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.

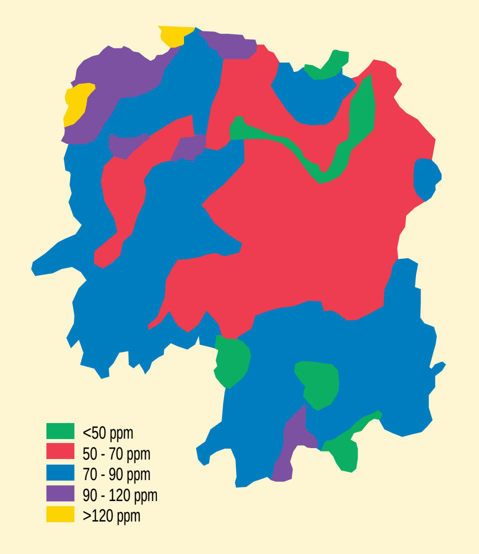

Figure 1. Distribution of available K in upland soils of Hunan province.

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.

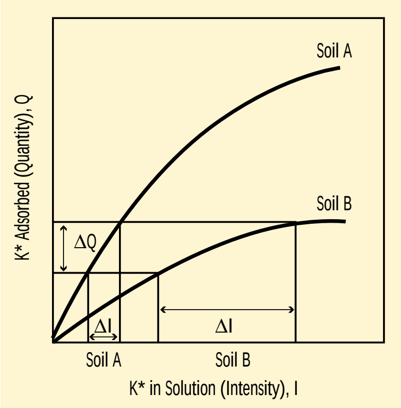

Figure 2. Relationships between K intensity and K* quantity in two soils with different potential buffering capacities (PBC). Soil A has a high PBC since a certain change in Q (ΔQ) results in a small change in intensity (ΔI) while soil B has a low PBC because ΔQ results in a large ΔI. (From Mengel and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

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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