Economic Benefits of Potash Fertiliser Application in Major Cereals Grown in the Indo-Gangetic Plains

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Potash (K) fertiliser cost has increased considerably in India over the past three years. This has raised doubts about the profitability of potash fertiliser application in cereals. Recent K response studies in rice, wheat and maize (corn), spread across the Indo-Gangetic Plains (IGP), highlighted substantial grain yield and economic response to K fertiliser application. Results suggested that skipping application of potash in the three cereal crops would cause variable yield and economic loss even at higher potash prices. The economic assessment based on projected cost of K fertiliser and projected minimum support payment of the cereals also showed favourable return on investment for K fertiliser

The general perception that Indian soils are rich in potash and do not require K fertilisation is no longer relevant in the intensive crop production scenario. In fact, there is a growing evidence of increasing deficiency of potash as a result of sub-optimal or no application of K fertilisers, and unbalanced use of nitrogen (N) and phosphorus (P).

The situation becomes even worse with the recent increase in K fertiliser price. It is clear that there are two ways of coping with increasing fertiliser prices: (1) by improving crop yields by a certain yearly increment or (2) by increasing crop prices. Earlier studies across regions in India revealed sizable yield response of crops to K fertilisation and economic returns associated with K application. The economic return of potash application in the above response scenario, based on minimum support payment of crops and prevailing unit price of K_2O indicated that investment of one rupee on K fertiliser could result in a return of more than 15 rupees. This current study was initiated across the IGP region to assess (1) the yield response of rice, wheat and maize to potash application in a range of growing environments and (2) the economic returns of K fertiliser application in major cereals at the increasing fertiliser price scenario. On-

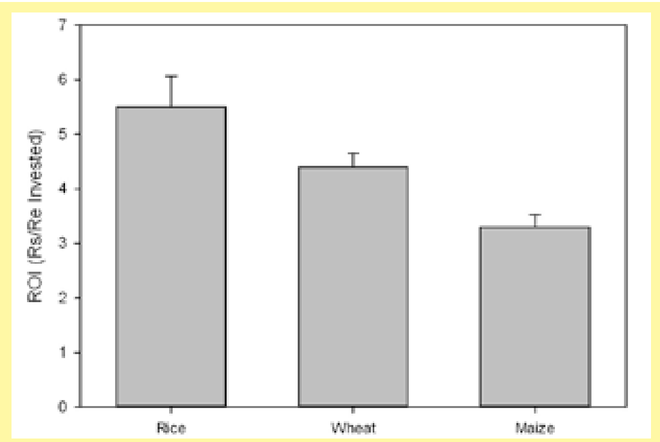

Figure 2. Return on investment (ROI) of K application incereals in the IGP at Rs. 18.83/kg K_2O.

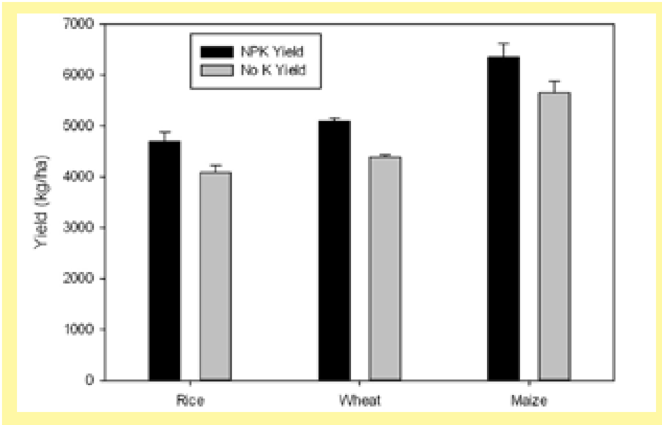

Figure 1. Average yield increase (kg/ha) with K fertilizationin different crops across growing environments.

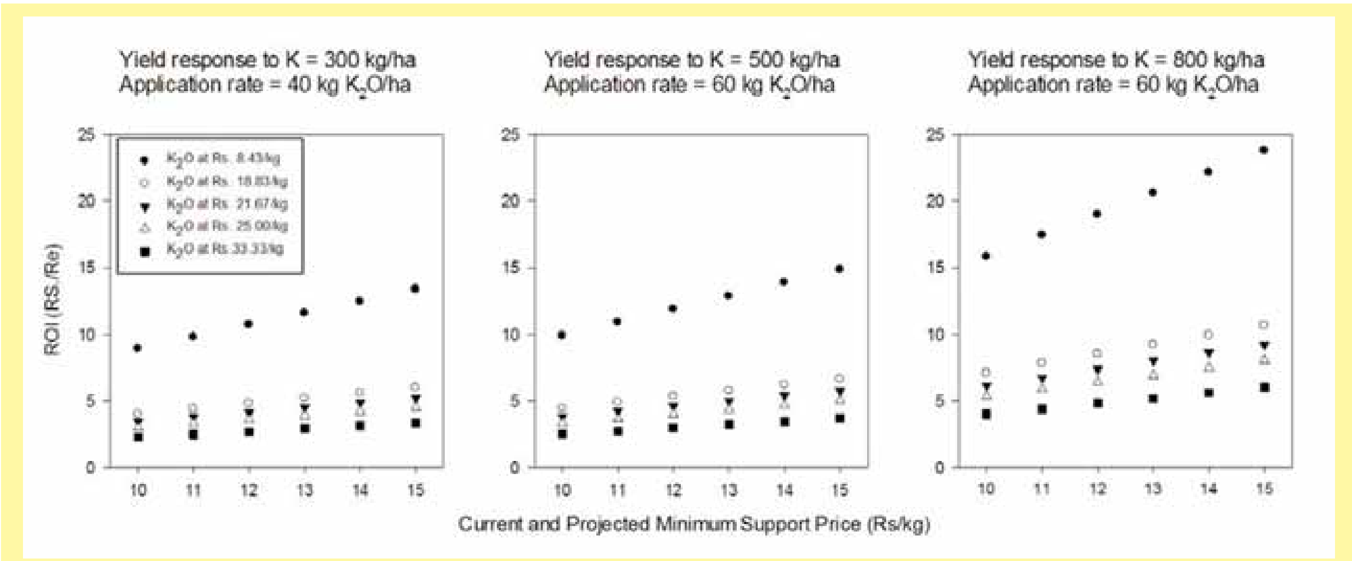

Figure 3. Return of investment (ROI) in K fertiliser at different K response levels, projected costs of K fertiliserand minimum support prices for rice.

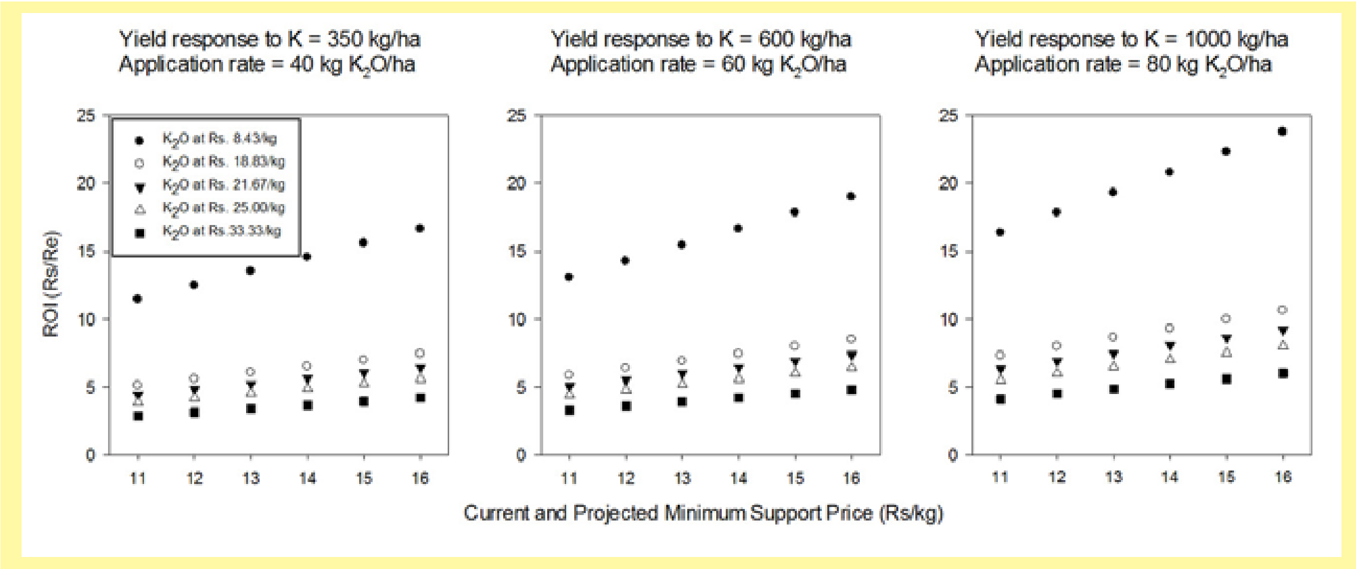

Figure 4. Return on investment (ROI) of K fertiliser at varying K response levels, cost of K_2O, and minimum support price of wheat.

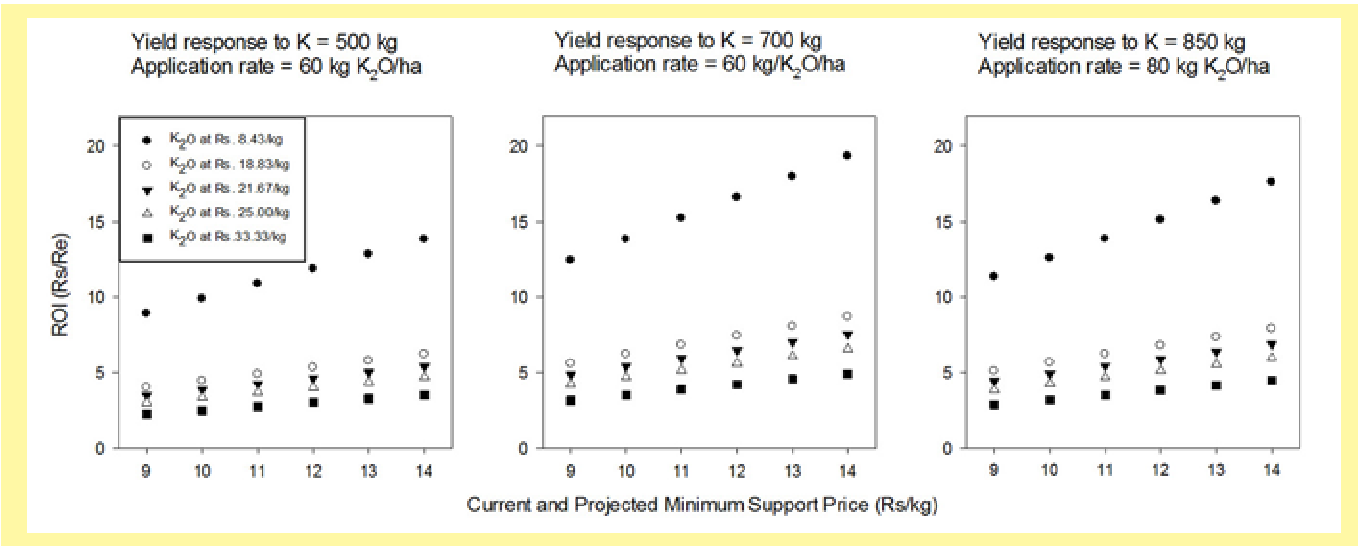

Figure 5. Return on investment (ROI) of K fertiliser at varying K response levels, cost of K_2O, and minimum support price of maize.

farm trials were conducted across the IGP during 2009-2011 by the International Plant Nutrition Institute (IPNI) in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT) under the Cereal Systems Initiative for South Asia (CSISA) project to capture the nutrient response of crops under variable soil and growing environments. Overall, 45, 141 and 36 on-farm trials on rice, wheat and maize were conducted respectively in the states of Punjab, Haryana, Uttar Pradesh, Bihar, Jharkhand, and West Bengal, representing irrigated intensive production systems and relatively large farmsin the western IGP to rainfed, low intensity fragmented farming systems of eastern India.

Results

On-farm potash response studies in major cereals across a large geographical area highlighted that:

1) Grain yield response to K fertiliser is significant and skipping application of potash in the three cereal crops will cause variable yield and economic loss to the farmers.

2) Average yield losses in rice, wheat and maize in farmers' fields due to K-omission were 622, 715 and 700 kg/ha, respectively. This strengthens the concept of low potash supply levels of most soils in India.

3) Generalised potash recommendations would lead to under or over application in most cases, causing economic losses to farmers. The strategy for deciding potash application rates should, therefore, be based on the expected crop response at a location for improved yield and profitability instead of considering the native soil test status for potash alone.

Overall, the study showed a variable reduction in yields of rice, wheat, and maize due to potash omission trials in farmers' fields. The return on investment in K fertiliser was reasonably high in most of the cases dispelling the myth that potash application is uneconomic in cereals.

Methodology

The following four treatments were assessed in the on-farm experiments:

1) Ample NPK

2) Omission of N with full P and K

3) Omission of P with full N and K

4) Omission of K with full N and P

The ample application rates of NPK for rice were 125–175 kg N/ha, 50–80 kg P_2O_5/ha and 60–90 kg K_2O/ha based on estimated yield target of 5–8 t/ha. For wheat, N application rates were 150–180 kg/ha for 5–6 t/ha of yield target, while P and K rates were fixed at 90 kg P_2O_5 and 100 K_2O per hectare. The ample NPK rates of maize were 150–180 kg N, 70–115 kg P_2O_5 and 120–160 kg K_2O per hectare for yield targets between 6–8 t/ha. The ample NPK treatment received nutrients in excess of actual requirement of the crops, following the omission plot experiment protocol, to ensure no limitation of nutrients except the omitted one. The omission plot experiments allowed us to estimate the yield response due to K, which is equivalent to the yield difference between K omission plots as compared to the ample NPK plot, in each location. We estimated the return on investment (ROI) for K (i.e. rupees returned per rupee invested on K fertiliser) at four price scenarios of potash fertiliser, Rs. 4,455* , Rs. 5,055 , Rs. 11,300 and a further higher price of Rs. 13,000/tonne, at four different crop response levels, 200, 500, 1,000, and 1,500 kg/ha, and at three different K application rates (100, 80 and 60 kg/ha) (*1 USD = Rs. 50 approx.). The range of K response used in the calculation was taken from the current set of on-farm trials. In addition, we also used current and projected prices of K fertiliser and MSP of rice, wheat and maize to estimate ROI for the three crops under future scenarios.

Rice

On-farm studies across 45 locations revealed that average yield with ample application of NPK was 4,701 kg/ha andyield loss due to no K application was on average 622 kg/ha across locations (**Figure 1**). Even areas traditionally known as less responsive to K application, such as Punjab and Haryana, showed yield loss of 500-1,000 kg/ha in the K omission plots. Economic analysis showed that ROI of K ranged between 0.8–16 Rs/Rs, which suggests that every rupee invested in fertiliser K produced additional rice yield worth Rs. 0.8 to Rs. 16, with a mean of Rs. 5.5 across the locations (**Figure 2**). Economic return of less than Rs. 1 per rupee invested on K was registered at three locations only. The economic calculations based on projected crop and K prices (**Figure 3**) showed that the ROI at the highest projected price of K (Rs. 33.33/kg of K_2O) and the lowest MSP (Rs. 10/kg rice) was 2.3 at an application rate of 40 kg K_2O/ha for a 300 kg/ha crop response, suggesting profitable re turn on potash application. Obviously the profitability increased as the MSP of the crop was increased. At higher crop response levels of 500 and 800 kg/ha, ROI was 2.5 and 4.0, respectively at the lowest MSP and at an application rate of 60 kg K_2O/ha. In the on-farm omission plot experiments, 60–100 kg K_2O/ha was applied based on the yield targets of rice. A yield loss of ≥ 500 kg/ha of rice due to no application of K was observed in more than 50% of locations. This suggests that in such locations, application of K at 40-60 kg K_2O/ha will provide a good ROI to thefarmers and will maintain the K fertility status of the soil. It should be understood that the vast rice growing soils of the IGP have large variability in K supplying capacity and K management decisions in this area must be based on expected K response at a particular location.

Wheat

In our present study, on-farm trials (141 locations) across the trans and upper Gangetic Plains showed that wheat yield with ample application of NPK was 5,096 kg/ha and the gap between K omission plot yield and full NPK plot yield ranged from 0–2,222 kg/ha with a mean of 715 kg/ha (**Figure 1**). The average yield loss of 715 kg/ha translates to economic loss of Rs. 8,366/ha at the current MSP of wheat (Rs. 11.7/kg). The majority of these omission plot trials were set up in Punjab, Haryana and Western Uttar Pradesh that are typically thought of as areas rich in inherent soil K and require either no, or less external K application. ROI of K in the wheat experiments was 0–13.22 Rs/Rs with a mean return of Rs 4.44 (**Figure 2**). The ROI of K was lower than 2.0 only in 24 out of the 141 sites studied (17%). ROI was calculated based on MSP of wheat and cost of potash (Rs. 18.83/kg of K_2O).

Economic calculations based on projected cost of K and MSP of wheat showed that ROI declined sharply as the K price increased from Rs. 8.43/kg K_2O to a projected price of Rs. 33/kg K_2O (Figure 4). Nonetheless, ROI at the current MSP and the projected maximum price of K_2O would be 2.9, a return ratio of 1:3 even at the low-response locations. At high-response locations (K response ≈ 1,000 kg/ha) the ROI at highest projected K price was 4.1 at the current MSP of wheat, making it a profitable option for the farmers. K response was >1 t/ha in 25% of the locations in the present study and those locations would produce a ROI of 8.0 at the current cost of K and current MSP of wheat.

Maize (corn)

Maize omission plot trials were conducted in Bihar and West Bengal where maize is coming up as a preferred alternative crop to both rice and wheat during monsoon and winter seasons, respectively. Maize yield reduction in K omission plots, as compared to ample NPK application, ranged from 140–1,320 kg/ha and mean yield loss due to no K application was 700 kg/ha (**Figure 1**). At the current MSP of maize (Rs. 8.80/kg grain), the yield losses in these experiments were equivalent to economic loss of Rs. 1,232–11,616/ha, with a mean of Rs. 6,160/ha. Maize is grown in India in winter, spring and rainy seasons. The present data includes both winter and spring maize. Spring maize average yield in these trials was 4,936 kg/ha whereas that of winter maize was 7,748 kg/ha. Average yield response to K application in winter maize alone was nearly 200 kg/ha higher than the pooled data of both crops. Return per rupee invested on K in maize ranged Rs. 0.65–6.17 and the average return across all sites was Rs. 3.27 (**Figure 2**). Even with the lowest MSP among the three cereals, there were only six of the 36 locations reported here that had return below Rs. 2.0 per rupee 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