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Economics of Potassium Fertiliser Application in Rice, Wheat and Maize Grown in the Indo-Gangetic Plains

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Potassium (K) fertiliser cost has increased considerably over the past three years. The sharp increase in price has raised doubts about the profitability of potassium application in cereals where the Minimum Support Prices (MSP) is low. On-farm K response studies in rice, wheat and maize, spread across the Indo-Gangetic Plains, highlighted that grain yield response to fertiliser K is highly variable and is influenced by soil, crop and management factors. Average yield losses in rice, wheat and maize in farmers' fields due to K-omission were 622, 715 and 700 kg/ha, respectively. This suggests that skipping application of K in the three cereal crops will cause variable yield and economic loss to the farmers of the region and will affect overall cereal production in the country. The return on investment of applied potassium in rice, wheat and maize were Rs. 5.5, 4.4 and 3.2 respectively per rupee invested on K. Economic assessment based on projected cost of K fertiliser and projected MSP of the cereals also showed favourable return on investment for K fertiliser. Considering the high variability in K response, blanket K recommendations would most likely lead to economic loss for farmers due to under or over application in most cases. A site specific potassium management strategy, based on the expected crop response to K at a location, would improve yield and profitability of cereal farming.

Potassium (K) is one of three primary nutrients required by crops to complete their life cycle and produce food. It did not receive much attention in India till the 1980s because of the general belief that Indian soils were well supplied with K (7). However, the scenario of crop responses to K in India has been changing with time. Indeed, there is growing evidence of increasing deficiency of K as a result of i) sub-optimal or no application of K fertilisers and ii) imbalanced use of nitrogen (N) and phosphorus (P). Even under the so-called optimum rates of NPK application in long-term experiments, the K balance under most of the soils and cropping systems was negative (9). Such imbalance in K application, however, has variable impact on crop production due to the fact that K-supplying capacities of soils vary based on mineralogy and K dynamics of a particular soil type.

Rice, wheat, and maize are the mainstays of food security in India, grown in 82 million hectares (mha) of the cultivated land in the country and producing over 200 million tonnes (mt) of cereal grains (2). These crops are grown on different soil types and agro-ecologies across the country, which reflect the variable productivity (attainable yield) and subsequently the variable nutrient requirement by the crops and nutrient balances in the soils.

Earlier studies (IPNI Unpublished data) across regions in India revealed sizable yield response of crops to K fertilisation and economic returns associated with K application **(Figures 1 & 2)**. **Figure 1** shows that yield increase were more in cash crops (fruits, vegetables, and spices), sugarcane, and potato while three cereal crops had an average yield improvement of about 900 kg/ha.

The economic return of K application in the above response scenario, based on minimum support prices (MSP) of crops and prevailing unit price of K_2O at the time of conducting the experiments, indicates that investment of one rupee on K fertiliser would result in a return of more than 15 rupees, even for cereals **(Figure 2)**. Site-specific potassium management studies conducted in rice- wheat and rice-maize cropping systems in the Indo-Gangetic Plain region (IGP) indicated that response to K application and benefit: cost ratio in cereals could be further improved with cultivation of modern high yielding and hybrid varieties (1,11). For other crops, the return on K application was much higher.

OBJECTIVES

Rice, wheat, and maize utilize the

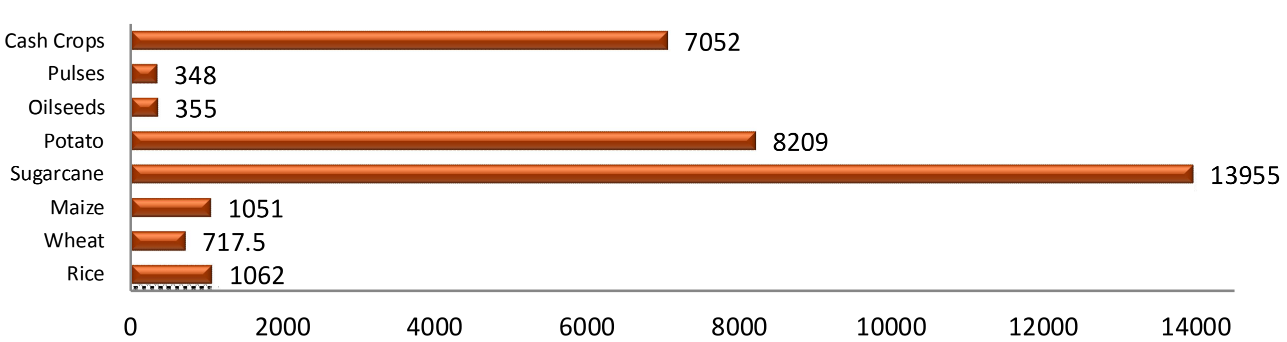

Figure 1 – Average yield increase (kg/ha) with K fertilisation in different crops across growing environments

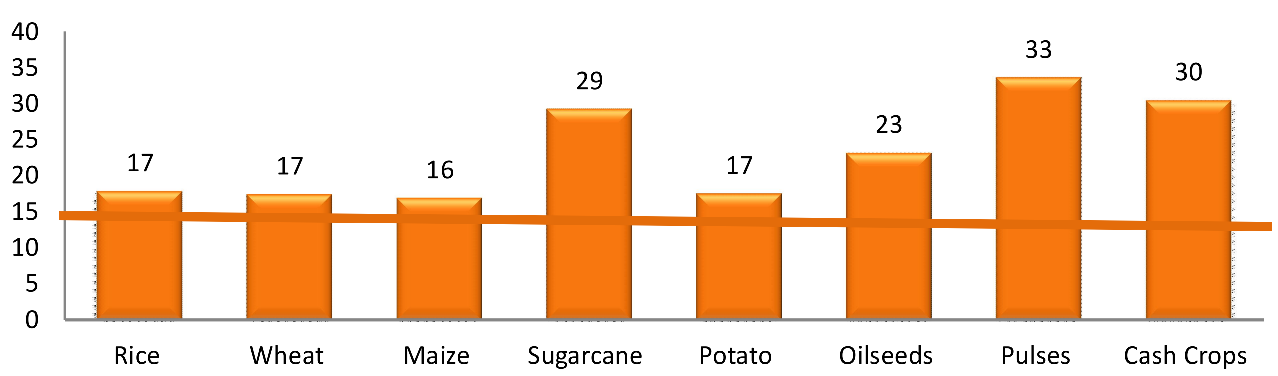

Figure 2 – Return on investment (ROI) on potassium# # Cost of potassium= Rs. 7.50/kg K_2O

majority of fertilisers consumed in India. According to estimates (3), these three crops use 53% of N, 46% of P_2O_5 and 43% of K_2O (corresponding to 8.8 mt of N, 3.7 mt of P_2O_5 and 1.5 mt of K_2O in 2010-11) of the total nutrients consumed in the country. Considering the importance of rice, wheat and maize in the food security scenario, scope of enhancing their productivity through judicious fertiliser use and scarcity of information on yield and economic advantages of K application in relation to variable indigenous K supplies, we undertook this study to estimate: **(a)** response of cereals to K application in the Indo-Gangetic Plain region, **(b)** economic returns on application of K and **(c)** profitability of K application with changing fertiliser price scenario.

MATERIALS AND METHOD

On-farm trials were conducted across the IGP during 2009-2011 by International Plant Nutrition Institute (IPNI) and International Maize and Wheat Improvement Centre (CIMMYT) under the Cereal Systems Initiative for South Asia (CSISA) to capture the nutrient response of crops under variable soil and growing environments.

In all, 45, 141 and 36 on-farm trials on rice, wheat and maize were conducted in the states of Punjab, Haryana, Uttar Pradesh, Bihar, Jharkhand and West Bengal, representing irrigated intensive production systems and relatively large farm scenario in the Western IGP to rainfed, low intensity fragmented farming systems of eastern India **(Table 1)**.

Table 1 – Characteristics of the experimental sites

State	Districts	Agro-climatic Zone	Soil texture	Average annual precipi-tation (mm)	Cropping system	Crops studied	Ecology
Punjab	Ludhiana, Amritsar, Gurdaspur, Sangrur, Fatehgarh Sahib	Central Plain Zone to Sub-Mountain Undulating Zone	Sandy loam to silty loam	600-1020	Rice-Wheat, Cotton-Wheat	Rice and Wheat	Irrigated
Haryana	Karnal, Kuruka-shetra, Kaithal, Ambala, Yamunanagar	North Western Plain zone	Sandy loam to clay loam	400-600	Rice-Wheat	Rice and Wheat	Irrigated
Uttar Pradesh	Agra	South Western Plain Zone	Sandy loam	650	Pearl millet-Wheat	Wheat	Irrigated
Bihar	Vaishali, Samastipur, Purnea, Katihar, Begusarai, Patna and Jamui	North West, North East and South Bihar Alluvial Plains	Sandy loam to silty clay loam	1100-1400	Rice-Maize	Rice and Maize	Irrigated
West Bengal	Uttar Dinajpur and Nadia	Old and New Alluvial zone	Sandy loam to silty clay loam	1300-1500	Rice-Maize	Maize	Irrigated

Treatments

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

For rice, application rates of NPK 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. Maize trials were concentrated in Bihar and West Bengal and ample NPK rates for 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. Nutrients were applied in excess of actual requirement of the crops, following the omission plot experiment protocol, to ensure no limitation of nutrients except the omitted one. At maturity grain yields were determined from a 10 m^2 harvested area in each plot; combined after harvesting from four predetermined 2.5 m^2 areas within each plot. After sun-drying for three days in the field, the total biomass (grain + straw) was threshed with a plot thresher and grain yield was weighed, and adjusted to 13% moisture content for all the crops.

Yield Response to K and Profitability of K Application

Yield increase due to K fertiliser (K response) and K application economics were estimated using the following equations:

1) K response (kg/ha) = Grain yield in ample NPK plot (kg/ha) – Grain yield in K omission plot (kg/ha).

2) Return on investment (ROI) on K fertiliser = Yield increase due to K fertiliser (kg/ha) MSP of crop (Rs/kg) / Applied K_2O (kg/ha) cost of K_2O (Rs/kg).

K fertiliser cost has increased considerably over the past three years. The sharp increase in price has raised doubts about the profitability of K application in rice, wheat, and maize where the MSPs are low. The omission plot experiments in the current study allowed us to estimate the yield response due to K, which is equivalent to the yield loss in 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 per rupee invested on K fertiliser) at four price scenarios of Muriate of Potash (MOP), Rs. 4455 (2009 price), Rs. 5055 (2010 price), Rs. 11300 (current price) and a further higher price of Rs. 13000/ tonne, at four different K response levels, 200, 500, 1000, and 1500 kg/ha, and at three different K application rates (100, 80, and 60 kg/ha). 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. Calculations were based on the following criteria:

♦ Four price levels of K_2O between Rs. 8.43/kg K_2O to Rs. 33.33/kg K_2O that correspond to Muriate of Potash (MOP) price between Rs. 5058 and Rs. 20000/ tonne.

♦ Three K response levels corresponding to 25^{th}, 50^{th} and 75^{th} percentile of the actual responses in each crop. The K response levels were: 300, 500, and 800 kg/ha for rice; 350, 600, and 1000 kg/ha for wheat; and 500, 700, and 850 kg/ha for maize.

♦ Fertiliser K rates assumed to be sufficient for the observed K responses:

• *Rice* : K response of 300 kg/ha justifies application of 40 kg K_2O kg/ha while K response of 500 and 800 kg/ha will require application of 60 kg K_2O/ha.

• *Wheat*: calculations are based on 40, 60 and 80 kg K_2O /ha application rates at locations with 350, 600 and 1000 kg K response per hectare, respectively.

• *Maize*: calculations are based on application of 60 kg K_2O /ha at K response of 500 and 700 kg/ha, while 80 kg K_2O /ha was used for locations with K response of 850 kg/ha.

♦ MSP levels of Rs 10 to Rs 15 per kg rice, Rs. 11 to Rs 16 per kg wheat, and Rs 9 to Rs 14 per kg maize.

RESULTS AND DISCUSSION

Rice

Rice was grown in 41.9 mha in India with annual production of 95.3 mt of grains in 2010-11. All India average productivity of rice is 2125 kg/ha (2). However, average rice yield varies widely between major rice growing states and ranges from 4010 kg in Punjab to 1120 kg/ha in Orissa (2). The management yield gaps in rice productivity also varied widely between states, for example, 43% in Punjab, 60% in Haryana, 71% in Bihar and 69% in Tamil Nadu (3).

On-farm studies across 45 locations in the Indo-Gangetic Plains revealed that average yield with ample application of NPK was 4701 kg/ha and yield loss due to no application of K was 90–1806 kg/ha with an average yield loss of 622 kg/ha across locations **(Figure 3)**. Areas traditionally known as less responsive to K application (Punjab and Haryana) showed yield loss of 500-1000 kg/ha in the K omission plot as compared to ample NPK plots. Yield loss was greater in hybrid rice, which has higher yield potential than open pollinated high yielding varieties (HYVs) and traditional varieties, and has higher demand for K.

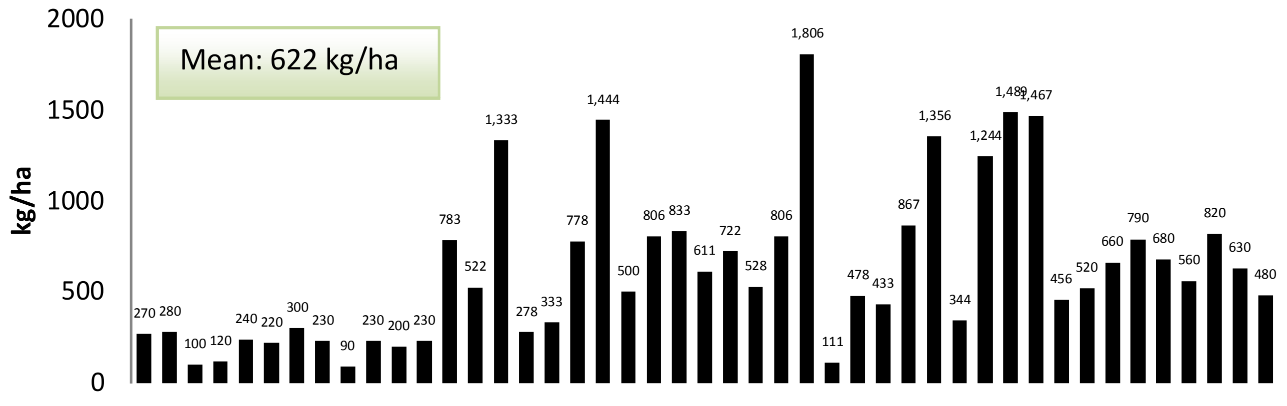

Figure 3 – Rice yield loss in K omission (–K) plots as compared to fully-fertilised (NPK) plots

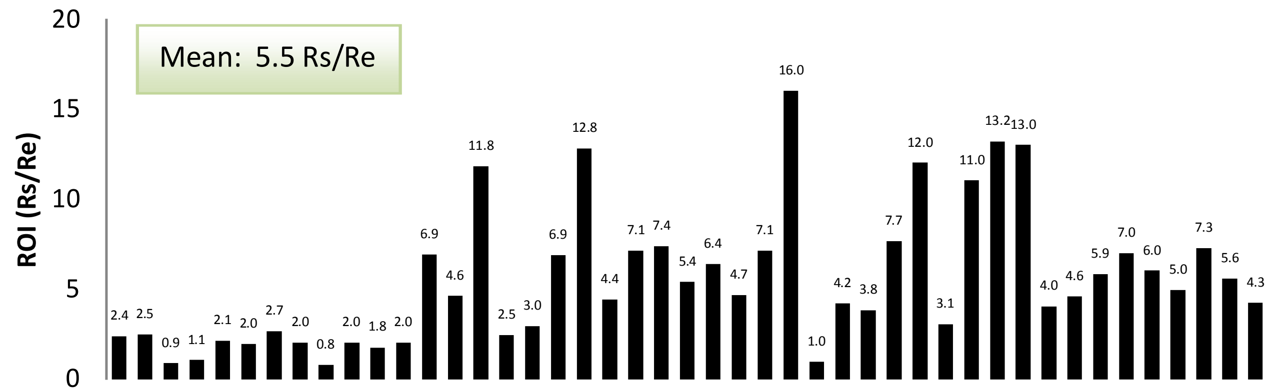

Figure 4 – Return on investment on K fertiliser in rice based on actual K rates and current fertiliser costs and MSP

Economic analysis showed that ROI of K ranged between 0.8–16 Rs/Re **(Figure 4)**, 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 4)**. Economic return of ≤ Rs. 1 per rupee invested on K was registered at three locations only.

Return on investment was calculated based on minimum support price of rice (Rs 10/kg) and cost of potash (Rs. 18.8/kg of K_2O).

Results revealed that K application is generally less attractive at low K response levels (yield loss in K omission plots ≤ 200 kg/ha, **Table 2**). However, K application at all three rates (100, 80 and 60 kg K_2O/ha) in rice are profitable, more so at 80 and 60 kg K_2O/ha, in areas where yield responses in rice due to K application exceeds 500 kg/ha.

Figure 5 shows that K application, in general, is economically profitable even in areas where K response is ≤ 500 kg/ha. At an application rate of 40 kg K_2O/ha for a 300 kg/ha response, the ROI at the highest price of K (Rs. 33.33/kg of K_2O) and the lowest MSP (Rs. 10/kg rice) was 2.3, suggesting profitable return on potash application. Obviously the profitability increased as the MSP of the crop was increased **(Figure 5)**. 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 the farmers and will maintain the K fertility status of the soil. It should be understood that the vast rice growing soils of the Indo-Gangetic Plains have large

Table 2 – Return of investment (ROI) on K fertiliser in rice at different crop response levels cost of MOP and application rates

Yield response to K (kg/ha) ⟶	200	500	1000	1500
Cost of MOP (Rs/ tonne) ↓	At 100 kg K_2O/ha application rate			
4455	2.69	6.73	13.47	20.20
5055	2.37	5.93	11.87	17.80
11300	1.06	2.65	5.31	7.96
13000	0.92	2.31	4.62	6.92
	At 80 kg K_2O/ha application rate			
4455	3.37	8.42	16.84	25.25
5055	2.97	7.42	14.84	22.26
11300	1.33	3.32	6.64	9.96
13000	1.15	2.88	5.77	8.65
	At 60 kg K_2O/ha application rate			
4455	4.49	11.22	22.45	33.67
5055	3.96	9.89	19.78	29.67
11300	1.77	4.42	8.85	13.27
13000	1.54	3.85	7.69	11.54

Calculated based on minimum support price of rice (Rs 10/kg of grain)

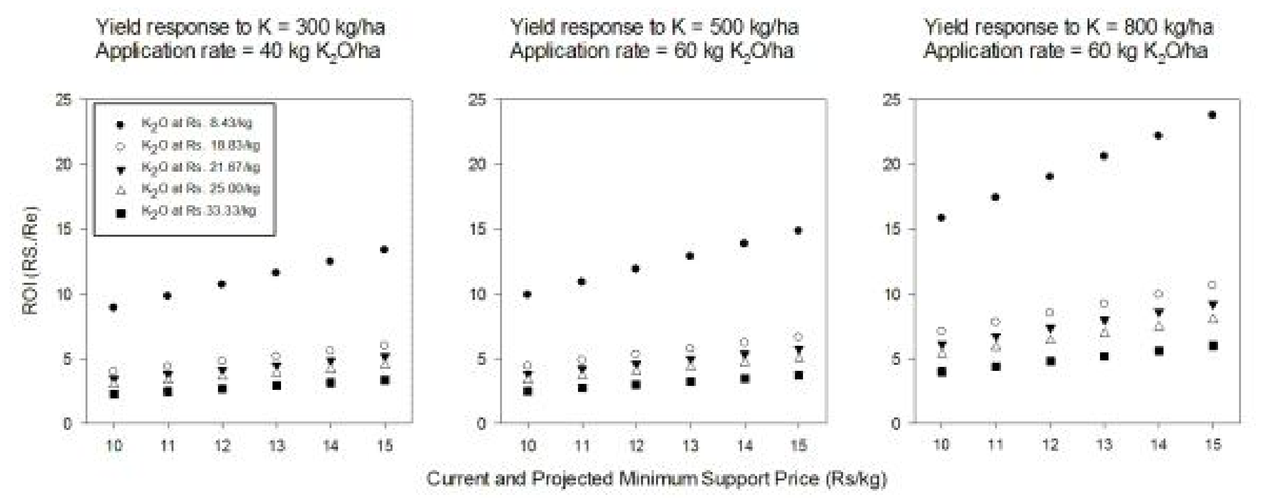

Figure 5 – Return of investment (ROI) of K fertiliser at varying K response levels, cost of K_2O and minimum support price of rice

variability in K supplying capacity and K management decisions in this area must be based on expected K response at a particular location. The general perception that Indian soils are rich in K and do not require K application is no longer relevant in the intensive crop production scenario.

Wheat

Wheat was grown on about 29 mha in India with an annual production of 87 mt in 2010-11 and average yield of 2839 kg/ha (2). Review of current statistics showed that there are considerable management yield gaps between the major wheat growing states in the country. For example, productivity in Bihar and Madhya Pradesh are about 45% of Punjab, while Uttar Pradesh, with the highest wheat acreage among the states (9.7 mha), has a productivity of 2846 kg/ha, about 66% of Punjab. The absolute management yield gaps in wheat in Punjab, Haryana, Eastern UP and Bihar are 17, 14, 47 and 48 %, respectively (3).

On-farm trials (n = 141) across the Trans and Upper Gangetic Plains showed that wheat yield with ample application of NPK was 5096 kg/ha and the gap between K omission plot yield and full NPK plot yield ranged from 0–2222 kg/ha with a mean of 715 kg/ha **(Figure 6)**. The average yield loss of 715 kg/ha translates to economic loss of Rs. 8366/ha at the current MSP of wheat. 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 per rupee invested

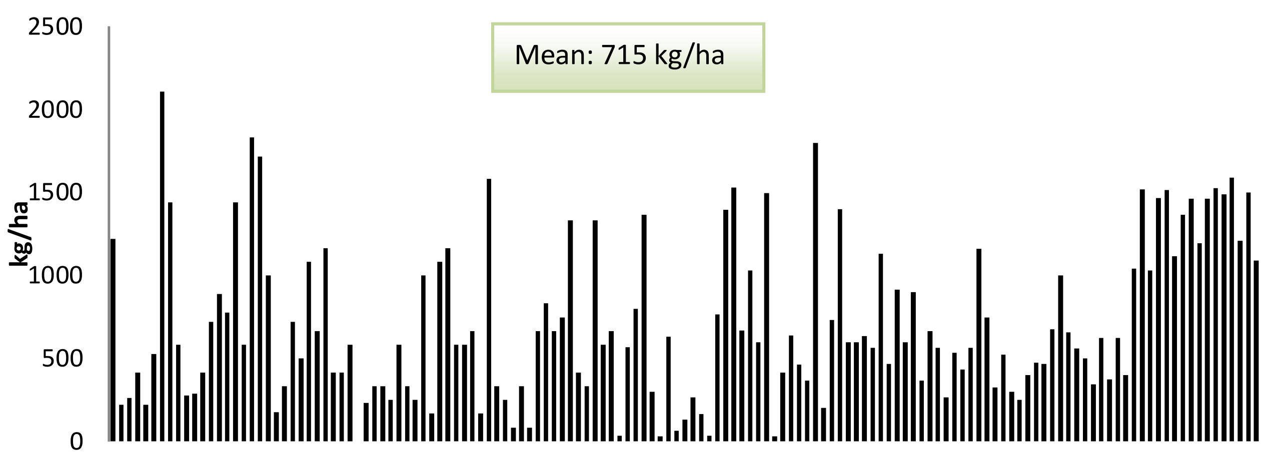

Figure 6 – Wheat yield loss in K omission (–K) plots as compared to fully-fertilised (NPK) plots

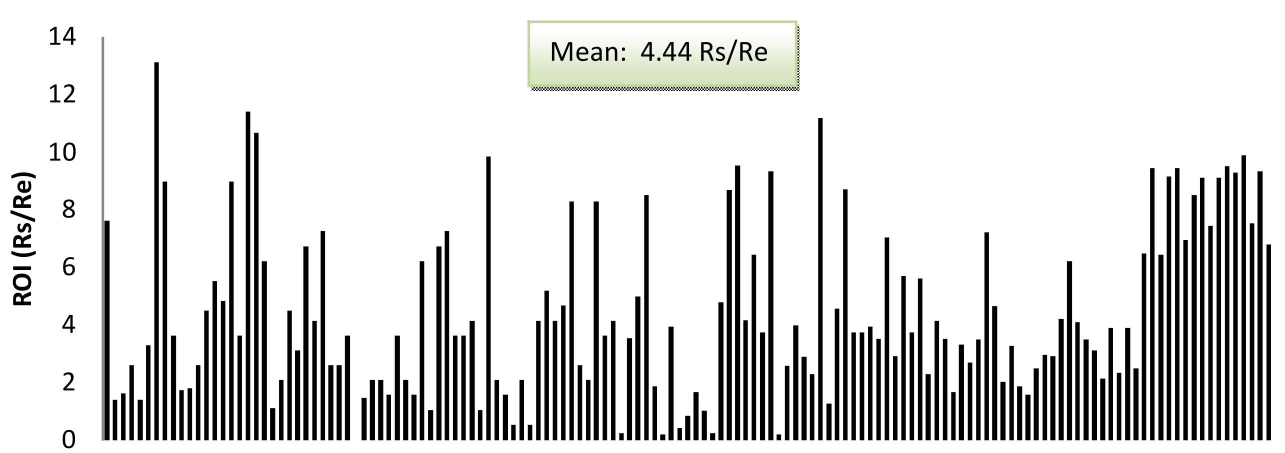

Figure 7 – Return on investment on K fertiliser in wheat based on actual K rates and current fertiliser costs and MSP

(Figure 7) on potassium. The ROI of K was lower than 2.0 only in 24 out of the 141 sites studied (17%).

Return on investment was calculated based on minimum support price of wheat (Rs 11.7/kg) and cost of potash (Rs. 18.8/kg of K_2O).

Similar to rice, K application at current K fertiliser price was found to be uneconomic at locations where wheat response to K was ≤ 200 kg/ha. However, K application was profitable at current price levels at locations where yield loss due to no application of K is ≥ 500 kg/ha **(Table 3)**. Comparatively higher MSP of wheat among the three cereals provides more opportunity to the farmers in terms of K application in the increasing K price scenario. It is clear that there are two ways of coping with increasing fertiliser price: **(1)** by improving yield of the crop by a certain yearly increment or **(2)** by increasing the MSP of the commodity. The first option seems to be more attractive as several studies (6, 8, and 10) have shown that there are wide gaps between farmers' plot yield and research station yields in the country. Decreasing such yield gap over a period of time will increase farmer profitability and help meet the increasing food demand. Location specific nutrient management strategies, particularly improved K management, are expected to play a critical role in bridging such yield gaps.

Economic calculations based on projected cost of K and MSP 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 8)**. Nonetheless, **Figure 8** suggested that 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 ≈ 1000 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 ROI

Table 3 – Return of investment (ROI) of K fertiliser in wheat at different crop response levels, cost of MOP and application rates

Yield response to K (kg/ha) ⟶	200	500	1000	1500	1800
Cost of MOP (Rs/ tonne) ↓	**At 100 kg K_2O/ha application rate**				
4455	3.15	7.88	15.76	23.64	28.36
5055	2.78	6.94	13.89	20.83	25.00
11300	1.24	3.11	6.21	9.32	11.18
13000	1.08	2.70	5.40	8.10	9.72
	At 80 kg K_2O/ha application rate				
4455	3.94	9.85	19.70	29.55	35.45
5055	3.47	8.68	17.36	26.04	31.25
11300	1.55	3.88	7.77	11.65	13.98
13000	1.35	3.38	6.75	10.13	12.15
	At 60 kg K_2O/ha application rate				
4455	5.25	13.13	26.26	39.39	47.27
5055	4.63	11.57	23.15	34.72	41.66
11300	2.07	5.18	10.35	15.53	18.64
13000	1.80	4.50	9.00	13.50	16.20

Calculated based on minimum support price of wheat (Rs 11.7/kg of grain)

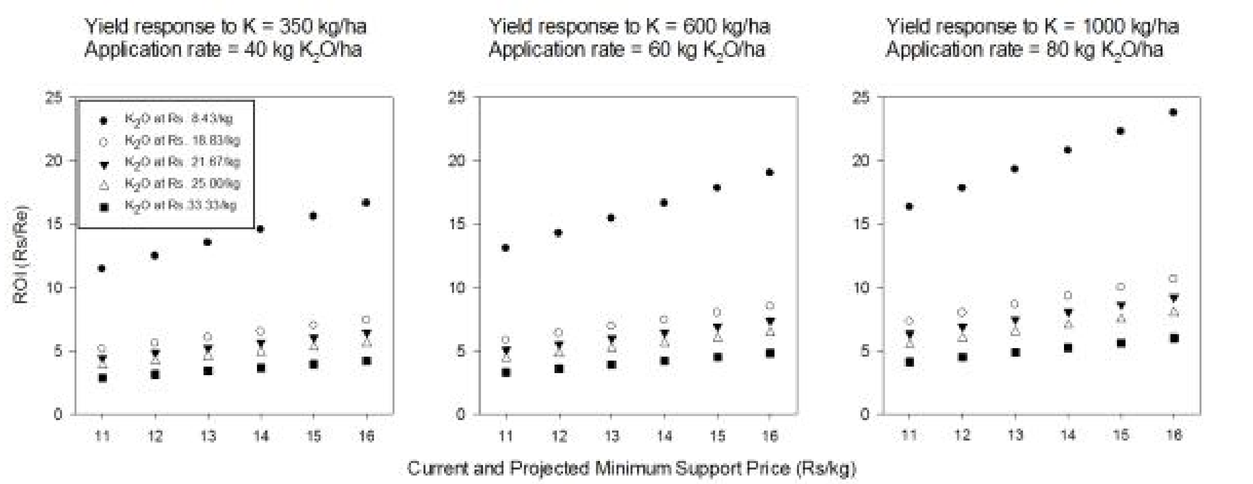

Figure 8 – Return on investment (ROI) of K fertiliser at varying K response levels, cost of K_2O and minimum support price of wheat

of 8.0 at the current cost of K and current MSP of wheat.

Maize

Maize is the third major cereal grown in India. Maize area and productivity are increasing steadily over the past years. During 2010-11, 8.55 mha area was under maize cultivation in India with an annual production of 21.7 mt at an average productivity of 2540 kg/ha.

The 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 140–1320 kg/ha and mean yield loss due to no K application was 700 kg/ha **(Figure 9)**. At the current MSP of maize (Rs. 8.80/kg grain), the yield loss in these experiments are equivalent to economic loss of Rs. 1232 – 11616/ha, with a mean of Rs. 6160/ha. Maize is grown in India in winter, spring, and rainy seasons. Attainable yields of maize differ between seasons, with highest yields obtained in winter maize. The present data includes both winter and spring maize. Spring maize average yield in these trials was 4936 kg/ha whereas that of winter maize was 7748 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 10)**. Even with the lowest MSP among the three cereals, there were only six locations out of 36 locations reported here that had return below Rs. 2.0 per rupee invested in K fertiliser.

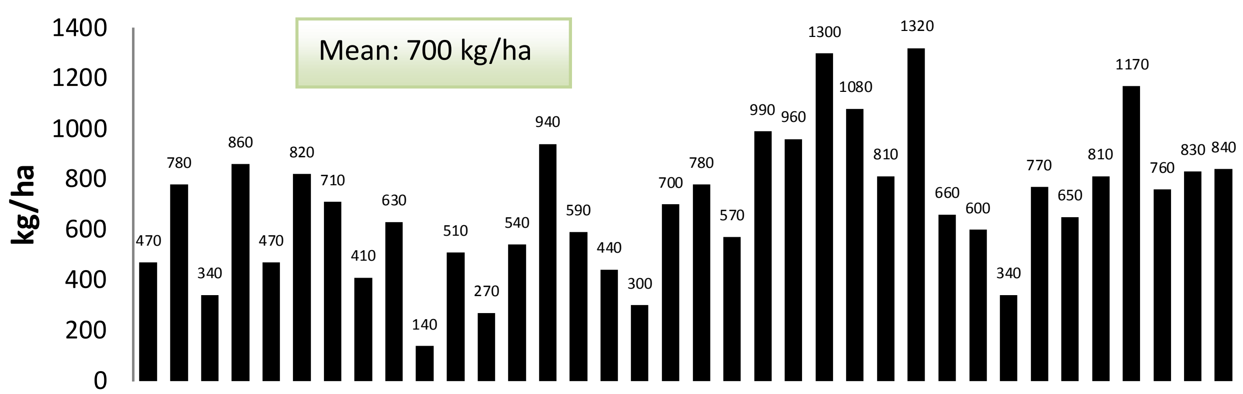

Figure 9 – Maize yield loss in K omission (–K) plots as compared to fully-fertilised (NPK) plots

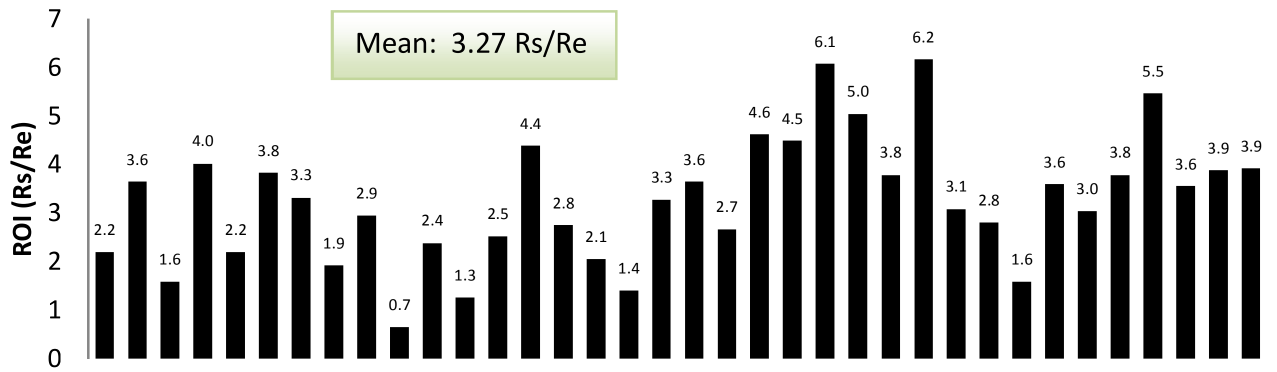

Figure 10 – Return on investment on K fertiliser in maize based on actual K rates and current fertiliser costs and MSP

Return on investment was calculated based on minimum support price of maize (Rs 8.80/kg) and price of potash (Rs. 18.8/kg of K_2O).

Table 4 shows that K application 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.

Median response of maize to K application was 700 kg/ha and response across sites were centered around the median value as was evident from the 25th and 75th percentile of the response, 500 kg and 850 kg/ha.

Table 4 – Return on investment (ROI) on K in maize at different crop response levels, cost of MOP and K application rates

Yield response to K (kg/ha) →	200	500	1000	1500
Cost of MOP (Rs/ tonne) ↓				
	At 100 kg K_2O/ha application rate			
4455	2.37	5.93	11.85	17.78
5055	2.09	5.22	10.45	15.67
11300	0.93	2.34	4.67	7.01
13000	0.81	2.03	4.06	6.09
	At 80 kg K_2O/ha application rate			
4455	2.96	7.41	14.81	22.22
5055	2.61	6.53	13.06	19.58
11300	1.17	2.92	5.84	8.76
13000	1.02	2.54	5.08	7.62
	At 60 kg K_2O/ha application rate			
4455	3.95	9.88	19.75	29.63
5055	3.48	8.70	17.41	26.11
11300	1.56	3.89	7.79	11.68
13000	1.35	3.38	6.77	10.15

Calculations based on minimum support price of maize (Rs 8.80/kg of grain)

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 500, 700, and 850 kg/ha K response, respectively. Our calculation showed that ROI was 2.3, 3.2 and 2.9 for 500, 700 and 850 kg/ha K response, respectively at the current MSP and the highest projected price of K_2O, giving reasonable return to farmers **(Figure 11)**.

CONCLUSION

The on-farm K response studies in rice, wheat and maize, spread across the Indo-Gangetic Plains, highlighted that

1) Grain yield response to fertiliser K is highly variable and is influenced by soil, crop and management factors. This suggests that skipping application of K 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 is contrary to the general perception that omitting potash for a season will not adversely affect cereal production in the country, and demonstrates clearly the low K

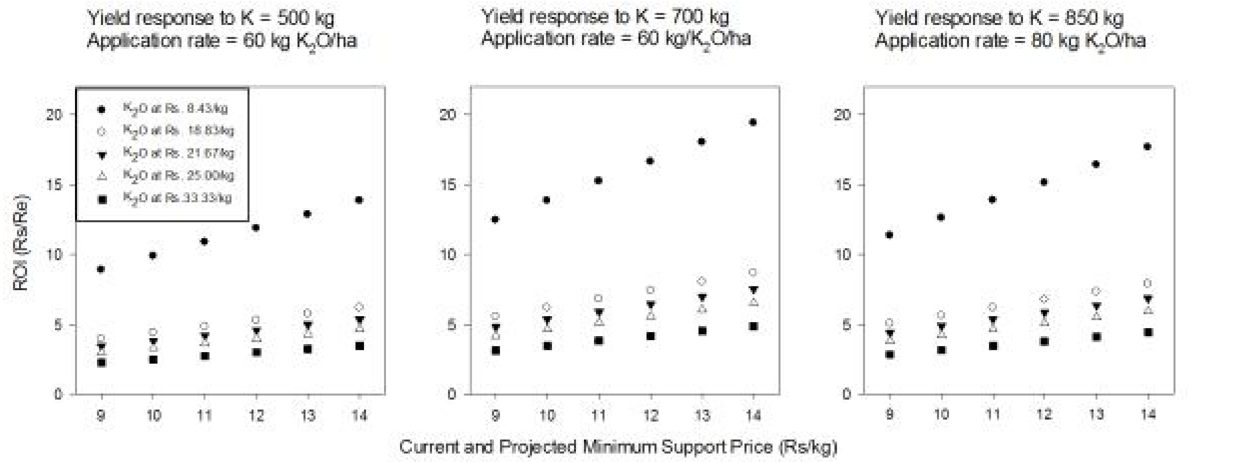

***Figure 11** – Return on investment (ROI) of K fertiliser at varying K response levels, cost of K_2O and minimum support price of maize*

supply levels of most soils in India.

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

The above study showed that a better understanding of the growing environment and crop response to potash application in cereals are critical for enhancing yield and profitability. However, it must be understood that potash nutrition, and nutrient management in general, is only a part of the overall crop management strategy. As we look at economics of fertiliser management, it must be kept in mind that water and labour resource costs will also increase, along with increase in fertiliser cost, in the near future. Farmers will need to increase the overall return from farming to offset such increased costs of production. The best way to achieve higher return would be to increase productivity per unit area through overall good crop management. Improved varieties, better pest management, improved water and nutrient use efficiencies and post-harvest handling would be critical to achieve such goals. As far as nutrient management is concerned, adhering to the four basic principles of applying nutrients at the right rate, at the right time, using the right source and by the right method would ensure higher economic return from fertiliser use as well as increased cereal productivity to meet the food security goals in the country.

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