvic-Eutric Gleysol (No. 5, at left) and the Eutric-Gleyic Luvisol (No. 1) of the recent alluvial soil group.

The largest dry matter yield, leaf K concentration, and K uptake occurred with the K-rich saline-intruded soil and was the result of leaching of free salts by rainwater. Dry matter yields were smallest in the acid sulfate and the grey degraded soils where exchangeable K concentration was low. Exchangeable K concentrations in soils decreased to 45 to 66 percent after two exhaustive crops (Figure 2). Potassium deficiency symptoms in rice were detected in all except two soils during the third crop sequence and dry matter yields were small. The exception was the saline-intruded soil where leaf K concentration was maintained above 1 percent and K uptake remained adequate. Potassium uptake from all the other soils was inadequate, indicating that the indigenous K supplying power of each soil is insufficient to support the intensive cropping system used by farmers in the Mekong Delta.

Potassium application to the fourth crop produced a large K response in all soils, causing leaf K concentration to be greater than 1 percent (Table 4) and dry matter yields greater than 6 g/pot (Table 3).

Potassium Supplying Power of the Soil

This study showed that, although soil exchangeable K concentration was greater than the critical amount of 0.21 cmol/kg, K fertilizer and proper rice straw and manure management are required in order to preserve soil K fertility in intensively cropped recent alluvial soils. Without proper management, the removal of large amounts of K with each of the two to three crops per year may cause a reduction in non-exchangeable K, decomposition of K-bearing clay minerals, and K fixation which is then only overcome by very large K applications (Tributh, 1987). Potash is required in the acid sulfate soils and the grey (degraded) soils of the Mekong Delta where K supplying power was found to be insufficient to support more than one rice crop.

The saline-intruded soils of the Delta (at least where only one crop per year is grown and straw is recycled) have the largest potential indigenous soil K supplying power as soil K supply was maintained over three consecutive exhaustive crops of rice. However, a response to the large indigenous K supply is only available after desalination. Total K uptake after exhaustive cropping provides an indication of the K supplying power of the soil (Gholston and Hoover, 1948) although plants may not respond to K application in the field despite responses found with the more intensive glasshouse experiments (Ren and Hoa, 1993).

Table 3. Dry matter yield of three consecutive exhausting rice crops (g/pot) and the fourth K-fertilized crop.

Soil No.	Crop 1 -K	Crop 2 -K	Crop 3 -K	Crop 4 +K
1	11.68 bc	9.35b	3.31b	10.17b
2	13.40a	7.88c	2.31c	10.24b
3	12.46ab	4.89d	1.25de	9.81b
4	12.69ab	5.06d	1.65d	8.16c
5	13.49a	3.26e	1.18de	10.16b
6	4.32f	10.87a	12.40a	12.52a
7	9.49e	3.12e	0.74e	7.87c
8	10.95cd	2.91e	0.93e	10.22b
9	9.98de	1.19f	+/	6.53cd
10	2.34g	1.02++/	+/	6.03d

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.
+/ Because of micronutrient problem in the first planting, tests are delayed one crop for correction of the problem. Therefore the third crop of this soil is skipped for the fourth K-fertilized crop.
++/ Replication was incomplete, therefore statistic analysis was not done.

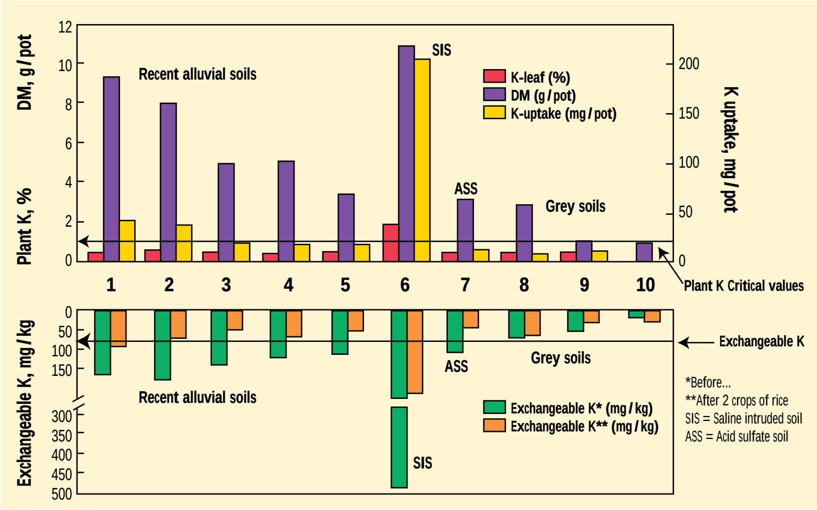


Figure 2. Plant K concentration, dry matter yield, and K uptake of rice grown without K fertilizer in 10 selected soils of the Mekong Delta in Vietnam and exchangeable K in these soils before and after two crops. Results from the second of two consecutive exhaustive rice crops grown in pots (1 kg soil, 50 rice plants per pot).

Correlation Between Amount of K Extracted by Chemical Methods and Amount Extracted by two Successive Exhaustive Crops

Exchangeable K, non-exchangeable K, total K extracted with HNO_3 (exchangeable K + non-exchangeable K), and total K showed no correlation with K released from non-exchangeable forms by soils. There was, however, a highly significant correlation between total K uptake and the amount of exchangeable K before cropping, non-exchangeable K, and total K removed in two crops (r = 0.981**, 0.806**, 0.945**, respectively). The correlation coefficient of the relationship between exchangeable K and K uptake was slightly lower when data from the saline-intruded soil were excluded, but remained highly significant (P<0.01). Non-exchangeable K was not correlated with K uptake when data from the saline intruded soils were excluded.

Table 4. Potassium concentration of rice plants (% K) in three consecutive exhausting crops without K application and the fourth K-fertilized crop.

Soil No.	Crop 1 -K	Crop 2 -K	Crop 3 -K	Crop 4 +K
1	0.75d	0.45c	0.38c	1.37c
2	1.07b	0.46c	0.35c	1.33c
3	0.91c	0.39c	0.49bc	1.40bc
4	0.54f	0.41c	0.48bc	1.64abc
5	0.74d	0.46c	0.55b	1.39bc
6	2.89a	1.90a	1.63a	1.74ab
7	0.68b	0.45c	0.46bc	1.68ab
8	0.51f	0.44c	0.55b	1.38c
9	0.51	0.62b	+/	1.68abc
10	0.48f	–	+/	1.85a

In a column, means followed by a common letter are not significantly different at the 5% level by DMRT.

+/ Because of micronutrient problem in the first planting, tests are delayed one crop for correction of the problem. Therefore the third crop of this soil is skipped for the fourth K-fertilized crop.

Conclusions

Only marginal to adequate concentrations of exchangeable K were found in the recently formed alluvial soils of Vietnam's Mekong Delta. Their K supplying power appears to be related to weathering stage and to K supply in sediments and irrigation water. Potash fertilization on these soils is required to replace nutrients removed in grain and straw, to avoid further deterioration of soil K fertility status, and to increase productivity of high quality rice. Potash must be applied to acid sulfate soils, where exchangeable K is insufficient to support the high yields required by farmers, and to exchangeable-K deficient grey soils. Among the ten representative soils studied, only the saline-intruded soil did not require the addition of fertilizer K after three consecutive and exhaustive rice crops.

Exchangeable K was determined to be a reliable index for measuring the amount of available K under very intensive cropping conditions. Non-exchangeable K, measured by difference, was not reliable for estimating K release to the crops. BCI

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Rice harvest in the Mekong Delta.

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Brazil: Fertility Management for Sustainable Cropping on an Oxisol of the Central Amazon

Researchers established an experiment to determine depletion patterns of soil nutrients, along with aglime and fertilizer requirements, for continuous cultivation after slash and burn clearing. Yield responses were evaluated over an eight-year period and involving 17 crops (including rice, soybeans, cowpea, and corn).

In the absence of fertilizer and aglime, soil nutrient levels dropped, soils became more acidic, and percent aluminum (Al) saturation increased. Mean crop yields with aglime and fertilizer application based on soil tests were 4.1 t/ha/yr compared to 0.2 t/ha/yr for check plots. Total grain yields obtained during eight years of proper soil fertility management were 24 times greater than those under shifting cultivation practices. BCI

Source: Cravo, M.S. and T.J. Smyth. 1997. R. bras. Ci. Solo, Vicosa, 21: 607-616.

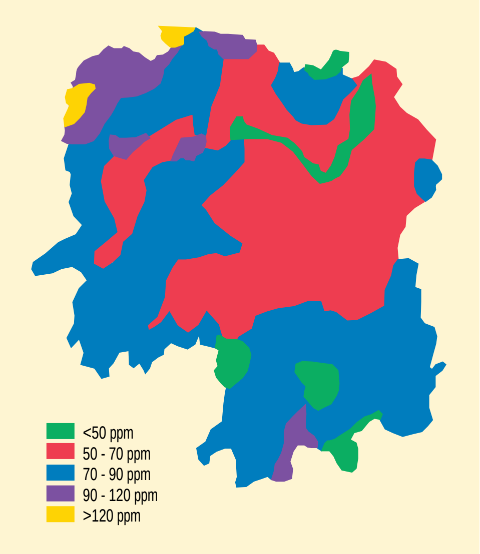
Potassium Supplying Capacity and High Efficiency Use of Potassium Fertilizer in Upland Soils of Hunan Province

By Zheng Shengxian

With recent development for agricultural commodities in the rural economy, upland agriculture is now receiving much more attention. Farmers are aware of the need for balancing the nutrient content of fertilizers they apply by increasing the application of potassium (K) fertilizers because it increases yields, improves crop quality and brings higher prices in highly competitive markets. Thus, it is important to determine the best practices to achieve and regulate K cycling and balance in upland soils.

The province of Hunan, China, has 3.51 million ha of cultivated land, of which 770,000 ha are upland soils. The main upland soil types are classified as red, yellow, yellow brown, black limestome, red limestone, purple, and aquic. In the past, K fertilizer was mainly used in paddy soils with little or none being applied to upland soils.

Figure 1. Distribution of available K in upland soils of Hunan province.



Potassium Content and Distribution in Upland Soils

The red and yellow soils in Hunan, although derived from various parent materials, contain little mica. Because of prolonged intense weathering, they are dominated by kaolinite, giving them the lowest K content of the province's upland soils. All other soils, except those derived from purple shale and Yangtze lacustrine deposits, are low in K (Table 1).

Results of a soil K survey conducted from 1990-1992 indicate that Hunan has about 700,000 ha of cultivated upland soil area suffering from K deficiency and that distribution of these soils is widespread (Figure 1). In the past, about 95 percent of the K fertilizer in Hunan was used on paddy soils. Potassium is required for greater yields on upland soils that have been depleted of their K fertility.

Results comparing the K supplying capacity of the various upland soils are discussed here.

The K supplying capacities of the seven soils (Table 1) were evaluated in terms of their quantity and intensity (Q/I) relationship. Quantity defines the amount of (labile) K adsorbed by the soil. Intensity is a measure of the K in soil solution. Considered together they explain the K supplying power of the soil as well as its buffering capacity and, thereby, its ability to maintain high levels of available K. The relationship of Q and I as it defines the soil's potential buffering capacity is shown in Figure 2.

Table 1. Potassium content of upland soils in Hunan province.

Soil type	Total K, %	Slowly available K, ppm	Available K, ppm
Red soil	1.50	163	62
Yellow soil	1.49	235	70
Yellow brown soil	1.49	237	80
Red limestone soil	1.65	266	74
Black limestone soil	1.90	307	88
Aquic soil	2.06	377	111
Purple soil	2.34	473	119

The concentration of K in the soil solution ranged from approximately 32 to 426 parts per million (ppm) and K adsorption from 0.046 to 0.205 meq/100 g soil. The K buffering capacity of the soil can be described by the ratio of the concentration of adsorbed K to solution K. It ranged from 16.5 to 62.5. Of the seven soils tested, only the purple soil had high K quantity, intensity and buffering capacity. These characteristics were low in the other soils tested, reflecting a poor K supplying capacity which is typical of most upland soils in Hunan.

Using H-resin in six successive soil K extractions to define the soil's K supplying power, it was found that the amount of K extracted was less than 150 mg/kg in six soils and high (623 mg/kg) in the purple soil.

Potassium uptake by 15 successive corn crops in a pot experiment growing in red soil and purple soil was 104 and 523 mg K/kg, respectively (Table 2). This five-fold difference verifies that with the exception of the purple soils, these upland soils have relatively little plant available soil K.

Other exhaustive experiments show that with application of N and P but no K fertilizers, plant available K decreased. In a 3-year, 15 corn harvest pot experiment, available K content in six of the seven soils declined to a minimum level of <40 ppm K by the fourth harvest when no K was applied. Once the available K reached a steady state, the nonexchangeable K was unable to supply sufficient K to plants. Only in the aquic and purple soils did available K decline to a minimum level of <60 ppm K after fifteen harvests.

These results show that K buffering capacity, K release, and K supplying power in upland soils in Hunan are low to very low and inadequate for good crop production. Crop responses to K application are now much more common and widespread.

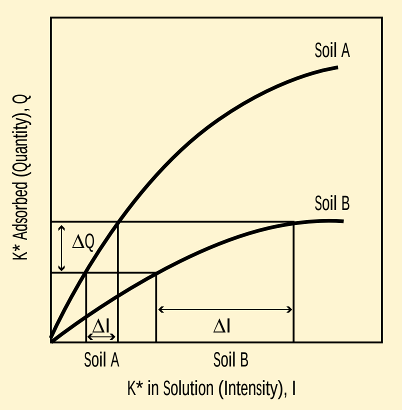


Figure 2. Relationships between K intensity and K* quantity in two soils with different potential buffering capacities (PBC). Soil A has a high PBC since a certain change in Q (ΔQ) results in a small change in intensity (ΔI) while soil B has a low PBC because ΔQ results in a large ΔI. (From Mengel and Kirkby. Principles of Plant Nutrition, 1982).*

Methods of High Efficiency Use for Potassium Fertilizer

About two-thirds of Hunan's cultivated upland area suffers from K deficiency. Unfortunately, fertilizer resources in the province are limited. Thus, it is important to develop and document high fertilizer K use-efficiency management systems which show its maximum benefit to overall fertilizer use efficiency.

There is a close relationship between K supplying power in soils and the effectiveness of applied K on crop yield. Based on this relationship, the effect of K application was divided into five categories (Table 3). It is apparent from these data that K fertilizers provide the greatest benefit in soils with low K supplying capacity as indicated by the calculated value: cost ratios (VCR). Table 3 also explains that the VCR for applied K varies depending on the crop grown and the level of plant-available soil K. The range of VCRs for K for the three crops were:

- Corn on soils with less than 130 ppm available K, 3.3 to 6.2.

Experiments with corn and other crops on Hunan soils show improved yields when K is used in balance with N and other nutrients.

- Peanut on soils with less than 120 ppm available K, 5.0 to 8.3
- Rapeseed on soils with less than 100 ppm available K, 3.1 to 3.8.

Potash applied to soils which have low available soil K levels provide farmers with excellent financial returns for their K investment.

Rational Allocation of Potassium Fertilizer According to Cropping Pattern

Hunan's agriculture can be characterized as being intensive and high yielding based on a multiple cropping system. Potassium application not only increases yields of the first crop in the rotation, but also provides substantial residual benefit to subsequent crops. However, since supplies of K are often limited for farmers, it is necessary to develop a rational allocation strategy which ensures the best supply of K to all crops in the rotation.

From 1989 to 1993 field experiments of four cropping systems showed that K application in the rotations of cotton-rapeseed and tobacco-corn should use the K allocation principle of 'heavy on cotton–light on rapeseed' and 'heavy on tobacco–light on corn.' In the rotations of corn-soybean-rapeseed and peanut-corn-rapeseed, K fertilizers should be allocated with priority to peanut, soybean and corn because they produce the most profit.

Table 2. Potassium uptake during 15 successive harvests of corn plants from upland soils (mg K/kg) in Hunan.

Soil type	Without K	With K[1]	Increase, %
Red soil	104.2	944.3	910
Yellow soil	120.1	967.5	860
Yellow brown soil	123.2	933.6	760
Red limestone soil	141.8	900.1	630
Black limestone soil	148.3	790.5	530
Aquic soil	416.4	1,490.5	360
Purple soil	532.6	1,290.6	240

[1] 1,080 mg K_2O/kg soil added.

Balanced Fertilization with Potassium and Other Nutrients

Nitrogen (N) fertilizer efficiency in upland soils has decreased over time and continues to do so as soil K supply diminishes. High N fertilization hastens soil K decline by producing larger plants with bigger root systems. Combining N with K fertilizers markedly increases the efficiency of N fertilizers as demonstrated in 18 corn experiments. The omission of K resulted in low yields. However, when 240 kg/ha of N was applied in combination with 120 to 225 kg/ha K_2O, yield increased by 25 to 40 percent.

Other experiments show that the addition of K has had the expected positive effect on ramie crop growth and development when it is balanced with N, phosphorus (P) and magnesium (Mg) fertilizer. Results from a 4-year experiment show that on soils with Mg deficiency (<6.0 mg Mg/100g), K application alone at the rate of 120 kg/ha K_2O increased average ramie yield by 4.3 percent. Combining K with Mg fertilizer (30 kg/ha Mg) increased yield by 37.6 percent.

Similarly, experimental results obtained from 1991-1993 suggest that rapeseed and cotton yields were not increased significantly with K application alone on soils with boron (B) deficiency. Potassium fertilizer was effective only when K and B fertilizers were combined. These examples point out the importance of a balanced fertilizer strategy that takes into consideration all plant nutrients. The Systematic Approach supported by PPI/PPIC in China defines the soil's nutrient status and indicates which plant nutrients must be supplied as fertilizers so that the yield opportunity is maximized.

Priority Use of Potassium Fertilizer on Crops Producing More Economic Benefit

The province of Hunan has great potential for growing many economic crops provided sufficient K fertilizer is made available to farmers. All of these crops respond well to K application and give profitable results. Potassium fertilizer should be preferentially allocated to cotton, tobacco, ramie, corn, vegetable, fruit tree and medicinal crops since all of them produce great economic benefit to farmers. BCI

The author is Professor, Soil and Fertilizer Institute, Hunan Academy of Agricultural Sciences, Changsha, China.

Table 3. Optimum rate of applied K, predicted yield, and VCR of three crops on soils with different K supplying powers.

Content of available K, ppm	Optimum rate of K application, K_2O, kg/ha	Predicted yield, t/ha	VCR
Corn			
<60	170	4.67	6.2
60-100	125	5.63	5.8
100-130	110	6.48	3.3
130-150	90	6.38	2.1
>150	68	6.70	2.0
Peanut			
<50	151	2.75	8.3
50-70	108	3.12	6.1
70-90	100	3.43	5.7
90-120	63	3.87	5.0
>120	35	4.05	3.2
Rapeseed			
<50	150	1.09	3.8
50-80	105	1.21	3.6
80-100	92	1.39	3.1
100-120	87	1.45	2.8
>120	45	1.73	1.5

Dr. Fernando O. Garcia Named Director, Latin America – Southern Cone Program

Dr. Fernando O. Garcia joined the staff of PPI/PPIC as Director, Latin America-Southern Cone Program, effective May 1, 1998. He will be based in Buenos Aires, with responsibility for PPI/PPIC programs of agronomic research and education in Argentina, Chile, Uruguay, Paraguay, and Bolivia, as well as the two most southern states of Brazil.

A native of Buenos Aires, Dr. Garcia received his B.S. degree in agronomy in 1980 at the University of Buenos Aires. He then began working at the Balcarce Experimental Station for Argentina's National Institute of Agricultural Technology (INTA). In August of 1987, he received a fellowship to pursue graduate studies at Kansas State University, where he completed his M.S. degree in 1989. After working as a research assistant in soil microbiology, he went on to earn his Ph.D. degree at Kansas State in 1992.

Since returning to Argentina that year, his research has been primarily related to wheat and corn fertilization. Nitrogen (N) and phosphorus (P) fertilization programs have been developed that include the calibration of diagnostic methods and evaluation of N and P sources. He has also studied N and P dynamics under conventional and no-till conditions.

In addition to research and extension, Dr. Garcia has been involved in teaching graduate courses and advising students. He and his family are relocating to the Buenos Aires area. BCI

Importance of Dietary Intake of Potassium in Renal Failure

By R. Prasad and R. Nath

This study, supported by PPI/PPIC, established a model for relating dietary potassium (K) deficiency to different biochemical aspects, using rats as the test animal.

Potassium is essential for all animals as well as plants. In human beings, K helps in the maintenance of normal physiological functions. Potassium plays a particularly important role in specific renal functions relating to heart and muscle control, or with afflicted people, in cardiac ailments and muscular weakness. In addition, erythrocyte function and chemical composition are significantly affected by dietary K intake.

Materials and Methods

Treatments consisted of three groups of rats (Winstar strain). A deficient group was artificially prepared by supplying rats with a K deficient diet (Table 1) and double distilled water while kept in metabolic cages. After the induction of K deficiency, a sub-group of rats was rehabilitated with a K salt mixture (Table 1) for four weeks, while another sub-group was maintained on a K-deficient diet. A normal diet group of rats was kept as the control. Renal functions were assessed by measuring different biochemical parameters, including blood urea, creatinine, plasma electrolyte, and the lipid profile.

Table 1. Compositions of low K diet and salt mixture.

Low potassium diet	Percent composition/100 g
Starch	60.5
Casein	30.0
Groundnut oil	3.5
Salt mixture (without K)	6.0
Vitamins (multi-vitamin tablet)	one tablet
Salt mixture	
Calcium carbonate	20.94
Calcium phosphate	41.00
Cobalt chloride	0.02
Cupric chloride	0.15
Ferric phosphate	3.20
Magnesium sulfate	19.70
Manganese sulfate	0.40
Sodium iodide	0.014
Sodium phosphate	14.80
Zinc sulfate	0.116

Note: Normal diet contained the salt mixture with 16 percent potassium chloride (KCl) and supplemented diet with 24 percent KCl.

Results

Plasma K in deficient rats was significantly lower as compared to rats fed normal or rehabilitation diets (Table 2). However, there was no significant change in plasma sodium (Na) levels in all study groups. Plasma urea and creatinine levels were significantly elevated in K deficient rats. Subsequent K rehabilitation successfully returned serum urea and creatinine to levels equivalent to the control group.

Plasma calcium (Ca) and magnesium (Mg) levels were significantly lower in K deficient rats as compared to the control group (Table 3). Potassium supplementation raised plasma Ca and Mg to levels equaling the control. Erythrocyte Mg level was significantly reduced in K deficient rats, but this Mg deficiency was successfully corrected in the rehabilitated group. These results reflect the important role of dietary K in the homeostasis of Ca and Mg levels in the bodies of rats.

Table 2. Plasma biochemical parameters in the different groups of rats.

	Sodium (Na^+)	Potassium (K^+)	Urea	Creatine
Group	meq/l		mg/dl	
Potassium deficient	142.0 ± 4	2.9 ± 1	58.0 ± 6	2.0 ± 0.5
Control	142.0 ± 3	4.0 ± 1	50.0 ± 6	1.5 ± 0.5
Rehabilitated	142.0 ± 3	4.3 ± 1	52.0 ± 5	1.6 ± 0.7

Values expressed as a mean ± standard deviation of 10 rats in each group.

Table 3. Plasma calcium and magnesium and erythrocyte in different groups of rats.

	Plasma Ca^{2+}	Plasma Mg^{2+}	Erythrocyte Mg^{2+}
Group		meq/l	
Potassium deficient	1.85 ± 0.10	0.70 ± 0.10	4.0 ± 0.60
Control	2.35 ± 0.09	1.20 ± 0.20	4.4 ± 0.80
Rehabilitated	2.40 ± 0.08	1.25 ± 0.21	4.8 ± 0.70

Values expressed as a mean ± standard deviation of 10 rats in each group.

Total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and very low-density lipoprotein (VLDL) were also compared among the treatment groups (Table 4). Serum cholesterol, LDL and VLDL levels were approximately two times higher in the K deficient group as compared to the control or rehabilitated group. Interestingly, the LDL/HDL ratio in the K deficient group was significantly higher than either the control or rehabilitated group. The consequence of this relatively high LDL/HDL ratio would likely be diagnosed as a precursor to coronary artery disease or atherosclerosis. Potassium supplementation, however, was able to return lipid profiles to a normal range.

This study shows that low dietary K intake has major deleterious effects on animal plasma, Ca, and Mg contents as well as lipid metabolism. Calcium and Mg play important roles in signal transduction, muscular activity, and integrity of the cellular membranes as well as in activities of the many enzymes that participate in normal cellular metabolism. It is noteworthy that K supplementation in a salt mixture normalized renal function, Ca, and Mg levels and the lipid profile. Due to recent clinical attention being given to mineral nutrition in body functions and particularly the importance K and Mg, the major intracellular cations, this study has identified their association with cardiac rhythm, general muscle function and the body's response to K rehabilitation. BCI

Dr. Prased is Assistant Professor and Dr. R. Nath is Professor Emeritus, Department of Biochemistry, Post-graduate Institute of Medical Education Research, Chandigarh, India.

Table 4. Total serum cholesterol, low-density lipoprotein, high-density lipoprotein, and very low-density lipoprotein in the different groups of rats.

		LDL	HDL	VLDL
Group	Total cholesterol		mg/dl	
Potassium deficient	200.0 ± 10	130.0 ± 5.0	30.0 ± 1.5	40.0 ± 2.0
Control	130.0 ± 7	60.0 ± 3.0	60.0 ± 2.5	20.0 ± 1.5
Rehabilitated	137.0 ± 8	70.0 ± 4.0	55.0 ± 2.8	25.0 ± 2.0

Values expressed as a mean ± standard deviation of 10 rats in each group.

Tree Phenology and Leaf Mineral Content in Mexican Plum under Rain-fed Conditions

By Samuel Salazar-García and Everardo Becerra-Bernal

Improved nutrient management and monitoring of concentrations could help improve fertilizer application rates and timing for Mexican plum orchards.

Mexican plum leaf and fruit at varying degrees of maturity.

Mexican plum (*Spondias purpurea* L.), also called Spanish plum, red mombin or Ciruela, is a tropical tree of the Anacardiacea family. In Mexico, this species provides an important source of income to many small growers in the states of Jalisco, Nayarit, Puebla, Sinaloa, Chiapas, and Yucatan. The fruit is usually consumed directly from the tree, but it is also appreciated in the ice cream and flavoring industry when dehydrated. Very little information is available on the nutritional requirement, preferred growing conditions, and special growing habit of the tree. Therefore, nutritional and physiological studies are considered quite timely. This study reports the phenology and nutritional status of a rain-fed Mexican plum orchard throughout an annual cycle.

In contrast to most tropical and subtropical fruit trees, Mexican plum undergoes defolia-

Figure 1. Mexican plum tree phenology and climatic data over the annual cycle in Jicote, Nayarit, Mexico (measurements averaged over two years).

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		Flowering										
			Fruit harvest									
				Harvest								
					Vegetative growth							
						Root growth						
								Floral differentiation				
									Defoliation			
	Dormancy										Dormancy	
Temp (°C)	22	23	24	24	28	30	29	28	28	28	27	25
Rain (mm)	0	0	0	0	0	21	330	355	274	19	35	36

Table 1. Comparison between established N, P, K, Ca and Mg leaf concentration levels of stone fruit trees[1] and nutrient levels of Mexican plum leaves measured in September.

	Nutrients (% dry weight)				
	N	P	K	Ca	Mg
Stone fruit trees[1]	2.0 - 3.5	0.14 - 0.25	1.1 - 3.5	1.4 - 4.0	0.25 - 0.80
S. purpurea[2]	2.39	0.10	0.70	1.48	0.27

[1] Based on adequate levels of stone fruit trees (Robinson 1986).

[2] Average nutrient concentrations found in Mexican plum during the September 19th sampling.

tion in the fall and dormancy during most of the winter season. Flowering and fruiting occur when trees are defoliated. In this study, the first sign of new vegetative growth was detected in May during the start of fruit harvesting (Figures 1 and 2). During this vegetative stage, leaf growth, expressed both as dry matter and leaf length, showed a double sigmoid curve (Figure 3). Vegetative growth ceased by October, which brought the first symptoms of leaf senescence and subsequent tree dormancy.

Leaf growth and foliar content of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) were determined in the Mexican plum leaf dry matter at monthly intervals (Figure 4).

Concentrations of N, P, K, and Mg decreased with leaf age until leaf growth finished in September. Leaf Ca concentration increased during the same time period. The various sampling times and nutrient concentrations suggest fertilization calculations and nutrient diagnostics would be most successful when based on leaf analysis of samples taken in September. Tree nutritional status obtained in September was compared to each sampling time as well as nutritional standards considered optimal for stone fruit trees (Table 1). Results suggest adequate N, Ca, and Mg levels were present, but P and K were below optimum throughout May to October. It is apparent that increased P and K fertilization is an important part of improving yield and fruit quality of commercial Mexican plum orchards. Time of application and amount of P and K fertilizers are factors that limit fruit productivity and profit and require detailed study. BCI

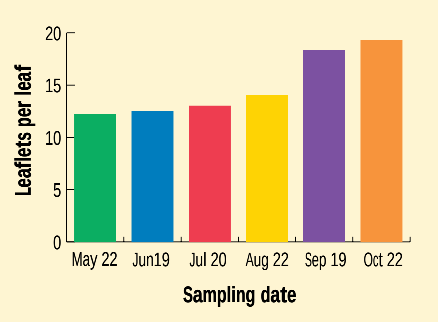


Figure 2. Leaflet production in leaves of Mexican plum over the vegetative growth period.

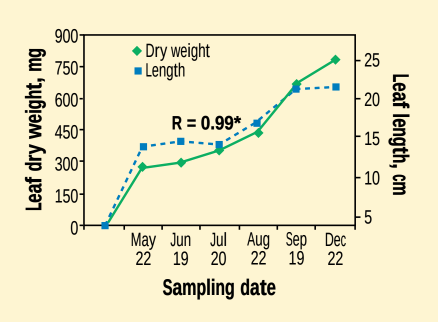


Figure 3. Leaf growth and dry matter accumulation in Mexican plum.

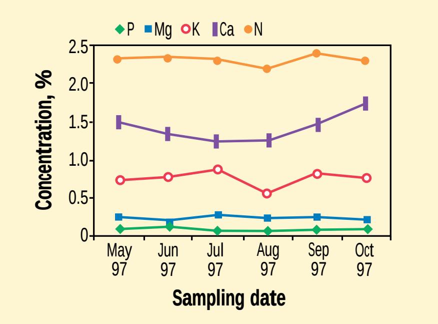


Figure 4. Foliar nutrient dynamics in Mexican plum.

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Effect of Annual Potassium Application in Fixed Location Trials with Rice in Jiangxi Province

By Luo Qixiang, Tao Qixiang, Liu Guangrong, Li Zuzhang and Xu Zhaolian

Jiangxi is one of the major rice producing provinces in south China. There are 2.54 million hectares sown to paddy rice in the province. The double rice cropping system occupies over 80 percent of the total cultivated area. About 80 percent of the potassium (K) consumed in the province is used on paddy soils.

This study to determine the best K rates when manure is used, and the resulting soil K balance for the double rice cropping system, began in 1986. It was conducted for five years at two locations. One soil was derived from alluvial material (Liantang town), the other from sandy rock (Gao'an county).

The five plant nutrient treatments used were: (1) NPK_0; (2) NPK_{45}; (3) NPK_{90}; (4) NPK_{135}; (5) NPK_{90} (OM), where the numbers indicate the amount of applied K_2O per ha for each crop. In treatment 5, half the K came from inorganic fertilizer...potassium chloride (KCl), the other half from organic manure (OM)...milk vetch for early rice, rice straw for late rice. The same adequate rates of nitrogen (N) and phosphorus (P) were applied to all treatments.

Yield results over five years with 10 rice crops indicated that for both locations very significant yield responses resulted as the K rate increased from zero to 135 kg K_2O/ha for each crop (Table 1). For early rice, the average yield increase was 405 to 1,345 kg/ha (percent increase ranging from 8.9 to 23.9 percent). One kg K_2O produced 5.7 to 18.6 kg rice with a profit of 486 to 1,614 yuan/ha and a value: cost ratio (VCR) ranging from 8.1 to 26.4.

For late rice, the same rates of applied K increased rice yield by 765 to 1,329 kg/ha

Table 1. Response of different rates of K application on rice yield during 1986 to 1991.

			Early rice, 5-year average			Late rice, 5-year average		
Soil	K_2O rate, kg/ha	5-yr total yield	Yield, kg/ha	Increase from K, %	kg rice/kg K_2O	Yield, kg/ha	Increase from K, %	kg rice/kg K_2O
Alluvial soil	NPK_0	47,399	4,842	–	–	4,488	–	–
	NPK_{45}	56,543	5,827	16.7	18.6	5,457	21.6	21.5
	NPK_{90}	59,082	6,061	21.4	11.9	5,755	28.2	14.1
	NPK_{135}	60,167	6,187	23.9	8.9	5,815	29.6	10.2
	NPK_{90}(OM)	57,764	5,829	16.8	9.3	5,722	27.5	13.7
Red sandy soil	NPK_0	48,273	4,557	–	–	5,277	–	–
	NPK_{45}	55,016	4,962	8.9	9.0	6,042	14.5	17.0
	NPK_{90}	57,137	5,257	15.4	7.8	6,169	16.9	9.9
	NPK_{135}	58,113	5,322	16.8	5.7	6,300	19.4	7.8
	NPK_{90}(OM)	57,396	5,238	14.9	7.6	6,153	16.6	9.7

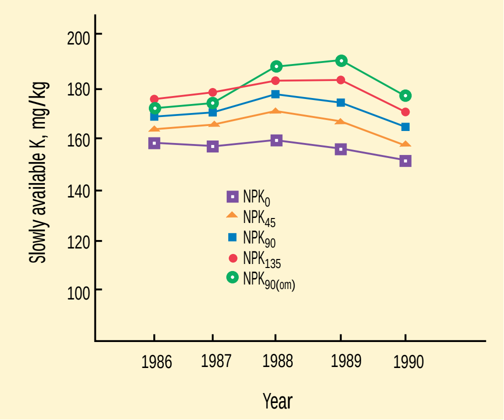

Figure 1. *Annual dynamics of slowly available soil-K in different treatments.*

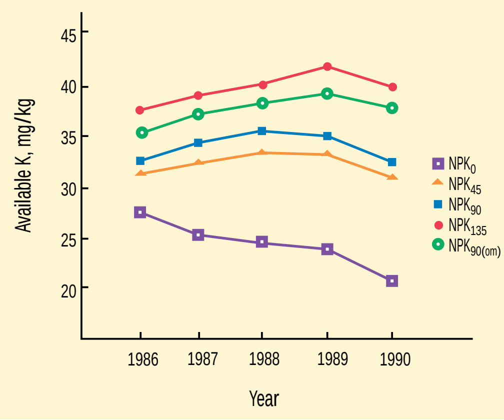

Figure 2. *Annual dynamics of available soil-K in different treatments.*

(percent yield increase ranging from 14.5 to 29.6). Profit ranged between 399 to 640 yuan/ha with a VCR of 2.4 to 8.7.

The response to K application by late rice was better than early rice for two possible reasons. Reason 1: The soil's K-supplying capacity when early rice is growing is better than during late rice growing period. This reason relates to the long fallow period between late rice harvesting and early rice transplanting. Soil weathering could release more available K during this time whereas available K content during late rice growth may be very low because of uptake by early rice. Reason 2: Hybrid rice which is very popular for late rice plantings requires more K than traditional varieties.

Rice yield was increased by increasing K fertilization. The optimum rate calculated by regression analysis between yield and fertilizer rate was 117 to 135 kg K_2O/ha/yr. The ratio of K needed for early rice to that needed for late rice was about 1:1.4 to 1.6 or 45 to 63 kg K_2O/ha for early rice and 72 to 90 kg K_2O/ha for late rice.

When comparing K from inorganic fertilizer (NPK$_{90}$) and organic manure [NPK$_{90}$(OM)], the responses were similar. This indicates that K from milk vetch or rice straw had the same effect as K from mineral fertilizer except for early rice on the alluvial soil. Planting green manure and returning rice straw to the field in combination with fertilizer K should improve soil K balance as well as reduce the K fertilizer requirement needed to grow the other three treatments.

Table 2. Effect of different rates of K application on K uptake by rice plants.

Soil	Treatment K_2O rate, lb/A	Total K uptake in five years, kg K_2O/ha	Total K input, kg K_2O/ha	K uptake increase		K utilization efficiency, %
				kg/ha (NPK$_{45}$-NP)	% (NPK$_{45}$-NP/NP)	
Alluvial soil	NPK$_0$	754.7	–	–	–	–
	NPK$_{45}$	1,181.9	450	427.2	56.6	95.1
	NPK$_{90}$	1,536.6	900	781.9	103.6	86.7
	NPK$_{135}$	1,871.4	1,350	1,116.7	148.0	82.7
	NPK$_{90}$(OM)	1,549.4	900	794.7	105.3	88.3
Red sandy soil	NPK$_0$	813.9	–	–	–	–
	NPK$_{45}$	1,241.3	450	427.4	52.5	94.7
	NPK$_{90}$	1,643.4	900	829.5	101.9	92.2
	NPK$_{135}$	1,825.8	1,350	1,011.9	124.3	75.0
	NPK$_{90}$(OM)	1,607.3	900	793.4	97.5	88.2

Grain K content was not influenced by different rates of K application. The K content of grain depended mainly on genetic characteristics of the variety. Potassium content of rice straw was, however, influenced by K rates. In treatments with the highest K rate, plants showed luxury consumption of K. There was some difference in K utilization efficiency between different treatments with efficiency for

Comparison of NP and NPK treatments in the field.

Long-term experimental field for different rates of K on rice.

grain production decreasing as rates of application increased (Table 2).

The total annual K uptake by rice plants in the NPK_0 treatment (without applied K) declined rapidly year by year. For instance, total K uptake by rice plants for this treatment on the alluvial soil in the fifth year was only 50.9 percent of that in the first year. In the red sandy soil, it declined even more rapidly to only 27.2 percent of the amount of K taken up in the first year (Table 3).

Data from the red sandy soil (Table 4) show that total soil K, slowly available K and available K in the NPK_0 treatment after five years of cropping were much lower than before the experiment began. While the soil K status for treatment NPK_{45} generally remained unchanged, the content of available K and slowly available K increased for treatments NPK_{90} and NPK_{135} compared with original levels. This demonstrates that in the case of high rates, K can accumulate in the soil. Applying organic manure with K fertilizer favored a good soil K supplying capacity as this treatment increased K supply from all soil K sources. See Figures 1 and 2.

Conclusions

- The application of K to either early (45 to 63 kg K_2O/ha) or late rice (72 to 90 kg K_2O/ha) produced significant responses and was profitable.
- Potassium response on late rice was greater than with early rice.
- Growing and incorporating green manure and/or returning rice straw to the field added supplemental K to the soil, allowing for reduction in mineral K requirements to sustain the same yield level.
- When K was applied, high levels were found in the rice straw which acted as a reservoir

Table 3. Total annual K uptake in NPK_0 treatment.

	1986	1987	1988	1989	1990	Total
Soil	kg/ha					
Alluvial soil	213.3	125.3	175.5	131.8	108.7	754.5
Red sandy soil	354.0	136.7	120.8	105.8	96.3	813.9

Table 4. Comparison of soil K content in different forms between experiment initiation and after 5 years on a red sandy soil.

Experiment initiation				After five years of experiment					
Total K, %	Slowly available K, ug/g	Available K, ug/g	Treatment	Total K %	±	Slowly available K ug/g	±	Available K ug/g	±
1.72	161	27.4	NPK_0	1.72	0	154	-7	21.4	-5.6
			NPK_{45}	1.72	0	161	0	30.5	3.1
			NPK_{90}	1.72	0	167	6	34.0	6.6
			NPK_{135}	1.74	.02	174	12	38.0	10.6
			NPK_{90}(OM)	1.74	.02	180	19	40.0	12.6

that could be returned to the soil.

- As expected when K was not applied, soil K was depleted. This is a prime example of soil nutrient mining and proves that if adequate K is not applied with present crops, more will be needed in the future.
- Potassium is an important plant nutrient for rice production in the alluvial and red sandy soils of Jiangxi province. BCI

Luo Qixiang is President, Soil and Fertilizer Institute (SFI); Tao Qixiang is Director, SFI; Liu Guangrong is Deputy Director, SFI; Li Zuzhang is Fertilizer Division Chief, SFI, Jiangxi Academy of Agricultural Sciences, Nanchang.

Potash Development Institute Established in Pakistan

To sustain the CIDA-Canpotex-PPIC inititative on research and development of potash (MOP) use in Pakistan, the Pakistan Agricultural Research Council (PARC) has set up the Potash Development Institute. Inaugurated on March 17, 1998, at the National Agricultural Research Centre, Islamabad, by Dr. Zafar Altaf, Chairman, PARC, and Dr. Mark D. Stauffer, President, PPIC, the Institute operates with the following objectives:

- To study the behavior of potassium (K) in Pakistan soils.
- To monitor the effects of fertilizers on a long-term basis at selected sites.
- To promote the use of balanced fertilization, with emphasis on potash, through demonstrations in farmer fields.
- To disseminate technical information amongst extension agronomists and farmers.
- To address environmental concerns related to soils and fertilizer use.
- To liaise with the government and fertilizer industry on issues related to current and future use of potash in Pakistan. BCI

Dr. M.D. Stauffer, left, and Dr. Zafar Altaf, right, at opening of Potash Development Institute. M. Tahir Saleem, second from right, serves as PPIC project coordinator.

Potash Studies Show Early Benefits in Western Australian Grain

By M. Wong, N. Edwards and Yash Pal

A jointly-funded study on potassium (K) for wheat in Western Australia was initiated in 1995 and is already showing strong yield responses to the application of fertilizers.

The benefit from K applications to soils in the higher annual rainfall (over 600 mm) regions has already been demonstrated, especially on pasture where increases in dry matter production and pasture quality (more clover and protein) are obtained.

This study was established with the main objectives of:

- Identifying and qualifying the soil processes by which K and other major soil cations are cycled, retained, or depleted under normal farming practices in the medium rainfall (400 to 600 mm rainfall) cereal belt.
- Determining the factors which affect grain yield and quality on a range of soil types; responses to applied K, including the effects of increased yield potential on K requirements; nitrogen (N), phosphorus (P), K, sulfur (S) interactions; and the residual effects of applied K on subsequent pasture, wheat and lupin crops.
- Developing laboratory methods for predicting K requirements and improving K recommendations for sustainable farming systems on the sandplain and duplex soils in Western Australia.

Premature yellowing of young leaves starting from the tip and stunted growth of K-deficient wheat are shown in plant at left (which received NPS) compared with healthy plant at right (which received NPKS). Photo source: Wesfarmers – CSBP.

The soils in the main cereal producing areas of Western Australia are predominantly duplex soils with a very sandy surface layer overlying a thin layer of gravel and a clayey subsoil. These very old soils are mostly devoid of K bearing minerals. Large areas of similar soil types are used for crop production in other states of Australia. The depth of the overlying sand layer varies from about 25 cm to nearly one metre. The clay consists mainly of kaolinite and sesquioxides.

Deep sand plain soils have very low K reserves and soil K test values (less than 40 mg K/kg soil Colwell sodium bicarbonate extractable K in the top 10 cm) but are important agricultural soils in the region. Trends of increasing grain yield have been obtained by the use of N, P and micronutrients, better rotations, weed management and other agronomic practices. Little K is currently used in spite of the fact that it is one of the plant nutrients that is removed in the greatest amounts during harvest.

Field trials located at five Western Australia sites (from Moora and Badgingarra north of Perth to Nyabing, 400 km southeast of Perth) included basal fertilizer treatments of N, P, and trace elements as required. Potassium fertilizer was applied at various rates and times to wheat, lupins, and subterranean clover pastures to measure current and residual responses to K, interactions with other nutrients and its cycling in the crop/soil system. The climate is Mediterranean. Crops are sown in May/June in autumn and harvested in December/January in summer.

Three years of drought conditions very badly affected all sites in the program. In 1996, improved seasonal conditions, with rainfall much closer to normal, enabled marked responses to the fertilizer treatments.

Some notable results to date include:

- Dry matter production measured during the growing season showed a 32 percent increase with the highest rate of K applied over the nil K treatment at the site testing 40 mg K/kg in the top 10 cm of soil.
- At this site, the highest K treatment increased grain yield by 25 percent. At another site, grain yield increased 35 percent with the highest rate (200 kg K/ha) when applied the previous year.
- Differences in the effect of crop rotation on the response to residual K. Wheat grown after lupin gave a 20 percent increase in yield compared to the 35 percent increase for wheat grown after sub clover. The residual effect of K fertilizer is important.
- Soil analysis showed that K applied in 1995 was either taken up by the plant or remained largely in the cereal rooting depth of the soil. In a supplementary leaching study which sampled soil solution, calcium (Ca) and magnesium (Mg) were leached in the greatest amounts. The amount of K lost by leaching was similar to the amount of K taken up by crops. It is expected that research on leaching will enable better recommendations for optimum timing of K fertilizer application and its residual value.
- Preliminary conclusions show that there is a high correlation between grain yield of wheat and rate of applied K at responsive sites. This relationship is described by the Mitscherlich equation which states that when plants are supplied with adequate amounts of all but one nutrient, their growth is proportional to the amount of the limiting nutrient supplied to the soil.
- Lupins are less responsive to K than wheat. Responses that are obtained are both smaller and inconsistent across sites.
- These soils absorb and release K in varying amounts according to their texture, organic matter content, and type of clay. The amount of K adsorption can be fitted accurately with the Freundlich adsorption isotherm. Each soil will exhibit different fertilizer requirements depending on its K adsorption and release characteristics.


Response of wheat to K on a duplex soil at Bulyee in Western Australia. Wheat at left was fertilized with NPKS; wheat at right received only NPS. Photo source: Wesfarmers – CSBP.

While it is too early in the program to draw firm conclusions on the recommended rate of K application, there is sufficient evidence to suggest that for a very large part of the Western Australian wheat growing area, large yield responses to applied K will occur. This is in contrast to findings several decades ago when responses of cereals to K fertilizers were inconsistent and rare. The depletion of the small reserves of native soil K by crop removal, leaching, and higher yields because of greater use of N, P, Ca, S, and micronutrient fertilizers and other agronomic practices explains the development of K deficiency in the cereal belt. It is considered that K deficiency not only limits crop performance, it also decreases the use efficiency of N and P fertilizers. These studies are continuing and are expected to be completed in 1999. BCI

M. Wong is with CSIRO Land and Water, N. Edwards is with Agriculture Western Australia, and Yash Pal is with the University of Western Australia. Research funding is provided by Australia Grains Research and Development Corporation (GRDC), CSIRO Land and Water, Agriculture Western Australia, University of Western Australia, Wesfarmers-CSBP Ltd. (a local fertiliser company), Canpotex Ltd., and PPI/PPIC through Agrow Australia Pty Ltd.

Potash Improves the Yield and Quality of July Elberta Peach

By R.P. Awasthi, V.P. Bhutani, M.S. Mankotia, N.S. Kaith and G. Dev

This study explains the effects of potassium (K) fertilizer on yield and quality of July Elberta peach. Potassium is known as the quality element. Important fruit characteristics that are significantly affected by K include size, shape, color, taste, shelf life and transportability. Peach is an important and highly nutritious fruit grown and consumed in India. Even though the importance of K in improving yield and fruit quality is known for several crops, little information is available in India for peaches.

Materials and Methods

Research was conducted during 1991 and 1992 at the University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. Potash treatments were 300, 400, 500, 600, 700, 800 and 900 g K_2O/tree applied as muriate of potash (KCl). Basal rates of nitrogen (N) and phosphorus (P) were applied as urea at 500 g N/tree and single superphosphate (SSP) at 250 g P_2O_5/tree. Half the N and all of the P and K were applied three weeks before flowering in the second week of February. The remaining N was applied just after fruit set in March-April. Nitrogen was broadcast, and P and K were placed 15 cm deep in the drip line of each tree. At harvest, yield per tree and weights per fruit were recorded. Ten representative fruit were collected at random from the periphery of each tree and analyzed for quality indicators such as total soluble solids (TSS), titratable acidity, and fruit firmness.

Potassium fertilization improved yield and quality of peaches in this study in India.

Results

In both years, application of 500, 600 and 700 g K_2O/tree progressively increased fruit yield over amounts obtained with 300 g K_2O/tree (Table 1). Fruit yield increased significantly as K application was raised from 300 to 700 g K_2O/tree. Highest yields over two years were 28.5 and 29.8 kg/tree with 600 and 700 g K_2O/tree, respectively. Potassium application beyond 700 g K_2O/tree depressed fruit yield in both years. Fruit yield and weight exhibited similar responses to fertilizer K.

Potassium application affected fruit quality by significantly increasing total soluble solids and fruit sweetness. Application of either 600 or 700 g K_2O/tree significantly increased TSS over amounts obtained with 300 g K_2O/tree. In both years, TSS was maximized at 11.7 and 11.3 percent, respectively, with 700 g K_2O/tree (data not shown). A two-year average of

Table 1. Effect of K fertilizer on peach yield and weight.

Treatment g K_2O/tree	Fruit yield, kg/tree Year 1	Year 2	Mean	Fruit weight, g/fruit Year 1	Year 2	Mean
300	25.6	20.9	23.3	86.8	87.6	87.2
400	26.9	22.5	24.7	89.6	90.7	90.2
500	27.6	23.2	25.4	93.2	93.9	93.6
600	29.9	27.0	28.5	96.0	97.5	96.8
700	31.2	28.3	29.8	99.0	102.4	100.7
800	26.0	23.2	24.6	90.0	91.2	90.6
900	25.6	22.7	24.2	88.8	88.2	88.5
C.D. (5%)	1.6	1.9	–	5.8	3.7	–

titratable acidity determined a maximum fruit sweetness of 0.49 percent, also obtained with 700 g K_2O/tree (data not shown). Differences in fruit firmness could not be detected amongst the various K application rates.

Current K recommendations for peach range from 500 to 600 g K_2O/tree. On the basis of this research it can be concluded that peach orchards would benefit from minimum K_2O rates of 600 g/tree. Fruit yields were highest at the 600 g K_2O/tree application rate.There was also a significant improvement in titratable acidity (sweetness) in the second year with 700 g K_2O/tree. Countrywide adoption of this science-based recommendation will lead to significant improvement in fruit production and quality, while helping India meet its large nutritional demands. BCI

Dr. Awasthi is Dean, College of Horticulture; Dr. Bhutani is Professor, Dr. Manokotia is Assistant Professor, Dr. Kaith is Assistant Scientist, at Dr. Y.S. Parmar University of Horticulture & Forestry, Nauni - 173 230, Himachal Pradesh. Dr. Dev is Director, PPI/PPIC-India Programme, Gurgaon - 122 016.

Dr. Chen Fang Joins PPI/PPIC Staff as Deputy Director, Central China

Dr. Chen Fang has joined the staff of PPI/PPIC in the new position of Deputy Director, Central China. He will work from a newly established office associated with the Hubei Academy of Agricultural Sciences in Wuhan, effective April 1998.

Dr. Chen was born in Guangdong province, studied Soil Science and Fertilization in Guangxi Agricultural College, and received a B.Sc. degree in 1982. He completed his Ph.D. degree in Plant Nutrition and Fertilization from Huazhong Agricultural University in 1997.

Recently, Dr. Chen has been involved in the Management Department of Scientific and Technical Projects, Hubei Academy of Agricultural Sciences. From 1987 to 1996, he had responsibility for numerous cooperative research and demonstration projects on balanced fertilization. During this time, potassium (K) need and improved nutrient application techniques were identified for numerous crops.

In his new responsibility, Dr. Chen will direct programs in agronomic research and education related to market development for potash and phosphate. BCI

Research and Education: They Are Mankind's Hope

Dr. M.D. Stauffer, PPI/PPIC, (seated at left) and President Liu Ding Fu, Hubei Academy of Sciences, (seated at right) sign agreements at inauguration of PPI/PPIC office in Wuhan, Hubei Province, China.

China's agriculture is emerging and transforming from traditional farming practices to one which strives for high yields, high quality, and high efficiency. This new agricultural objective...based on better science, new technology, and effective industry...is utilizing domestic capability as well as accessing global inputs.

Recent advances can only be characterized as outstanding in terms of rate of development and change, given the formidable challenges of population and a relatively small arable land area. PPI/PPIC has been recognized by our Chinese partners as being significant in the process of helping China meet its food production potential and in rediscovering its capacity to achieve the high level of food production its people require. Of course, advances were made through multiple alliances...with Canpotex Ltd., CIDA, the governments of Canada and Saskatchewan, and most importantly, the government of the People's Republic of China...all using the leverage provided by the North American producers of potash and phosphate fertilizers, through PPI/PPIC.

Alliances are important. China's emergence globally is fundamental to its transformation. Progress in agriculture requires the free-flow of ideas and people, science and technology, goods and services. As world population grows and man's impact on his environment increases, new technologies and further transformations must be sustained. Research and education are the tools. They are mankind's hope. BCI

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