invested in K fertiliser.

Application of potash fertiliser at existing price is profitable where maize yield response to K is more than 500 kg/ha. The results of the on-farm trials showed that 75% of the experimental sites had > 500 kg/ha of K response, and would give reasonably high ROI even at application rates of 100 kg K_2O/ha and fertiliser price of Rs 18.83/kg K_2O. Maize MSP is lowest among the three cereal crops. ROI at the current MSP and cost of K was 4.0, 5.6 and 5.1 at the 500, 700 and 850 kg/ha crop responses, respectively. Calculation based on projected K price and crop price showed that ROI was 2.3, 3.2 and 2.9 for a 500, 700 and 850 kg/ha K response, respectively, at the current MSP and the highest projected price of K_2O (Rs. 33/kg K_2O), giving reasonable return to farmers (**Figure 5**).

Potassium Fertiliser Use and Effciency in China

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Out of the total 1.3 billion hectares (B ha) being farmed globally, only 10% has little or no nutrient stress. Of the remaining area, about 40% has shown signs of potassium (K) deficiency (Yang, 1988; Jiang et al, 2003). In recent years, increasing crop yields with intensive farming has resulted in the extension of K deficient area within China. Sheldrick et al (2003) indicated that Chinese farmland lost 7.7 million metric tonnes of K_2O per year because of the removal of K in harvested crops.

According to its biological availability, soil K can be defined in four forms: water-soluble K, exchangeable K, fixed K, and structural K (Huang et al, 1979). Water-soluble K concentration is usually low in agricultural soils and always occupies a small proportion (less than1%) of total soil K content (Jin, 1993). However, this low soluble K concentration can only support lower yields. Commercial K fertilisers are readily available soluble sources and are critical in modern high yield agriculture. Except for some high yield forage crops and tuber crops such as potato, which need high levels of soluble K in soil, most crops need a moderate level of soluble K supply to achieve a normal yield.

Agricultural potash resources in China are quite limited so it is always critical to improve the use efficiency of commercial and natural potash resources.

With higher temperature, rainfall and intensive soil weathering in South China, nutrient loss by leaching and runoff is high. In addition, a high cropping index (average of 2.1 crops per year) removes more nutrients from fields in the absence of sufficient K supplementation. In the last three decades, about 2/3 of the paddy soil and 1/2 of the upland soils in south China showed K deficiency, which represents 80% of the total K deficient area in the country (Zheng and Chen, 2004).

In North China, with lower temperature, rainfall, and cropping index, soils usually contain more K-bearing minerals resulting in a lower efficiency of potash fertiliser than occurs in the south. Liu et al. (2011) and He et al. (2012) reported that K application increased wheat grain yield and its net profitability in most cases in North central China, but the average yield response was less than 1,000 kg/ha and efficiency parameters of K fertiliser use were relatively low.

Farmland soil potassium balance

Since 1980, commercial potash application in China has been greatly promoted with a number of research and technology demonstration projects. China's total commercial potash fertiliser consumption significantly increased from 386,000 tonnes in 1980 to 1.98 million tonnes in 1990 and 8.49 million tonnes in 2010. The average K application rates for farmland in different regions of China have varied in recent years from 87 to 178 kg K_2O/ha. Of all of the K used for agriculture, 38% has come from commercial K fertilisers, 35% from human and animal excretion, 17% from crop straw residues, 4%

Table 1. Farmland soil NPK balances (kg/ha/year) in three provinces of south China

Province	N			P_2O_5			K_2O		
	Input	Output	Balance	Input	Output	Balance	Input	Output	Balance
Jiangsu	481	394	87	155	91	64	163	196	-33
Hunan	583	253	330	188	156	32	318	361	-43
Shanghai	365	144	221	102	69	33	70	164	-94

Source: IPNI China Programme.

Table 2. Farmland soil NPK balances (kg/ha/year) in north China.

Province	N			P_2O_5			K_2O		
	Input	Output	Balance	Input	Output	Balance	Input	Output	Balance
Northeast	355	326	29	156	103	53	131	198	-67
Northcentral	475	391	84	246	118	128	219	226	-7
Northwest	401	309	92	172	89	84	170	170	0

Source: IPNI China Program

Table 3. Crop yield responses, profit and agronomic efficiency (AE) to K application in China.

Crops	Trial No.	Yield (t/ha)	Yield increased			Profit ($/ra)
			%	kg/ha	AE(kg/kg)	
Cereals	582	8.1	14	990	10.3	258
Vegetables	137	63.2	15	8500	58.0	1419
Fruit trees	51	32.5	23	6000	12.0	3548
Oil crops	87	3.0	17	433	4.8	292
Tuber crops	116	28.1	18	4000	44.0	787
Cotton	56	2.5	22	458	3.1	533
Tea	15	6.4	14	755	2.9	875

Source: IPNI China Program

from deposition, 4% from irrigation, 1% from green manure, and 1% from oilcakes (Li and Jin, 2011).

While potash consumption has greatly increased in the last 30 years, this growth is not sufficient to address the larger crop area and crop yields and their associated removal of K from soils. At the same time, China's commercial fertiliser application area increased by 14.4% (from 9.94 to 11.37 M ha between 1980 and 2008). However, the areas most associated with increasing K fertiliser application are those with cash crops, vegetables and fruit trees, which need much higher K supplies than grain crops.

Since 1980, scientists in South China, supported by the International Plant Nutrition Institute (IPNI), have carried out a number of research projects based on different soil K status, cropping patterns, interaction between different soil nutrients, and other factors. The common aim has been to increase K application efficiency by 5-10% while maintaining a value-to-cost ratio (VCR) above 3.0. **Table 1** presents farmland soil NPK nutrient status in three provinces in south China. While the soil nitrogen (N) and phosphorus (P) balances are positive (more input than output), the soil K balance in the provinces was negative. If this continues into the future, the farmland soil K deficiency could become a challenge to future food production.

In recent years, with increased use of high yielding crop cultivars and more N and P fertiliser application, farmland soil K balance has become negative in some North China regions. Jin (2011) reported soil K_2O loss in the northeast region (i.e. Heilongjiang, Jilin and Liaoning provinces) of 67 kg/ha, and in the North central region

Table 4. Expected crop yield, soil test values, recommended K application rates,and value-to-cost ratio (VCR).

Crop	Soil available K (mg/kg)	Recommend K_2O (kg/ha)	Expected crop yield (t/ha)	VCR ($/$)
Rice (n=135)	<40	117	6.1	4.8
	40-60	98	6.8	3.1
	60-90	90	7.0	2.5
	90-120	77	7.8	1.8
	>120	62	8.3	1.3
Corn (n=46)	<60	170	4.7	6.2
	60-100	126	5.6	5.8
	100-130	113	6.5	3.3
	130-150	90	6.4	2.1
	>150	68	6.7	2.1
Peanut (n=26)	<50	152	2.8	8.3
	50-70	108	3.1	6.1
	70-90	100	3.4	5.7
	90-120	63	3.9	5.0
	>120	35	4.0	3.2
Rapeseed(n=67)	<50	150	1.1	3.8
	50-80	105	1.3	3.6
	80-100	92	1.4	3.1
	100-120	87	1.4	2.8
	>120	45	1.7	1.5

Source: Cooperative projects of IPNI China Programme and Soil and Fertiliser Institutes of Hunan, Hubei, Jiangxi, Zhejiang, Sichuan, Guangxi and Guangdong provinces.

(i.e.Beijing, Tianjin, Hebei, Henan, Shangdong, and Shanxi provinces) of 7 kg/ha annually (**Table 2**).

Impact of potash application on main crops

Between 2001 and 2010, the IPNI China Programme conducted 1,044 field trials with different crops across the country (**Table 3**). These results indicated that fruit trees, cotton, tuber, and oil crops have the highest yield responses (17 to 23%) to K fertilization. Fruit trees, vegetables, and tea had the highest gains in profit (USD 875/ha to USD 3,548/ha) due to K application. Vegetables and tuber crops have the best agronomy efficiency (44 kg to 58 kg produce per kg K applied), which was significantly higher than other crops. IPNI has also summarised results from 1,041 field trials conducted over the past three decades in South China on 30 main crops. The results showed good yield responses to K fertilization in all crops. Most of the cash crops and vegetables showed better yield responses and net profits to K application than grain crops. In general, higher economic gains were found when potash was used on cash crops and vegetables first.

Soil test-based K fertiliser recommendations for selected crops

Table 4 presents optimum, soil test-based K application rates for four main crops in South China that were developed for farmer use. Many other crops in all regions also have similar recommended K fertilization rates. Further research by the IPNI China Programme and its cooperative research network will be focused on evaluating the effect of K application with varying soil water levels, nutrient spatial distribution in fields, and K movement in the farmland ecological system and its environmental effects, if any.

Conclusion

Potash fertilisation is very important and profitable in China's crop production. Our challenge is to use K efficiently to increase our crops needs.

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Precision Management of Root Zone Potassium for Corn: Considerations for the Future

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Precision technologies allow fertilized soil volume to be managed over time to create zones of higher fertility, but just how this should be done for optimum short-term and long-term crop response is not well understood. Relevant considerations for K fertilizer placement include the persistence of increased fertility after banded applications as well as the redistribution of K within the soil that occurs simply under normal crop development. Research indicates that the location of prior crop rows may be even more important to soil K levels than the location of past fertilizer K bands.

Precision guidance systems are capable of a very high level of repeatable accuracy in geo-positioning. Currently available equipment advertises 1 in. pass-to-pass accuracy. These technologies, in conjunction with geographic information system software, allow all equipment passes to be spatially referenced, recorded, and stored.

Abbreviations and notes: K = potassium; P = phosphorus; N = nitrogen; S = sulfur; ppm = parts per million.

Such capabilities provide new opportunities to manage nutrient applications, particularly those that are banded separately from (e.g. deep banding with strip tillage), or in conjunction with, crop planting operations. Instead of settling for a random array of past band applications in the field and limited knowledge of their exact location, farmers can now decide where future fertilizer should be banded in relation to past bands. If desired, farmers can place fertilizer in the same band year after year or offset