Economics of Fertiliser Application in Rice Grown on the Indo-Gangetic Plains

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In India, the sharp increase in fertiliser prices has raised doubts about the profitability of NPK application in rice, especially when the Minimum Support Price (MSP) and nutrient use efficiencies are low. Spatially distributed on-farm trials indicated variable yield loss of rice due to N, P, or K omissions from the fertilization schedule. On the other hand, economic assessment based on application rates, nutrient response, costs of fertilisers, and minimum support price of rice showed favorable return on investment in all these nutrients.

Rice is one of the major crops grown in the IGP region of India. It is grown on about 42 million (M) ha area with a production of about 89 M t and an average productivity of 2,125 kg/ha (FAI, 2011). However, the last decade (2000 to 2010) has seen no significant increase in productivity of rice. This has made the rice farming community increasingly concerned about the profitability of adequate nutrient application, especially with rising fertiliser prices. Additionally, while N, P, and K are the three primary nutrients for plant growth, farmers tend to apply more fertiliser N due to its lower price and visible impact on crops as compared to other nutrients. This has led to increasing deficiencies of P and K as a result of sub-optimal application or unbalanced use in the intensive cereal-based systems. In several long-term experiments, Subba Rao et al. (2001) observed negative K balances in most soils and cropping systems, even when the so-called optimum rates of NPK were applied. Such an imbalance in N, P, and K applications has negative impact on crop production.

Considering the importance of rice in ensuring the food and nutritional security of India, and also looking at the significant role of NPK inputs for meeting production goals in the coming years, the present study was undertaken to (1) estimate on-farm economic response of NPK application in rice across different soils and farmer management practices in the IGP region and (2) assess the economic profitability of NPK application in rice under current and some hypothetical future fertiliser price and MSP scenarios.

Methods

On-farm trials were conducted across the IGP (Punjab, Haryana and Bihar) during 2009 to 2011 by IPNI in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT) under the Cereal Systems Initiative for South Asia (CSISA) project. Characteristic features of the experimental sites are given in **Table 1**.

The trials included four treatments including (1) ample NPK, (2) omission of N with full P and K, (3) omission of P with full N and K, and (4) omission of K with full N and P. In all treatments, nutrients were applied in excess of the actual requirement of rice following the omission plot experiment protocol to ensure no limitation of nutrients except the omitted

IPNI is collaborating with several agencies to optimise nutrient management in rice.

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; IGP = Indo-gangetic plains; MSP = minimum support price; ROI = return on investment; DAP = diammonium phosphate; MOP = muriate of potash or potassium chloride (KCl); Rs = Rupees; Re = rupee.

Table 1. Characteristics of the experimental sites.

State	District	Agro-climatic zone	Soil texture	Average annual precipitation, mm	Cropping system	Ecology	Average farmer-type
Punjab	Ludhiana, Amritsar, Gurdaspur, Sangrur, Fatehgarh Sahib	Central Plain Zone to Sub-Mountain Undulating	Sandy loam to silty loam	600 to 1,020	Rice-Wheat	Favourable rainfed	Resourceful and large farmers
Haryana	Karnal, Kurukashetra, Kaithal, Ambala, Yumnanagar	Northwestern Plain	Sandy loam to clay loam	400 to 600	Rice-Wheat	Favourable rainfed	Resourceful and large farmers
Bihar	Vaishali, Samastipur, Purnea, Katihar, Begusarai, Patna and Jamui	North, West, Northeast and South Bihar Alluvial Plains	Sandy loam to silty clay loam	1,100 to 1,400	Rice-Maize	Favourable rainfed	Poor and small farmers

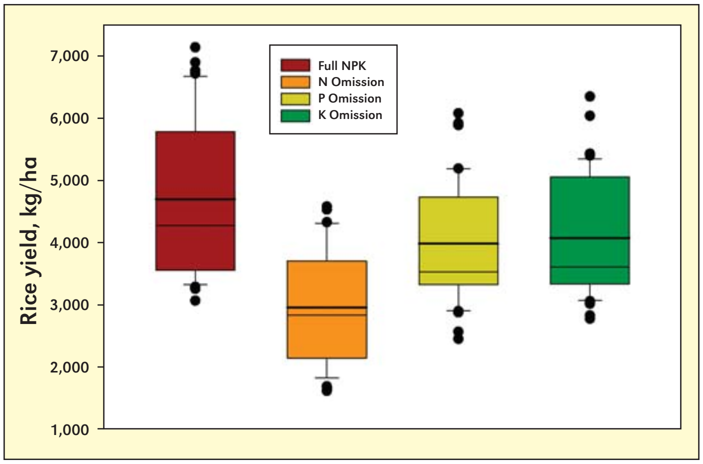

Figure 1. Rice yields in ample NPK and omission plots across 45 experiments locations in the Indo-gangetic plains. The error bars represent 10th to 90th percentile of the data, and the thick line represents the mean.

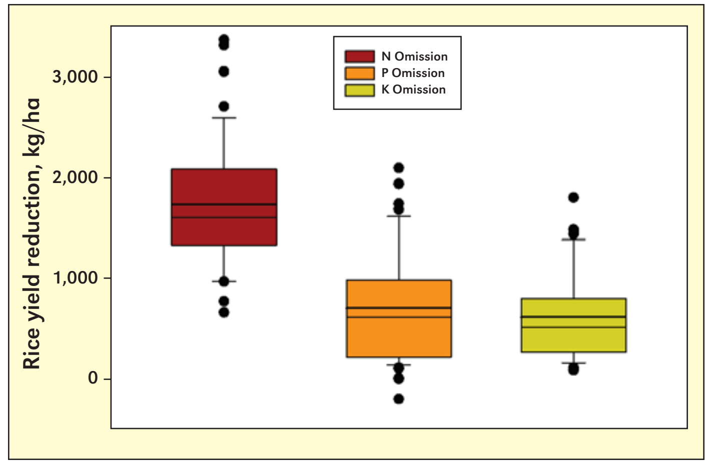

Figure 2. Rice yield loss in N, P, and K omission plots compared against ample NPK plots across 45 experimental locations in the Indo-gangetic plains. The error bars represent 10th to 90th percentile of the data, and the thick line represents the mean.

one. The application rates, based on estimated attainable yield targets between 5 and 8 t/ha, were 125 to 175 kg N/ha, 50 to 80 kg P_2O_5/ha, and 60 to 90 kg K_2O/ha depending on climate, growing environment, and farmer typology. At maturity, grain yields and total biomass (grain + straw yields) were determined and adjusted to 13% moisture content.

The yield response due to nutrient application (such as N response) and nutrient application economics were estimated using the following equations:

Nutrient Response (kg/ha) = Grain yield in ample NPK plot – Grain yield in targeted nutrient omission plot

Return on Investment (ROI) in fertilisers = (Yield increase due to target fertiliser [kg/ha] x MSP of crop [Rs/kg]) / (Applied targeted fertiliser [kg/ha] x cost of the fertiliser [Rs/kg])

The average MSP of rice was Rs. 10/kg during the study period. Return on investment in fertilisers were calculated based on N, P_2O_5, and K_2O prices of Rs. 11.54, 32.2, and 18.8/kg, respectively. Also, the following price levels of fertilisers and MSP range for rice were used to calculate the ROI (Majumdar et al., 2012, Jat et al., 2012; Satyanarayana et al., 2012):

1. Five price levels of N between Rs. 10.5 to 43.48/kg, corresponding to Urea prices between Rs. 4,830 and 20,000/t.
2. Five price levels of P_2O_5 between Rs. 19.26 to 50.20/kg, corresponding to DAP prices between Rs. 10,750 and 25,000/t.
3. Four price levels of K_2O between Rs. 8.43 to 33.33/kg, corresponding to MOP prices between Rs. 5,058 and 20,000/t.
4. Rice MSP levels of Rs. 10 to 15/kg.

The 25th, 50th, and 75th percentiles of the actual N, P, and K responses observed for rice in this study were considered as benchmarks for estimating ROI at current and estimated future prices of fertiliser and MSP of rice.

Results

The average rice yield with ample application of NPK was 4,701 kg/ha with a range of 3,070 to 7,140 kg/ha (**Figure 1**). The average yield across trials was more than double the cur-

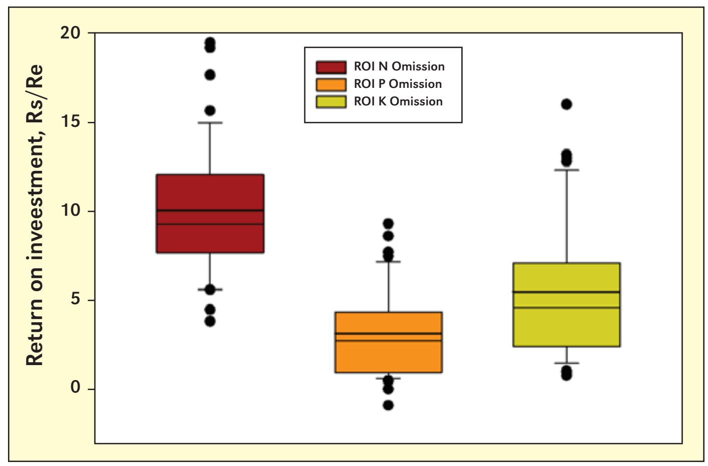

Figure 3. Return on investment in N, P and K fertilisers based on current application rates, fertiliser costs, and minimum support price for rice. The error bars represent 10th to 90th percentile of the data, and the thick line represents the mean.

rent average yield of rice in India. Omission of nutrients from the ample NPK treatment caused variable yield reduction in farmers' plots. Reduction of yield was highest for N omission (667 to 3,370 kg/ha) with an average of 1,739 kg/ha (**Figure 2**). For N omission plots, the results are in agreement with the findings of Saha et al. (2008) who reported a yield response of 1,510 kg/ha with application of N in the long-term fertiliser experiment conducted at Raipur. Yield reductions in P and K omission plots also varied widely across different locations (-194 to 2,100 kg/ha and 90 to 1,806 kg/ha, respectively) with mean respective yield losses of 712 kg/ha and 622 kg/ha. The results clearly highlight the variability of nutrient supplying capacity of rice-growing soils and system management practices by farmers with diverse socio-economic profiles.

Return on investment in fertiliser N ranged from 3.9 to 19.5 (**Figure 3**) with an average of Rs. 10.04 per rupee invested on N. Similarly, ROI in fertiliser P ranged from -0.9 to 4.0 Rs/Re. Average ROI for fertiliser P across locations was 3.0 Rs/Re. ROI was ≤ 1 Rs/Re in 12 locations at an average ample

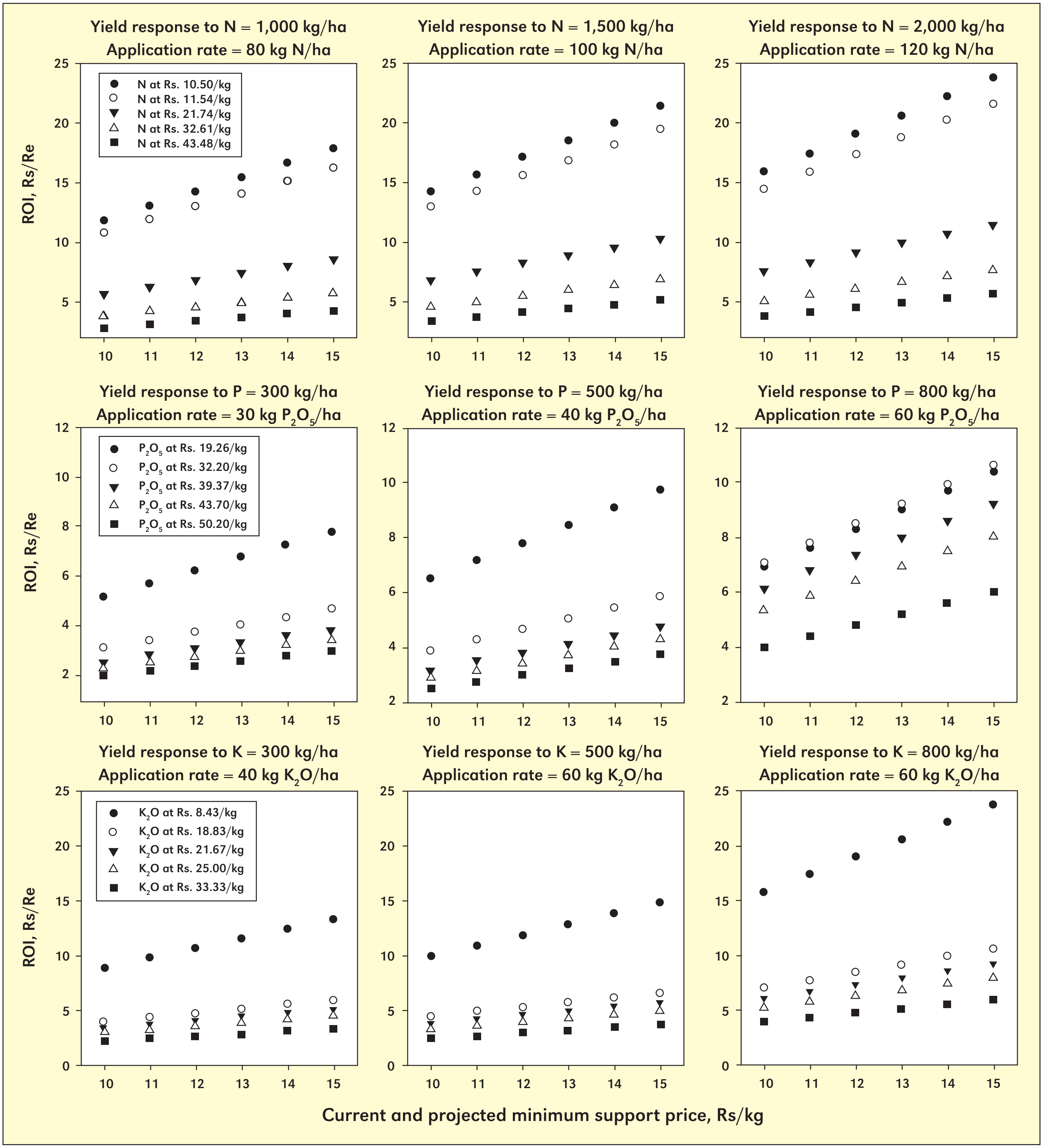

Figure 4. Top Row: Return on investment (ROI) in N fertiliser at different N response levels and projected costs of N fertiliser and minimum support prices for rice. Middle Row: Return on investment (ROI) in P fertiliser at different P response levels and projected costs of P fertiliser and minimum support prices for rice. Bottom Row: Return of investment (ROI) in K fertiliser at different K response levels, projected costs of K fertiliser and minimum support prices for rice.

application rate of 70 kg P_2O_5/ha. Likewise, ROI in fertiliser K ranged between 0.8 to 16 Rs/Re, which revealed that every Rs. invested in fertiliser K produced an additional rice yield worth 0.8 to 16 Rs., with a mean of Rs. 5.5 across the locations. Economic return of < Rs. 1 per rupee invested on K was registered at three locations only.

The results highlight that nutrient responses, and consequently ROI, differed considerably across sites. The economic return from applied fertiliser is integrally related to the crop response to any particular nutrient, which in turn depends on the indigenous nutrient supplying capacity of a particular field or location. Optimising fertiliser application based on expected crop response at a particular field can ensure higher returns from fertiliser application. This is the essence of site-specific nutrient management, where nutrients are applied on the basis of soil nutrient supplying capacity and the nutrient requirement for a particular nutrient. This ensures that nutrients are not under- or over-applied leading to economic loss. The results from rice experiments, showed a wide range of response to N, P, or K application. Breaking up such a range of responses into definite "response segments" and suggesting nutrient application rates that achieve higher yield, higher profit without depleting the soil nutrient resources would ensure food and economic security of the farmers and maintenance of soil health.

Considering the high variability of rice response to N, P, or K fertiliser application across sites, the ROI for the 25th, 50th and 75th percentiles of the actual N, P, and K responses observed in the present experiments were also assessed. We assumed that N response of 1,000 kg/ha justifies application of 80 kg N/ha, while N response of 1,500 and 2,000 kg/ha will require 100 and 120 kg N/ha. Similarly for P, 300 kg/ha of response justifies application of 30 kg P_2O_5/ha, while P response

At a rice trial site in Punjab, Dr. Kaushik Majumdar (on left) with participating farmer.

of 500 and 800 kg/ha will require applications at 40 and 60 kg P_2O_5/ha, respectively. A K response of 300 kg/ha justifies application of 40 kg K_2O/ha, while K response of 500 and 800 kg/ha will require applications of 60 kg K_2O ha. The application rate was kept similar for 500 and 800 kg/ha considering generally micaceous mineralogy of the study area soils, high utilization efficiency of K, and cost of fertiliser. The aim of this exercise was to estimate ROI at actual and hypothetical (future scenario) costs of N, P_2O_5, and K_2O as well as at current and projected minimum support prices of rice.

Figure 4 shows that N application, at chosen application rates, is economically profitable. At an application rate of 80 kg N/ha for a 1,000 kg/ha N response, the ROI at the highest price of N (Rs. 43.5/kg) and at the lowest MSP for rice (Rs. 10/kg) was 2.9, suggesting profitable return on N application—even in worst case. Further, the profitability increased with an increase in the MSP of rice as well as the crop response levels. **Figure 4** shows that P application, in general, is economically profitable even in areas where P responses were low (300 kg/ha). At an application rate of 30 kg P_2O_5/ha, the ROI at the highest price of P fertiliser (Rs. 50/kg P_2O_5) and the lowest MSP (Rs. 10/kg rice) was 2 Rs/Re—suggesting profitable return on P application even under low P response situations. Obviously the ROIs increased with increase in the crop response levels. Returns to the farmer could be increased through reasonable increase in MSP of rice under increasing fertiliser price scenarios. **Figure 4** shows that K application at the predetermined rates, in general, is economically profitable even in areas where K response is as low as 300 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. The profitability increased with increase in the MSP for rice. A yield loss of $\geq$ 500 kg/ha of rice due to no application of K was observed in more than 50% locations. This suggests that in such locations, application of 40 to 60 kg K_2O/ha will provide a good ROI to the farmers and will also maintain the K fertility status of the soil.

It should be noted that maximum economic yields are obtained only with adequate and optimum nutrient application. The diverse rice-growing environments (soils and climatic conditions) and farmer management practices across the IGP present large variability in nutrient supplying capacity. Therefore, nutrient management decisions in this region must be based on expected nutrient response of rice at a particular location. Providing adequate and balanced rates of N, P, K, and other limiting nutrients, considering the expected yield response in the rice-growing soils of the IGP, will not only help in economic sustainability but also will offer better environmental stewardship of nutrients applied to soil. The general perception that Indian soils are rich in K and, therefore, do not require K application—or that most soils have high build-up of P due to continuous historical application of P fertiliser and may not respond to P application—were not supported by these well distributed, recent on-farm experiments. Rationalisation of fertiliser management strategies, based on spatially and temporally variable crop responses and nutrient balances in highly intensive cereal systems would be required to sustain food and economic security of farmers.

Summary

The study showed a variable reduction in rice yields in N, P, or K omission trials in farmers' fields. The ROI in N, P, and K fertilisers was profitable in most of the cases, even at lowest crop response and with the present MSP for rice. BC-SA

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