Research Findings

Paddy rice demonstration plot in Uttar Pradesh, India. The difference in the height and number of leaves between the plants on the left (with potash applied) and the plot on the right (without) is clear. Photo by Potash for Life.

Fertilizing Indian Rice Plots with Potash: Results from Hundreds of Locations Across the States of Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Telangana, Uttar Pradesh and West Bengal

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Abstract

Agriculture forms the backbone of India's economy; however, declining soil fertility is directly impacting crop productivity. The appropriate application of fertilizer is a key factor in enhancing soil fertility and productivity and for overcoming potassium (K) depletion, which has been shown to have clear negative effects on India's rice production.

In order to evaluate the response of rice to muriate of potash (MOP), and to demonstrate to farmers the increased yield and profitability obtained when fertilizing rice plots with MOP, a large-scale trial project was launched in 2013: Potash for Life

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(PFL). The methodology was straight forward - two identical rice plots side by side, with the only difference being that one of them was fertilized with additional MOP. The results were very clear: virtually every trial showed a yield increase in response to the MOP addition, and the average yield increase was significant, ranging between approximately 6 and 15%.

It was concluded that the soil status of plant available K is significantly lower than plant demand in the six project states of Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Telangana, Uttar Pradesh and West Bengal. This means that MOP fertilization is necessary in these states in order to improve agricultural practices and optimize yields. At this stage of research, we recommend that local MOP application standards should follow those performed in this trial. However, further trials and research are necessary to fine tune high-precision recommendations at a location-specific level.

Introduction

Agriculture is forming the backbone of the Indian economy in spite of concerned efforts towards industrialization in the last three decades. As such, agriculture contributes a high share of the net domestic product in India (FAO, 2018).

India's economy has experienced remarkable progress during recent decades. To a large extent due to overall growth in industrial production, IT exports, agricultural production and exports, foreign investments and enhanced inward remittances of funds by expatriates. In spite of that, 70% of the population still live in rural areas and are dependent on agriculture (FAO, 2018). The ever-increasing demand for food, feed, and fibres, and the limitation of arable land, necessitate not only the practices of preserving, managing, and enriching the natural resources, but also the up-scaling of land-use-efficiency. Soil forms the basis for any crop production activity and is the most precious natural resource. Declining soil fertility is one of the primary factors that directly affect crop productivity. Therefore, soil fertility management is crucial in order to ensure productivity and nutritional security, while maintaining soil health and sustainability (Prasad and Power, 1997).

Subsequently, fertilizer-use is a key factor in order to ensure soil fertility and productivity. Fertilizers are one of the costly inputs in agriculture. Still, if used correctly they can be one of the most profitable (FAO, 2005).

It's a fact that imbalanced and incorrect use of fertilizers not only afflicts nutrient use efficiency, but that it can also cause deterioration in soil quality (Wallace, 2008).

Therefore, balanced fertilizer use must be promoted, as it's an absolutely necessary way to prevent both soil fertility decline from too low use, and soil quality deterioration from over-use or imbalanced use.

In an effort to promote balanced use, the project "Potash for Life (PFL)" was launched in 2013 in response to recent negative developments in potash use in India, and to support profitable agriculture. PFL is a collaborative project between Indian Potash Limited (IPL) and ICL Fertilizers. One important crop in the PFL project is rice.

The rice harvesting area in India is the world's largest. Rice is not only one of the most important food crops in India, serving as the staple food for 65% of the total population (FAO, 2017), it is also one of the most important cash crops as it provides income and employment for 50 million households.

The PFL project is raising awareness of the importance of muriate of potash (MOP) fertilization for rice crops, mainly through demonstration plot trials in collaboration with local farmers. The results and profitability of MOP application were clearly demonstrated to other rice producers through the trials. PFL is engaged with rice demonstration plot trials in six states: Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Telangana, Uttar Pradesh and West Bengal.

Objectives

The trials had two main objectives:

- To demonstrate to farmers the increased yield and profitability of rice obtained as a result of applying MOP in addition to the conventional use of diammonium phosphate (DAP), urea and manure.
- To evaluate the response of rice to MOP using recommended fertilizer blends on K-deficient soils.

Materials and methods

Experimental set-up

Verification trials were conducted in the fields of different farmers throughout the six project states. Each farmer grew rice, and for the experiments at each farm, two adjoining plots were used - one was applied with MOP and one was the control. Between the plots was a 1 m wide path. The plots within the same state were relatively similar, but not between states.

Treatments

There were two treatments for each experiment: 1) control, where the common fertilizer practice of urea, DAP and in some cases manure was applied, and; 2) '+K treatment', where MOP was typically applied at 75 kg ha^{-1} in addition to the urea, DAP and manure fertilizers. The local fertilizer recommendations varied between and throughout the states, mainly due to the variation in recommendations by the local authorities, or soil type and crop varieties, or due to variations in the soil test levels. Therefore, MOP doses varied. The details of the variations are described in Table 1. For each demonstration plot trial, the plot size was always the same for both treatment and control. However, between plot trials the plot sizes sometimes differed among the different farms and locations; the plot sizes varied between 0.13-14 ha. Farmers used the improved rice varieties recommended for their area, and all recommended agronomic practices such as seed rates, planting distances, irrigation schedules and plant protection measures were followed according to local recommendation and relevance.

Table 1. Fertilizer type and typical dose applied in the two treatments for the rice demonstration plot trials. The typical treatment is representative for each state, although there were deviations from them in all states.

Fertilizer	Treatment	
	Control	+K
	---kg ha^{-1}---	
N (from urea + DAP)	120	120
P_2O_5 (from DAP)	60	60
Manure[(a)]	X[(b)]	X[(b)]
K_2O (from MOP)	0	75[(c)]

[(a)]Manure was derived from different kinds of domesticated animals depending on location and production.
[(b)]There was no set standard for manure application. In some cases, no manure was applied and when it was, application depended on the practice of the farmer in question. The letter 'X' signifies that whatever dose and procedure of manure was applied, it was the same for both the treatment and control.
[(c)]The MOP dose in all states was the same except in Chhattisgarh, where the dose was 60 kg ha^{-1}, and West Bengal where the dose was either 60, 90 or 120 kg ha^{-1}.

Statistics

The statistical analyses were performed using pairwise t-tests, with a confidence level of 0.95. Data analysis was conducted separately and independently for each region and crop. Prior to statistical analyses, the data were trimmed in order to remove any outliers.

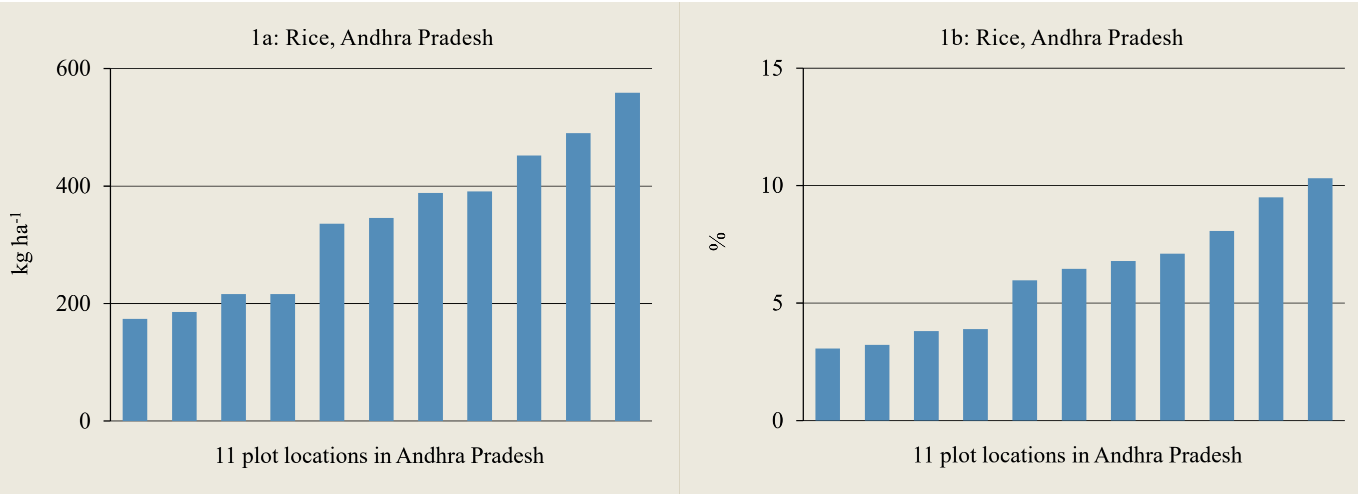
Results

Absolute yield increase

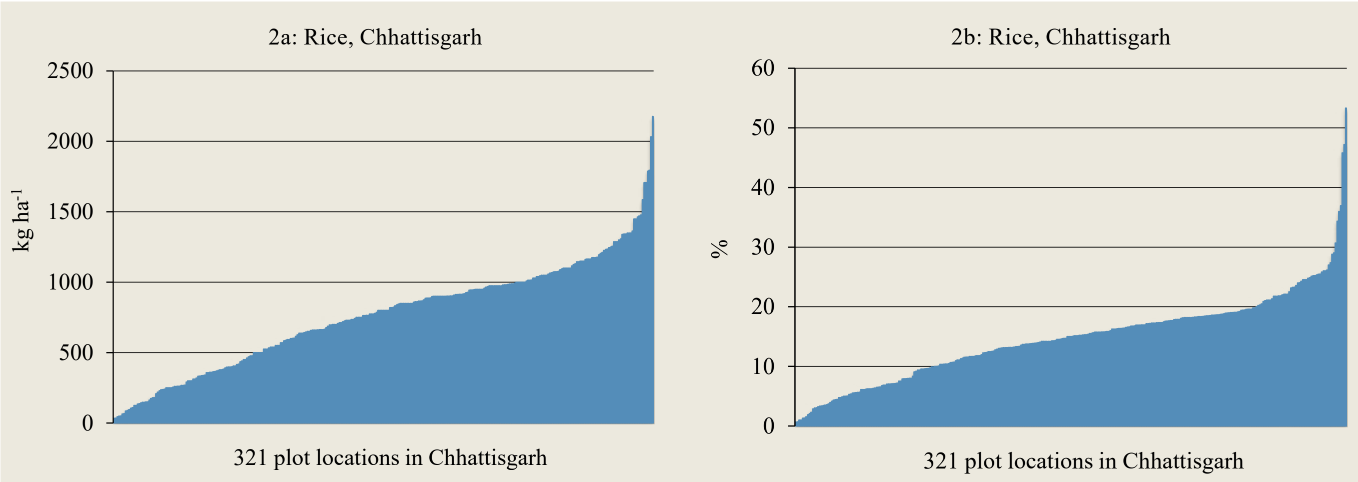
Application of MOP in addition to the common fertilizers urea, DAP and manure, gave rise to average rice yield increases of 341, 779, 509, 422 and 234 kg ha^{-1}, in Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Telangana, Uttar Pradesh and West Bengal, respectively (Fig. 8). The range in rice yields under the control conditions and the response patterns to MOP followed similar trends for most states, even though there were some differences within and between the regions. The control rice yields predominantly ranged from 3,000 to 7,000 kg ha^{-1}, although they were mainly clustered above 5,000 kg ha^{-1} in Andhra Pradesh and Telangana, and below 5,000 kg ha^{-1} in Madhya Pradesh and Uttar Pradesh. Except for Chhattisgarh, which had its own pattern, the yield increase response patterns to MOP application ranged from roughly 100 to 700 kg ha^{-1}, although this increased to up to around 800 kg ha^{-1} in Uttar Pradesh (Figs. 1-7). In Chhattisgarh, the yield increase response ranged evenly from 50 to 1,500 kg ha^{-1}, with some outlying values. Most other states also had an evenly distributed yield increase in response to MOP except for Madhya Pradesh, which had low variation in its response.

Relative yield increase

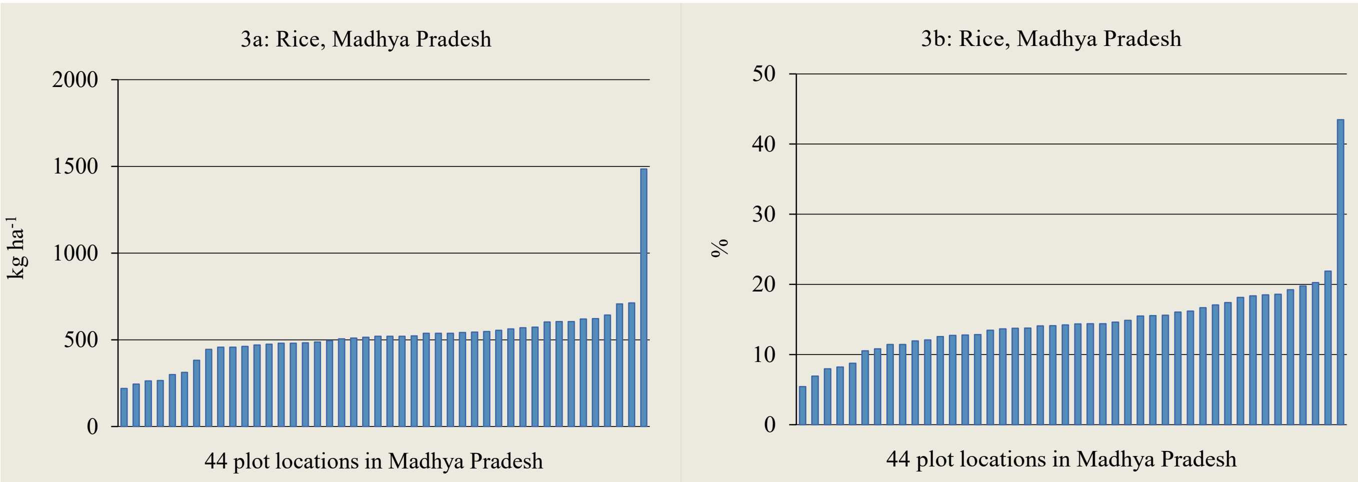
The application of MOP in addition to the common urea, DAP and manure fertilizers, gave rise to average rice



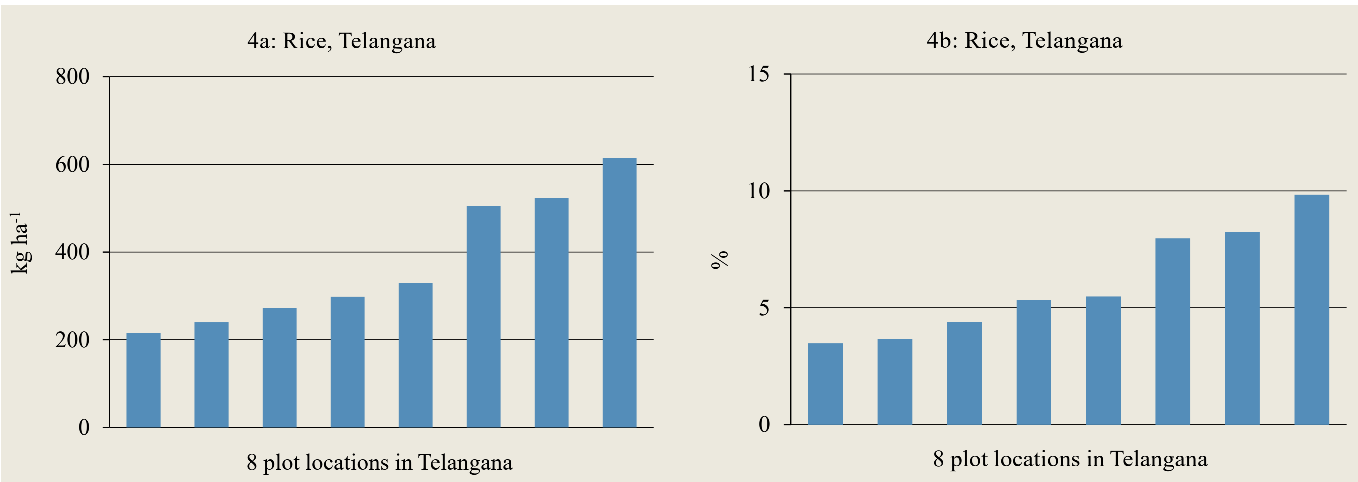
Figs. 1a and 1b. Yield increase in rice plots fertilized with MOP in comparison to control plots with no MOP fertilization for 11 plot pairs across Andhra Pradesh. The plots were harvested in 2015.



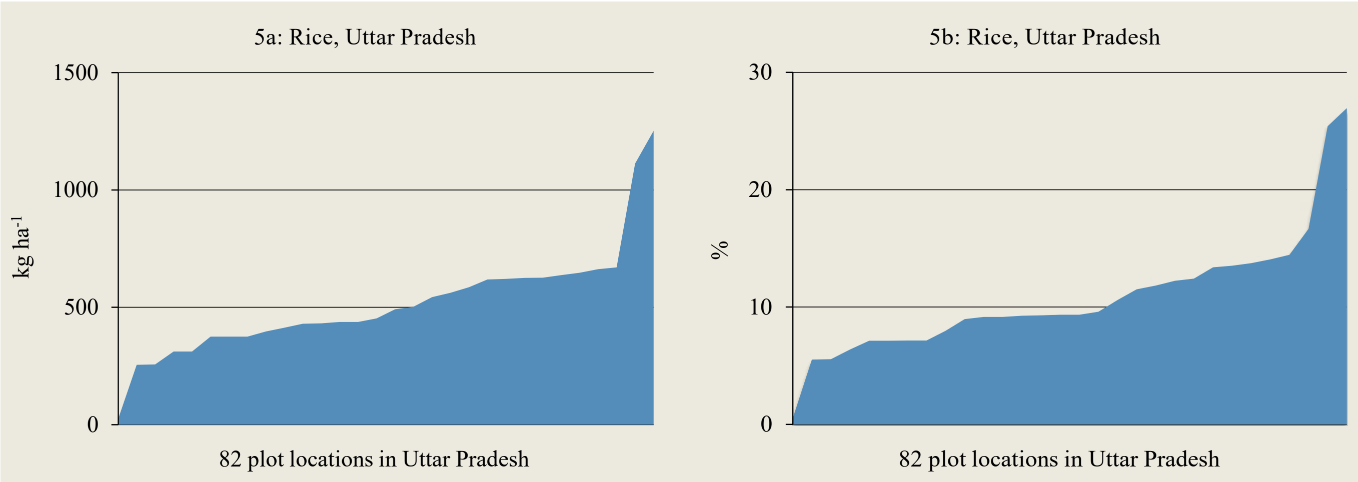
Figs. 2a and 2b. Yield increase in rice plots fertilized with MOP in comparison to control plots with no MOP fertilization for 321 plot pairs across Chhattisgarh. The plots were harvested in 2014, 2015 and 2016.



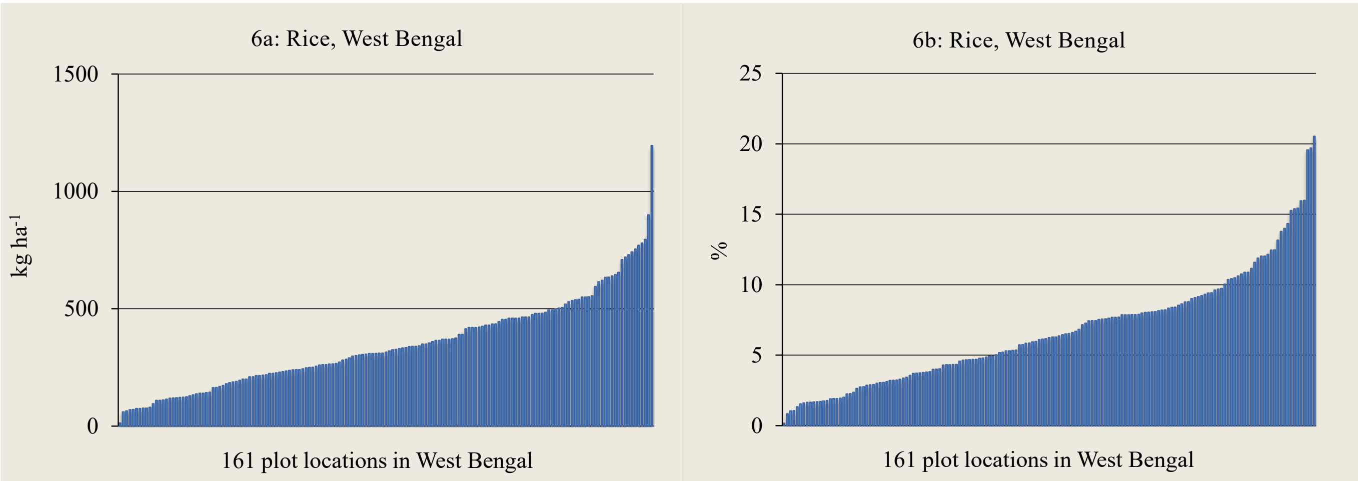
Figs. 3a and 3b. Yield increase in rice plots fertilized with MOP in comparison to control plots with no MOP fertilization for 44 plot pairs across Madhya Pradesh. The plots were harvested in 2016.



Figs. 4a and 4b. Yield increase in rice plots fertilized with MOP in comparison to control plots with no MOP fertilization for 8 plot pairs across Telangana. The plots were harvested in 2016.



Figs. 5a and 5b. Yield increase in rice plots fertilized with MOP in comparison to control plots with no MOP fertilization for 82 plot pairs across Uttar Pradesh. The plots were harvested in 2015 and 2016.



Figs. 6a and 6b. Yield increase in rice plots fertilized with MOP in comparison to control plots with no MOP fertilization for 161 plot pairs across West Bengal. The plots were harvested in 2014, 2015 and 2016.

yield increases of 6, 15, 15, 6, 10 and 7% in Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Telangana, Uttar Pradesh and West Bengal, respectively (Fig. 10). The patterns of yield increase response to MOP application ranged roughly between: 2 and 10% in Andhra Pradesh and Telangana; 5 and 20% in Madhya Pradesh and Uttar Pradesh: 2 and 20% in West Bengal; and 2 and 30% in Chhattisgarh, with some outlying values up to around 50% (Fig. 9). Except for Madhya Pradesh, in which most data were relatively close to the median, there was a steady increase in yield increase response for MOP between the highest and the lowest response value in all states.

Discussion

On average, the additional MOP brought about significant increases in rice yields across all six Indian states (Fig. 8 and Fig. 10). These results indicate that, in general, the soils of the experiment locations have undergone nutrient depletion and lack plant available K. Consequently, MOP fertilization practices seem to have considerable potential to increase rice productivity in India. However, the diversity in yields obtained for both the control and '+K treatment', within, as well as between regions, calls for careful dissection before any recommendations are disseminated.

The diversity in control yields is not surprising, considering the huge scope of the demonstration plot trials, as well as the geographic heterogeneity of the locations across and within the six states. Considering the variety in altitude, rainfall, temperature and disease presence, as well as the genetic diversity between the cultivars used in the experiment, and the different

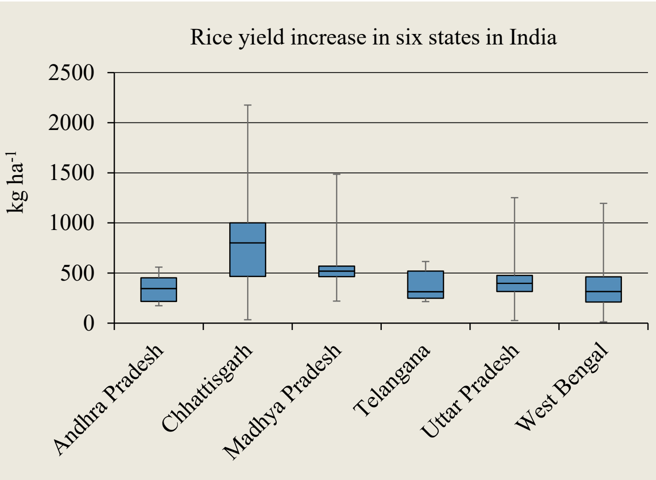


Fig. 7. Box plot diagram of rice yield increase across demonstration plots fertilized with MOP, in comparison to control plots with no MOP fertilization, for six states in India. The crops were harvested in 2014, 2015 and 2016. For each box plot, the middle line represents the median. The lower and upper edges of the box represent the first and third quartile respectively, and the end of the bars indicate the maximum and minimum values.

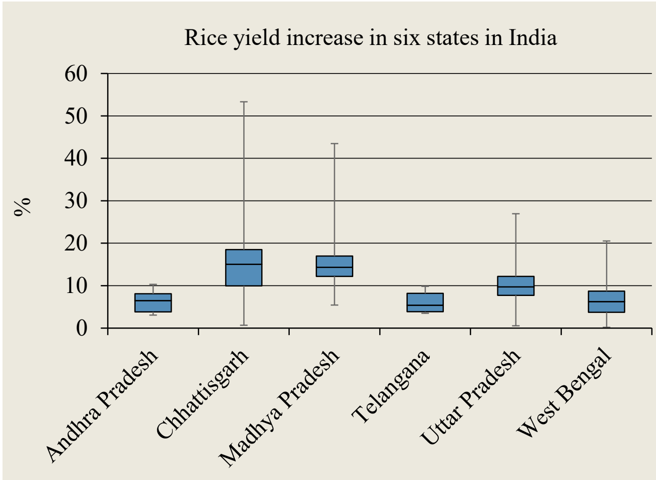


Fig. 9. Box plot diagram to show the relative rice yield increase in demonstration plots fertilized with MOP, in comparison to control plots with no MOP fertilization, in six states in India. The crops were harvested in 2014, 2015 and 2016. For each box plot the middle line represents the median value; the lower and upper edges of the box represent the first and third quartile respectively, and the end of bars indicate the maximum and minimum values.

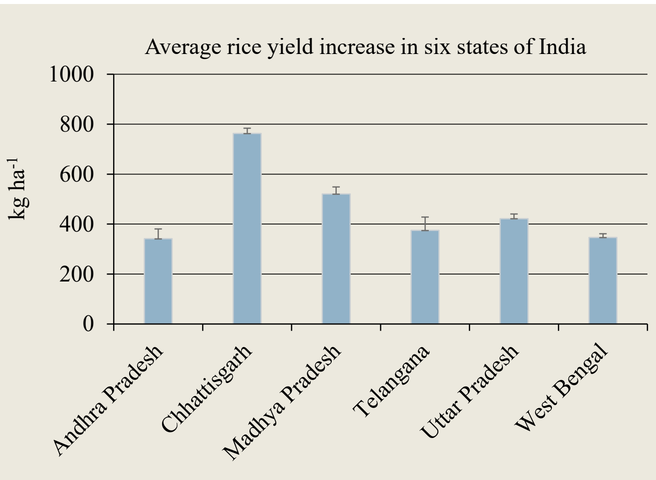


Fig. 8. Mean absolute yield increase in the six project states in India. The error bars signify the standard error.

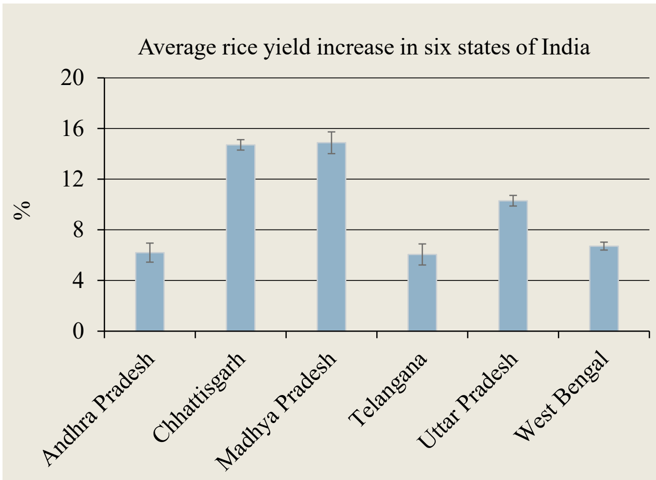


Fig. 10. Mean percentage yield increase in the six project states in India. The error bars signify the standard error.

soil types present throughout the locations, the control yield variation between 3,000 to 7,000 kg ha^{-1} is actually reasonably narrow. Furthermore, the variation in yield increase response was even more moderate. As seen in Fig. 7 and Fig. 9, the distribution of yield increase response to MOP indicates a clear trend for each state. Combined with the stable average values obtained (Fig. 8 and Fig. 10), these results provide strong evidence that the response patterns are due to region-specific soil K status, and the local practices of nutrient balancing and fertilizer management.

One interesting pattern in the variation of the MOP response was that in most regions, the yield increase was linearly distributed within the response range. This suggests a significant natural variability of K depletion within the response range, which in turn, opens up the discussion for MOP dosage levels. An increased MOP dose might lift the average response closer to the upper limit in the response range and perhaps decrease response variation.

Furthermore, in spite of the differences between the states, the results are surprisingly similar throughout the experiment in terms of growth response to MOP application. This suggests that the levels of plant available K present in the soil is a common governing factor for the outcome: that these levels are relatively

PFL agronomist Sunil Aarya (left) with farmer at the paddy demonstration plot in Khadda, Kushinagar, Uttar Pradesh, India. Photo by Potash for Life.

This rice plant from a demonstration plot in Rudlapur, Maharajganj district, Uttar Pradesh, India shows a clear difference between a plant with potash applied (right) and one without (left). The plant grown with potash has larger and stronger roots, and more panicles resulting in a higher yield. Photo by Potash for Life.

similar for all six states; and that this factor is clearly affected by balanced MOP applications.

Of course, there is no way to predict crop response to MOP application at a given location other than by conducting a comprehensive soil test. Using the information from such a test, a relevant and tailored approach can be developed to include a whole package of solutions. On the other hand, the consistently stable rice yield increases obtained during this study, indicate a high probability that an overwhelming majority of farmers within the six project states would obtain significantly higher yields as a result of following the MOP application practices of this trial. Further, to finalize nutrient balances at field scale by means of comprehensive soil testing would likely be expensive and unfeasible for local smallholding farmers.

Raising awareness of balanced fertilizer use, and correct suggestions of MOP application rates based on empirically verified large-scale trials, could gradually improve the existing practices within local mixed farming systems. The fine tuning of dosage and nutrient balancing at the local field level would then be cost and resource effective, and could provide a safe path to food security, profitability and sustainability, at a regional scale.

Conclusions

The plant available K in the soil is significantly lower than plant demand for all six states. MOP fertilization is necessary in these states to improve agricultural practices and optimize yields. The results show indications of clear trends, patterns and similarities throughout the six states for rice production. Therefore, the amount of MOP used in this trial could serve as a substantiated starting point for future recommendations to rice farmers. However, the variations in the MOP response give reason to investigate a higher MOP dose, as well as ways to fine tune the recommendations at the field scale, either through trial-and-error or through comprehensive soil tests.

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The paper "Fertilizing Indian Rice Plots with Potash: Results from Hundreds of Locations Across the States of Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Telangana, Uttar Pradesh and West Bengal" also appears on the IPI website.