Economics of Fertilizing Irrigated Cereals in the Indo-Gangetic Plains

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On-farm studies in the Indo-gangetic plains (IGP) clearly indicated the positive response of cereals (rice, wheat, and maize) to NPK fertilization. Economic assessment of data, based on current as well as future fertilizer price and crop value or minimum support price (MSP) scenarios, showed favorable return on investment in N, P, and K fertilizers in the IGP.

Cereals constitute the staple food in India, and about 61% of the total protein requirement of the Indian population is met through cereals. They use about 63% of the total fertilizer consumed in India, of which rice, wheat, and maize use 37, 24, and 2% of the total, respectively (Chanda, 2008). Cereals are grown under variable conditions in the IGP (i.e. soil types, cropping systems, agro-ecological regions, etc.). Such variability in land characteristics and growing environments is reflected in the productivity (attainable yield) and subsequently in nutrient requirement by these crops. This necessitates the integration of crop response data with fertilizer decision support for increased productivity, higher economic returns, and better environmental stewardship. This study was conducted to estimate: (1) response of cereals to NPK application, (2) economic return on investment in N, P, and K fertilizers, and (3) profitability of NPK application under current and projected future fertilizer price and crop value or minimum support price (MSP) scenarios.

The International Plant Nutrition Institute (IPNI) and the International Maize and Wheat Improvement Centre (CIMMYT) under the Cereal Systems Initiative for South Asia (CSISA) project conducted 45, 141, and 36 on-farm trials in rice, wheat, and maize, respectively, across the IGP during 2009 to 2011. The objective was to capture the nutrient response of crops under variable soil and growing environments. The IGP covers the states of Punjab, Haryana, Uttar Pradesh, Bihar, Jharkhand, and West Bengal representing irrigated, intensive production systems and a relatively large farm scenario in the Western IGP to rainfed, low intensity, fragmented farming systems of eastern India (**Table 1**).

The experiment consisted of four treatments including: T_1 - ample NPK, T_2 - omission of N with full P and K, T_3 - omission of P with full N and K, and T4 - omission of K with full N and P. For rice, NPK application rates were 125 to 175 kg N/ha, 50 to 80 kg P_2O_5/ha, and 60 to 90 kg K_2O/ha based on estimated yield targets of 5 to 8 t/ha. For wheat, N application rates were 150 to 180 kg/ha for yield targets of 5 to 6 t/ha, while P and K rates were fixed at 90 kg P_2O_5 and 100 K_2O/ha. Maize trials were concentrated in Bihar and West Bengal and ample NPK rates for maize were 150 to 180 kg N, 70 to 115 kg P_2O_5, and 120 to 160 kg K_2O/ha for yield targets of 6 to 8 t/ha. Nutrients were applied in excess of the actual requirement of crops, following the omission plot experiment protocol, to ensure no limitation of nutrients except for the omitted one. At maturity, total biomass (grain + straw) and grain yields were determined, and adjusted to 13% moisture content for all the three crops.

Yield increase (nutrient response in kg/ha) due to and economics of N, P, or K application were estimated using the following equations:

Nutrient response = Grain yield in ample NPK plot – Grain yield in a nutrient omission plot

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; INR = rupee; AE_N = agronomic efficiency of nitrogen; 1 US dollar = INR 51.85.

Table 1. Characteristics of the experimental sites (all irrigated).

State	Districts	Agro-climatic zone	Soil texture	Average annual precipitation, mm	Cropping system	Crops studied
Punjab	Ludhiana, Amritsar, Gurdaspur, Sangrur, Fatehgarh, Sahib	Central Plain Zone to Sub-Mountain Undulating Zone	Sandy loam to silt loam	600 to 1,020	Rice-Wheat, Cotton Wheat	Rice and Wheat
Haryana	Karnal, Kurukashetra, Kaithal, Ambala, Yumnanagar	North Western Plain Zone	Sandy loam to clay loam	400 to 600	Rice-Wheat	Rice and Wheat
Uttar Pradesh	Agra	South Western Plain Zone	Sandy loam	650	Pearl millet-Wheat	Wheat
Bihar	Vaishali, Samastipur, Purnea, Katihar, Begusarai, Patna, and Jamui	North West, North East, and South Bihar Alluvial Plains	Sandy loam to silty clay loam	1,100 to 1,400	Rice-Maize	Rice and Maize
West Bengal	Uttar Dinajpur and Nadia	Old and New Alluvial Zone	Sandy loam to silty clay loam	1,300 to 1,500	Rice-Maize	Maize

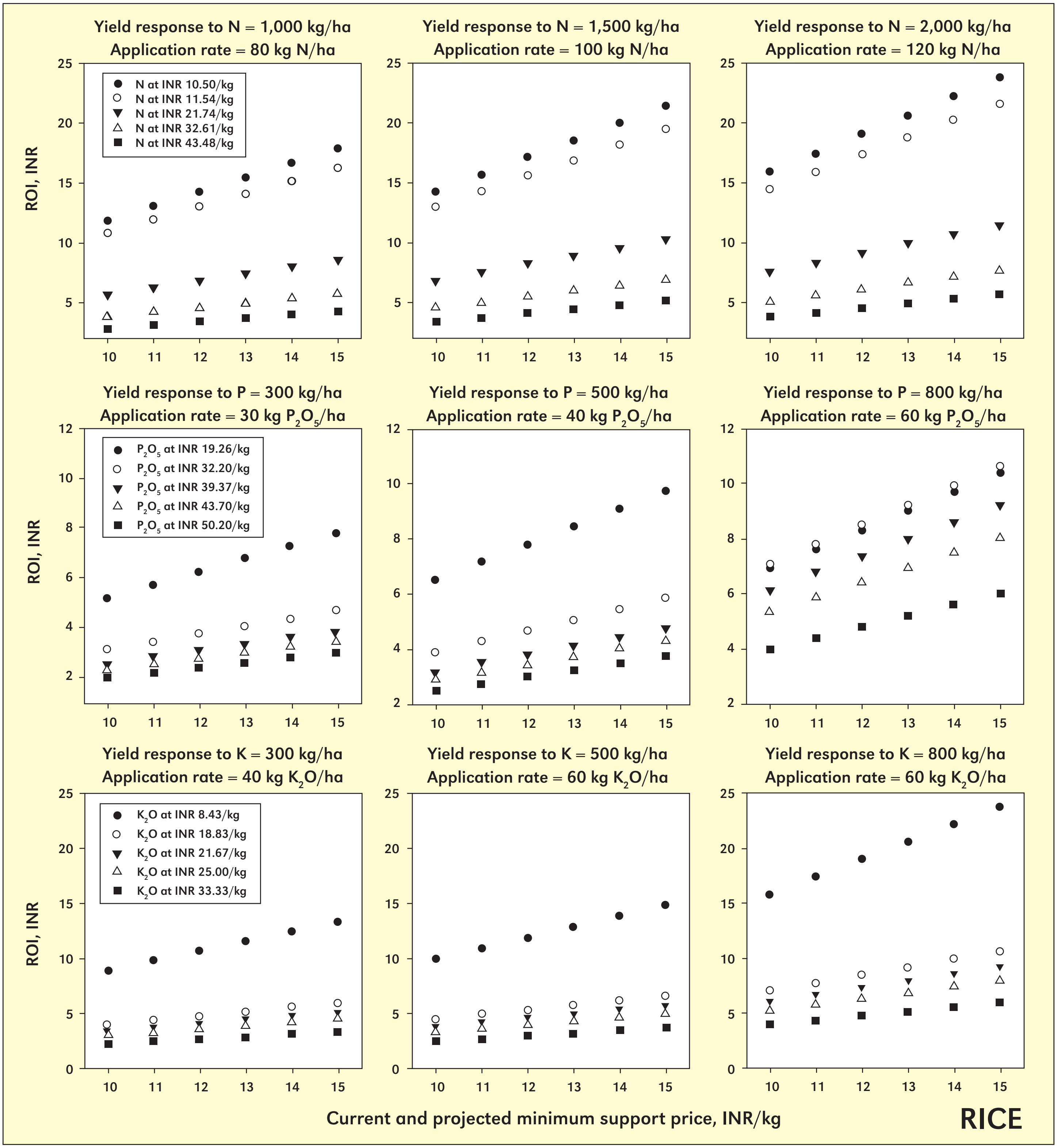

Figure 1. Top Row: Return on investment (ROI) in N fertilizer at different N response levels and projected costs of N fertilizer and minimum support prices for rice. Middle Row: ROI in P fertilizer at different P response levels and projected costs of P fertilizer and minimum support prices for rice. Bottom Row: ROI in K fertilizer at different K response levels, projected costs of K fertilizer and minimum support prices for rice.

Return on investment (ROI) in a fertilizer (nutrient) = Yield increase due to the fertilizer (nutrient) x Minimum support price (MSP) of crop / Applied fertilizer cost

Rice Results

The average rice yield with ample application of NPK was 4,700 kg/ha with a range of 3,070 to 7,140 kg/ha (data not shown). Likewise, omission of nutrients from the ample NPK treatment caused variable yield reduction in farmers' plots. Reduction of yield was highest for N omission plots (667 to 3,370 kg/ha) with an average of 1,739 kg/ha followed by P omission plots (range of -194 to 2,100 kg/ha with an average

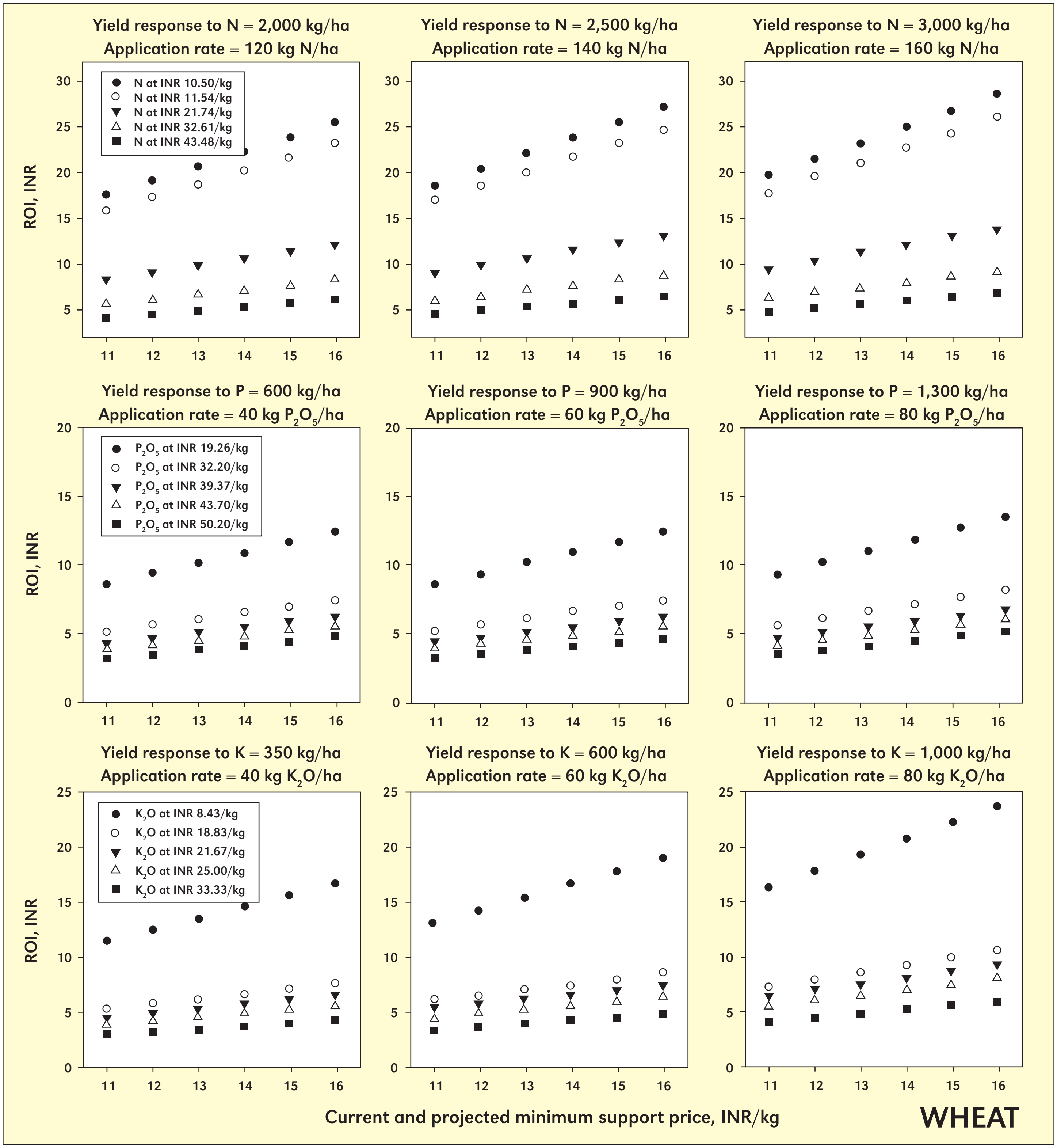

Figure 2. Top Row: Return on investment (ROI) in N fertilizer at different N response levels and projected costs of N fertilizer and minimum support prices for wheat. Middle Row: ROI in P fertilizer at different P response levels and projected costs of P fertilizer and minimum support prices for wheat. Bottom Row: ROI in K fertilizer at different K response levels, projected costs of K fertilizer and minimum support prices for wheat.

of 712 kg/ha) and K omission plots (range of 90 to 1,806 kg/ha with an average of 622 kg/ha). It is interesting to note that the average rice yield across trials with ample NPK application was more than double the current average yield of rice in India signifying how balanced nutrition can improve yields.

Figure 1 shows that N application, at pre-selected application rates, was 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 (INR 43.5/kg) and at the lowest MSP for rice (INR 10/kg) was 2.9, suggesting profitable return on N application—even in the worst case scenario. Further, the profitability increased with an increase in the MSP of rice

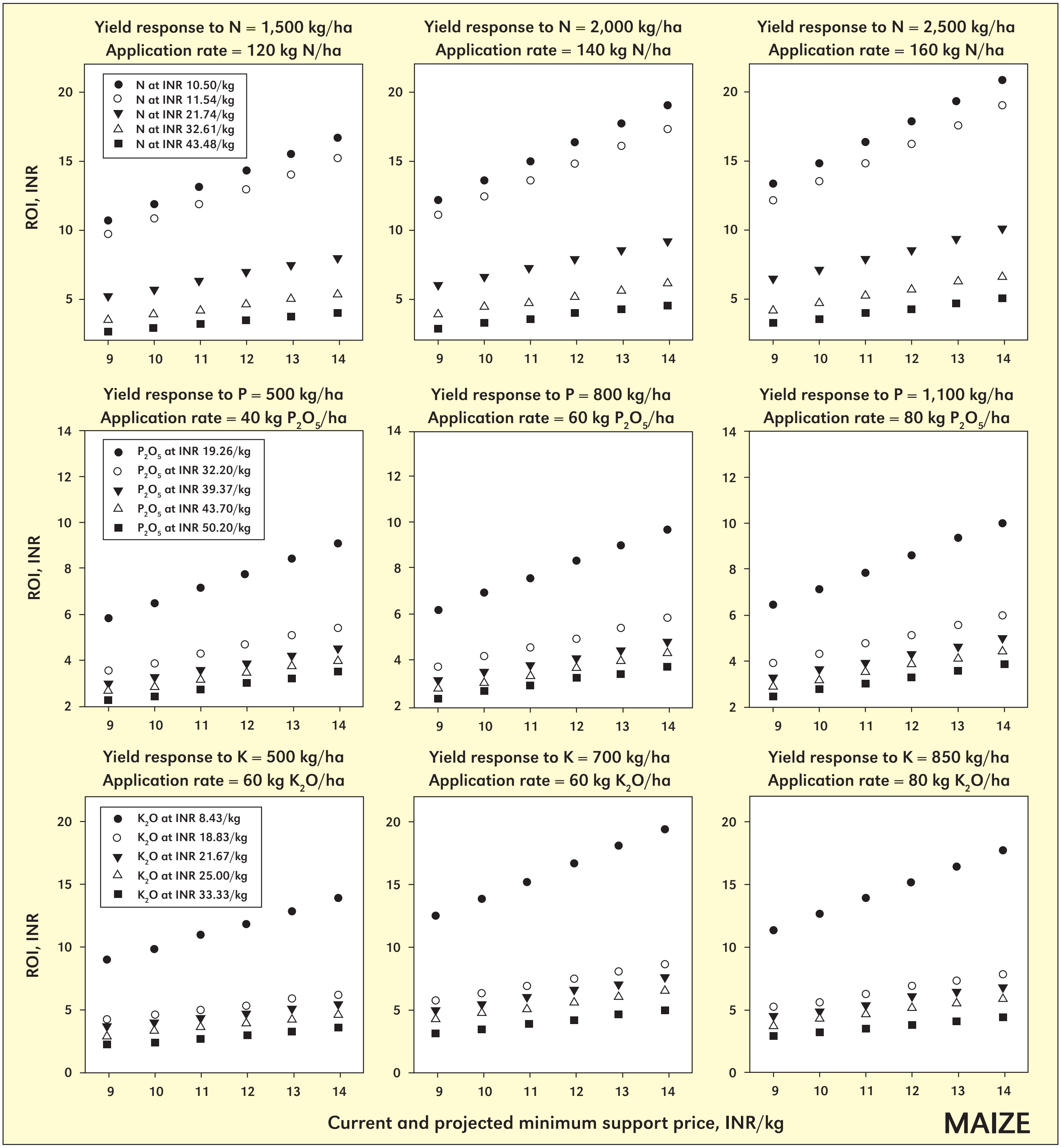

Figure 3. Top Row: Return on investment (ROI) in N fertilizer at different N response levels and projected costs of N fertilizer and minimum support prices for maize. Middle Row: ROI in P fertilizer at different P response levels and projected costs of P fertilizer and minimum support prices for maize. Bottom Row: ROI in K fertilizer at different K response levels, projected costs of K fertilizer and minimum support prices for maize.

as well as the crop response levels. Similarly, P application, in general, was 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 fertilizer (INR 50/kg P_2O_5) and the lowest MSP (INR 10/kg rice) was INR 2 per INR invested—suggesting profitable return on P application even under low P response situations. Obviously the ROIs increased with increase in the crop response levels. Likewise, K application at the predetermined rates, in general, was 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

(INR 33.33/kg of K_2O) and the lowest MSP (INR 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 ≥ 500 kg/ha of rice due to no application of K was observed in more than half of the locations. This suggests that at these locations, application of 40 to 60 kg K_2O/ha will provide a good ROI to the farmers and also maintain the K fertility status of the soil. Interestingly, we observed that ROI was higher than INR 2 for all the three cereals even at the highest hypothetical fertilizer prices used in the economic assessment.

Wheat Results

The average rice yield with ample application of NPK was 5,096 kg/ha with a range of 3,111 to 6,500 kg/ha (data not shown). Likewise, omission of nutrients from the ample NPK treatment caused variable yield reduction in farmers' plots. Reduction of yield was highest for N omission plots (500 to 4,750 kg/ha) with an average of 2,566 kg/ha followed by P omission plots (range of 67 to 2,806 kg/ha with an average of 969 kg/ha) and K omission plots (range of 0 to 2,222 kg/ha with an average of 715 kg/ha).

Profit analysis considering the projected cost of N fertilizer at varying MSPs of wheat (**Figure 2**) revealed that ROI decreased with increasing N fertilizer price from INR 10.5/kg to a future forecasted price of INR 43.48/kg of N, but increased with increasing MSP of wheat, irrespective of N fertilizer cost. Return on investment recorded at the current MSP and the projected maximum price of N fertilizer, across all N response levels, was ≥ INR 4.2 per INR invested making it a profitable option for farmers. Likewise for P, ROI at the current MSP and the projected maximum price of P fertilizer would be INR 3.3 per INR invested, even at the low P response areas. At high P response areas (P response of approximately 1,300 kg/ha), the ROI at highest projected fertilizer P price would be INR 3.6 per INR invested at the current MSP of wheat, again making it a profitable option for farmers. Similarly, for K application, ROI at the current MSP and the projected maximum price of K_2O would be INR 2.9, even at the low response locations. At high response locations (K response of approximately 1,000 kg/ha), the ROI at highest projected K price was INR 4.1 at the current MSP of wheat, again making it a profitable option for farmers. Potassium response was > 1 t/ha in 25% of the locations in the present study, and those locations would produce ROI of INR 8 at the current cost of K and wheat MSP.

Maize Results

The average maize yield with ample application of NPK was 6,343 kg/ha with a range of 4,020 to 9,420 kg/ha (data not shown). Likewise, omission of nutrients from the ample NPK treatment caused variable yield reduction in farmers' plots. Reduction of yield was highest for N omission plots (400 to 5,160 kg/ha) with an average of 2,154 kg/ha followed by P omission plots (range of 3,910 to 8,040 kg/ha with an average of 853 kg/ha) and K omission plots (range of 140 to 1,320 kg/ha with an average of 700 kg/ha).

Among the three cereals, maize has the lowest MSP. However, ROI at the current MSP and highest cost of N fertilizer were 2.6, 3.0, and 3.2 at the three N response levels of 1,500, 2,000, and 2,500 kg/ha, respectively (**Figure 3**). This suggests that N application at the highest projected price of urea would provide reasonable economic returns to farmers. The fertilizer N rates used for the three levels of N response correspond to AE_N values of 13, 14, and 16 kg grain/kg N. This suggests that ROI at these N response levels could still be improved if AEN is improved through better N management. For P, ROI at the current MSP and highest cost of P fertilizer were ≥ INR 2 at all the three P response levels. This suggested that like N application, P application at the given rates would also be profitable to farmers. For K application, ROIs were 2.3, 3.2, and INR 2.9 per INR invested for 500, 700, and 850 kg/ha K responses, respectively, at the current MSP and the highest projected price of K_2O, again giving reasonable returns to farmers.

Conclusions

The results clearly highlight the large variability observed in nutrient supplying capacity of cereal-growing soils and system management practices by farmers with diverse socio-economic profiles. Average yield losses due to K omission were high for all cereals grown in the IGP. This is contrary to the popular perception that omitting potash application for a season or forever will not adversely affect cereal production in the country. The data also clearly demonstrated that most of the soils in the IGP have low K supply levels. Economic assessment based on observed NPK response levels with current and projected prices of these fertilizers and MSPs of cereals showed ROI > INR 2 under all scenarios. This indicated that NPK application in cereals in the IGP is economical at current and future price scenarios, and farmers' profit can be assured when fertilizer application is guided by indigenous nutrient supply and expected nutrient response at a particular location. BC

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