Research Findings

Photo 1: Maize demonstration plot in Andrah Pradesh. Photo by the authors.

Response in Maize to Applied Potassium: Results from Field Demonstrations in the States of Andhra Pradesh, Chhattisgarh and Maharashtra

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Abstract

Under the project 'Potash for Life (PFL)' launched by Indian Potash Limited, New Delhi in collaboration with ICL Fertilizers, Beer Sheva, Israel, large scale field experiments were conducted to evaluate the potassium (K) response in maize (*Zea mays*) and demonstrate the profitability of K fertilization on the K-depleted soils. Comprehensive pairwise (adjacent –K and +K) plot trials were carried out on 9 sites in Andhra Pradesh, 4 sites in Chhattisgarh and 22 sites in Maharashtra. The methodology used was simple and straight-forward. Two identical plots, side by side (in pairs) were selected. One was fertilized with K and other did not receive any K. As revealed by the data, significant yield increases due to K application were obtained at each and every site. Mean yield increase due to K application was 407 and 664 kg ha^{-1} in Andhra Pradesh and Maharashtra, respectively which was 7.0 and 19.8% higher than the control (-K). For Chhattisgarh, these values were

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1,053 kg ha^{-1} or 19.0% more, but this increase was not statistically significant. Additional average profit accrued from K application was Rs. 4,568; 7,662 and 12,997 ha^{-1} in Andhra Pradesh, Maharashtra and Chhattisgarh, respectively.

Keywords: Potash fertilization, field demonstrations, maize, Potash for Life.

Introduction

In terms of its cultivated area and contribution to the nation's total grain production, maize ranks as India's third most important cereal crop after rice and wheat (Ranjit kumar *et al.*, 2014). Maize is not only used for human food and animal feed, but it also acts as an important basic raw material for thousands of industrial products, such as starch, oil, protein, alcoholic beverages, food sweeteners, pharmaceuticals, cosmetics, film, textile, gum, package and paper industries, etc. (APEDA, 2018). Predominantly a kharif crop (with 85% of the total area under cultivation being in kharif only), maize contributes around 10% to the country's total food grain production. Grown in almost all the agro-ecological regions of the country, it is now being cultivated throughout the year in many of the states for various purposes (Anonymous, 2018). The rate of increase in smallholder-based maize production in India has been high for the last two decades. However, despite the production strength, maize yields in India are much lower than the yields realized in the major maize-producing countries. There is, thus, an immense scope for substantially increasing maize production in the country by bringing more area under fertilizer-responsive hybrids and composites, adopting improved agronomic practices, and building a competitive maize supply chain (FICCI, 2014).

Selective implementation of the nutrient based subsidy (NBS) scheme on P&K fertilizers in April 2010 led to a sharp rise in the prices of muriate of potash (MOP). This price escalation made farmers either reduce or skip K application. This imbalanced fertilizer use widened the N:P_2O_5:K_2O ratio which had adverse consequences for soil health. Against these negative developments which led to the reduction in MOP use in the country, Indian Potash Limited (IPL) in collaboration with ICL Fertilizers, Beer Sheva, Israel launched a project "Potash for Life (PFL)" to support and advise Indian farmers to make agriculture more profitable with judicious use of MOP.

Photo 2: Farmers at demonstration plot in Maharashtra, India.
Photo by the authors.

Recognizing the importance of maize and realizing the fact that India is one of the largest producers of maize in the world, the crop was included in the PFL project. Currently, PFL is engaged with maize demonstration plot trials in three states: Andhra Pradesh, Chhattisgarh and Maharashtra. Andhra Pradesh and Maharashtra are among the top maize producing states in the country, while the yield levels in Chhattisgarh are somewhat lower (Anonymous, 2018). This paper reports the results on yield responses to applied K on farmers' fields in these states.

Materials and methods

Experimental setup

Verification trials for K response in maize were conducted on the farmers' fields in the states of Andhra Pradesh, Chhattisgarh and

Table 1. Fertilizer type and dose applied to the two treatments in the maize demonstration plot trials in the states of Andhra Pradesh and Chhattisgarh.

Fertilizer source	Andhra Pradesh		Chhattisgarh	
	-K	+K	-K	+K
	kg ha^{-1}			
N (from urea + DAP)	120[a]	120[a]	120	120
P_2O_5 (from DAP)	70[b]	70[b]	60	60
K_2O (from MOP)	0	75	0	60

[a] Average N dose was 120 kg ha^{-1}; however, the N dose in the state ranged between 100 and 140 kg ha^{-1}. Regardless of variation, dose and procedure were always the same for both the –K and +K treatments.
[b] Average P_2O_5 dose was 70 kg ha^{-1}; however, the P_2O_5 dose in the state ranged between 60 and 80 kg ha^{-1}. Regardless of variation, dose and procedure were always the same for both the –K and +K treatments.

Maharashtra. All nine trials in Andhra Pradesh were conducted in Kurnool district. Likewise, all 4 trials in Chhattisgarh were conducted in farmers' fields in the Durg district. Out of the 22 trials in Maharashtra, 1 trial was in Latur district and remaining 21 were conducted in Solapur district. The farmers grew maize, but in some cases, they grew other crops as well in a multi-cropping system. For the maize trials, two plots per farmer were laid out side by side, with one receiving K (+K) and the other a control (-K). These two plots were separated by a 1m wide path. Plots within a state could be considered to be relatively similar; however, the similarity could not be assumed for plots in different states. All the plots in the states were irrigated in accordance with the crop requirements, with exact details in irrigation practice varying from state to state. However, regardless of the differences, the irrigation practices were the same for both treatments in each individual trial. Plot size for the demonstration plots varied from trial to trial, primarily depending on state. However, it was always kept the same for both plots in a pair. In Andhra Pradesh, the plot size varied from 1 to 2.5 ha, while it was 0.4 ha in the states of Chhattisgarh and Maharashtra. Different improved varieties of maize recommended for the areas were used. All recommended agronomic practices, such as seed rates, planting distances, irrigation schedules and plant protection measures were followed according to the local recommendations.

Treatments

There were only two treatments: i) control (-K), where the common fertilizer practice of applying urea, DAP and manure was followed, and ii) K treatment (+K), where muriate of potash (MOP) was applied, in addition to the urea, DAP and manure applied in the control. Thus, the control and the treatments were identical at each location, except for the MOP input in the '+K' treatment. However, the local fertilizer practices, primarily the MOP dose, was different for each state (Table 1 and Table 2).

Table 2. Fertilizer type and dose applied to the two treatments in the maize demonstration plot trials in Maharashtra.

Fertilizer source	Maharashtra	
	-K	+K
	----------*kg ha^{-1}*----------	
N (from urea + DAP)	120	120
P_2O_5 (from DAP)	60	60
K_2O (from MOP) FYM[a]	0 x[b]	120 x[b]

[a] FYM (Farmyard manure) was derived from different kinds of domesticated animals depending on location and production.
[b] Dose varied between 1 and 2 t ha^{-1}, with an average of 0.7 t ha^{-1}. The letter 'x' signifies that whatever dose and procedure of manure were followed, these were same for both the -K and +K treatments.

Statistical inferences

Statistical analysis was performed using paired t-tests for two sets of data. In first case, all the data for the states was pooled and in the second case data was used separately for each state. In addition, the datasets were analyzed from different angles to have an insight into the observed variations. When comparing these secondary factors, two kinds of tests were used depending on purpose:

1. When comparing more than two groups or statistical populations, the one-way-ANOVA-test was used, with Bonferroni corrected post-hoc tests.
2. When comparing only two groups or statistical populations, other kinds of t-tests were used, as the samples had different sample sizes; either one of the two t-tests were used: (i) two-sample assuming *equal* variance, or (ii) two-sample assuming *unequal* variance. The assumption of same or different variance, preceding the t-test, was based on the results from an F-test.

Table 3. Mean maize yield levels with MOP application in the states of Andhra Pradesh, Chhattisgarh and Maharashtra as well as for all the states.

	All states	Andhra Pradesh	Chhattisgarh	Maharashtra
Control yield (kg ha^{-1})	4,261± 275*	5,909 ± 607	5,541 ± 1,013	3,354 ± 67
Yield with MOP (kg ha^{-1})	4,903 ± 290	6,315 ± 636	6,593 ± 1,342	4,018 ± 82
Increase in yield with MOP (kg ha^{-1})	642 ± 60	406 ± 46	1,052 ± 490	664 ± 62
Relative increase in yield with MOP (%)	15.1 ± 1.2	7.0 ± 0.7	19.0 ± 7.4	19.8 ± 0.2

* Values are means ± SE (Standard error of the mean)

Table 4. Average net profit increase and average benefit:cost (B:C) ratios with MOP application in maize.

	All states	Andhra Pradesh	Chhattisgarh	Maharashtra
Net profit (Rs. ha^{-1})	7,471	4,568	12,997	7,662
Benefit:Cost (B:C) ratio	6:1	5:1	13:1	6:1

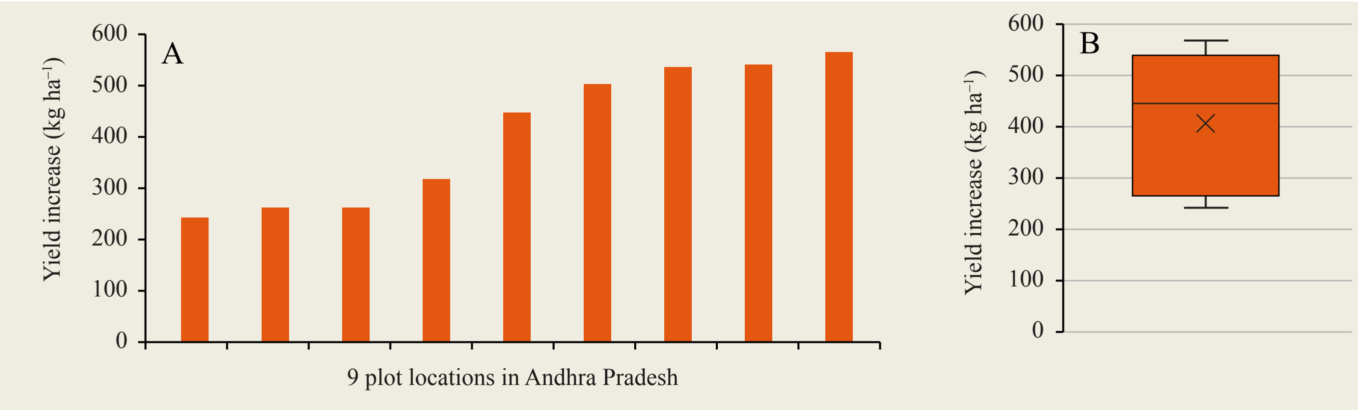

Fig. 1. Maize yield increase in 9 plot pairs across Andhra Pradesh obtained in 2015-2016. Absolute yield increase (A) in the plots fertilized with potash in comparison to control plots with no potash fertilization. Boxplot diagram (B) illustrates the distribution of the data. The middle line represents the median, the upper and lower edge of the box represent the 25th and the 75th percentiles respectively. The mean is signified by the x-marker. The bars reach the maximum and minimum values.

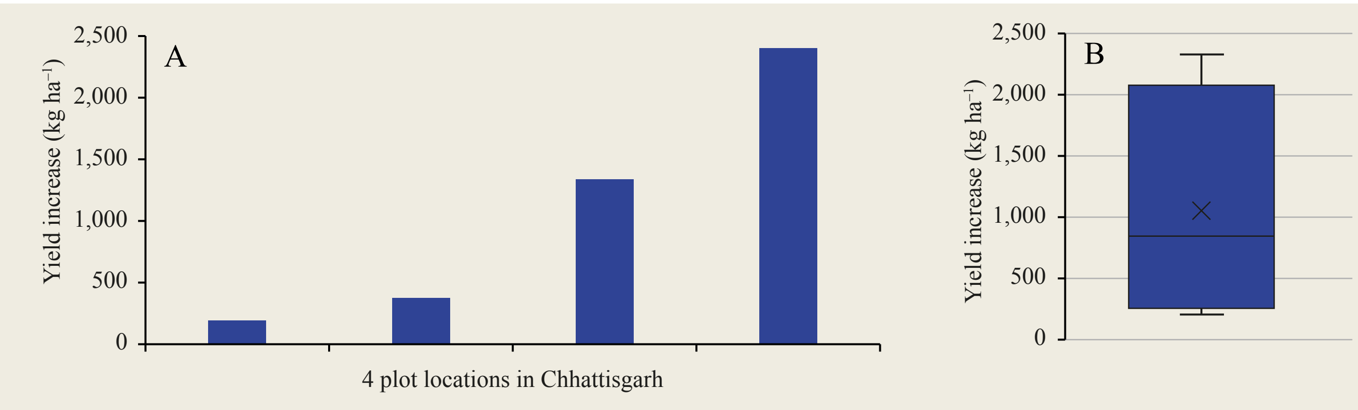

Fig. 2. Maize yield increase in 4 plot pairs in Chhattisgarh obtained in 2015-2016. Absolute yield increase (A) in plots fertilized with potash in comparison to control plots with no potash fertilization. Boxplot diagram (B) illustrates the distribution of the data.

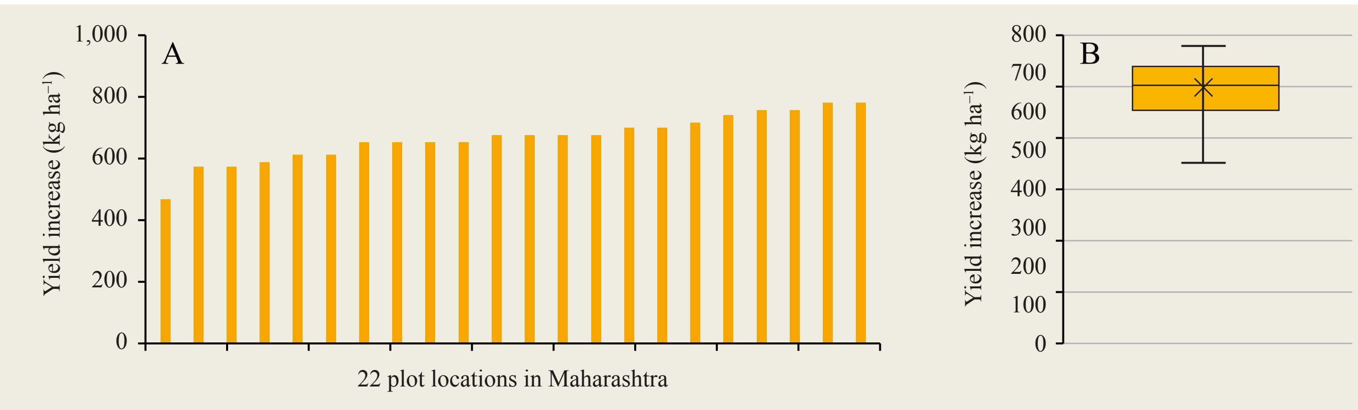

Fig. 3. Maize yield increase in 22 plot pairs in Maharashtra obtained in 2015-2016. Absolute yield increase (A) in plots fertilized with potash in comparison to control plots with no potash fertilization. Boxplot diagram (B) illustrates the distribution of the data.

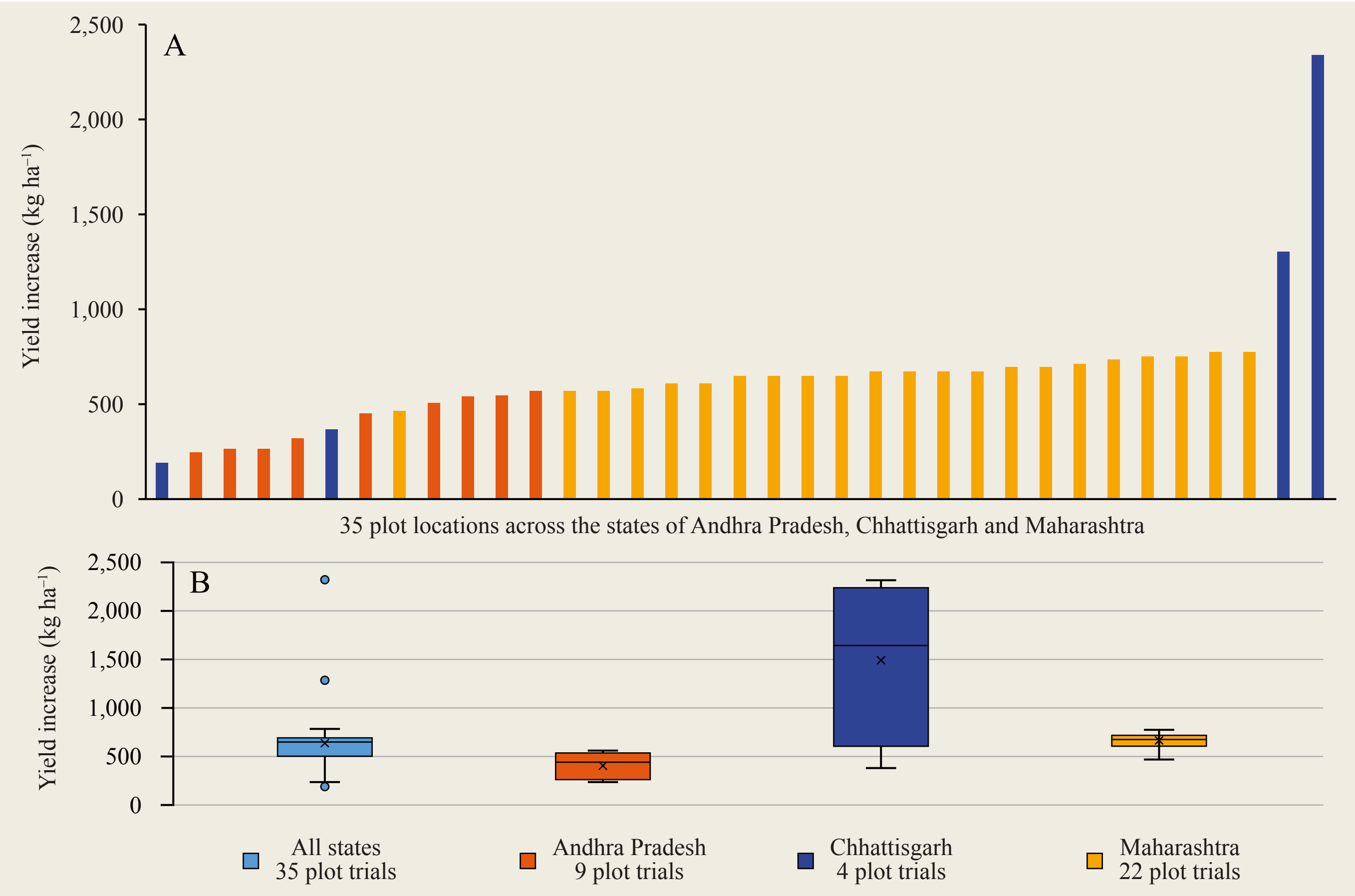

Fig. 4. Absolute yield increase (A) in plots fertilized with potash in comparison to control plots with no potash fertilization, in 35 plot pairs across the states of Andhra Pradesh, Chhattisgarh and Maharashtra, harvested in 2015-2016. Boxplot diagram (B) illustrates the distribution of the data. In the boxplot the middle line represents the median, the upper and lower edge of the box represent the 25th and the 75th percentiles, respectively. The mean is signified by the x-marker. The bars reach the maximum and minimum values, outliers excluded, which are signified by small coloured circles. Each district, as well as the state as a whole is represented by a specific colour.

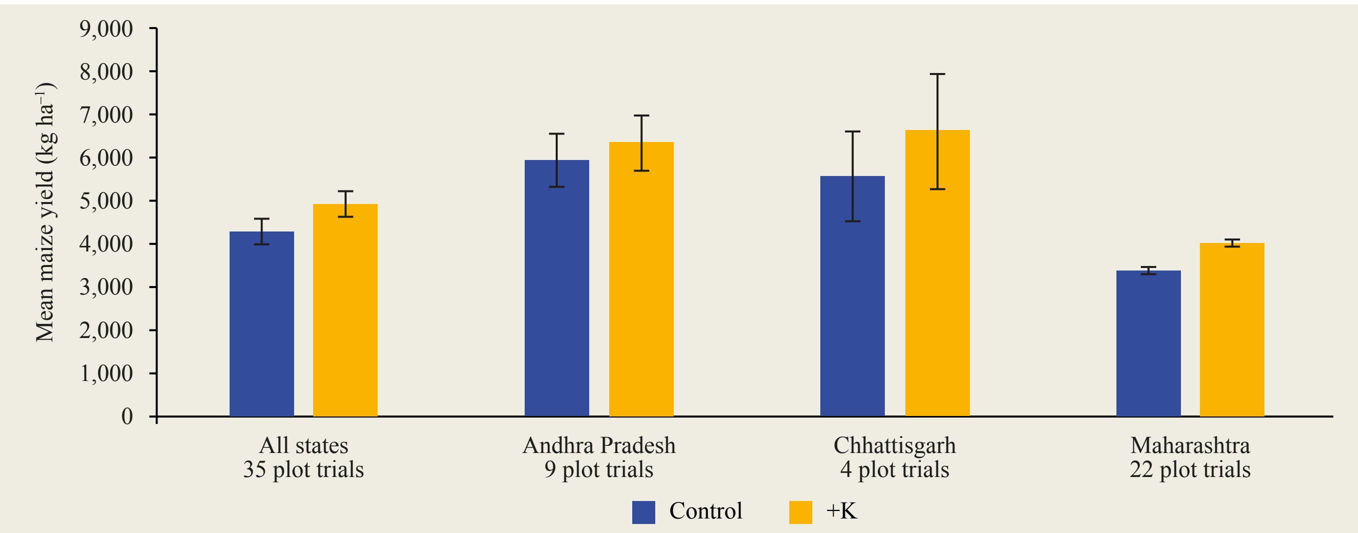

Fig. 5. Mean maize yield levels for control and '+K treatment' plots in the states of Andhra Pradesh, Chhattisgarh and Maharashtra. Error bars signify the standard error of the mean.

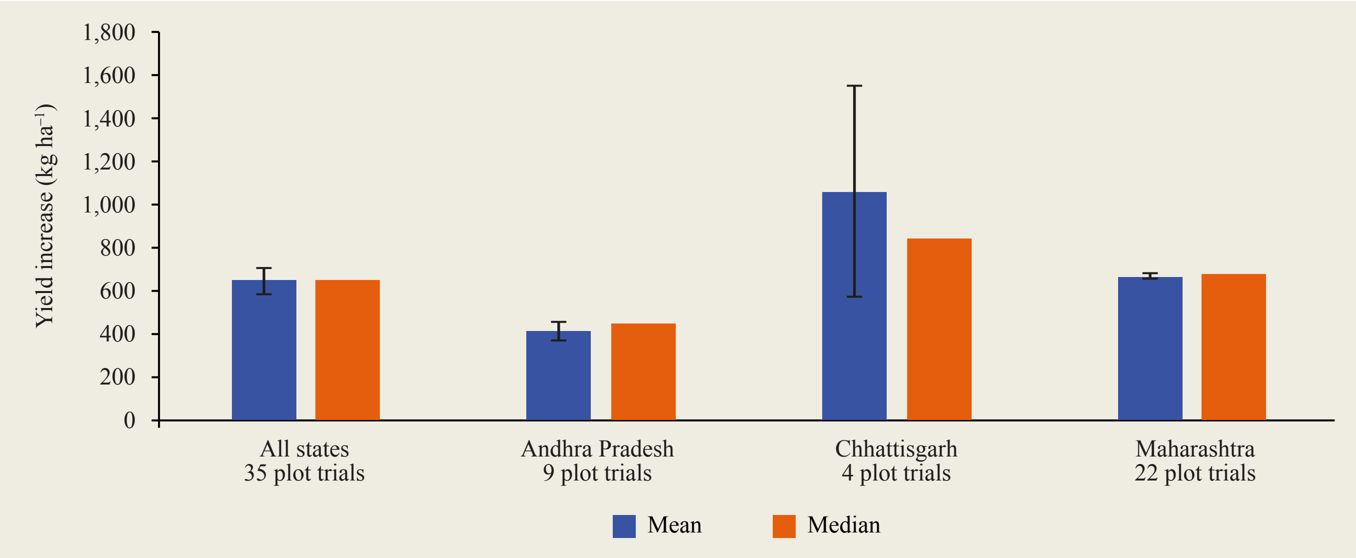

Fig. 6. Average yield increase illustrated both as mean and median in Andhra Pradesh, Chhattisgarh and Maharashtra.

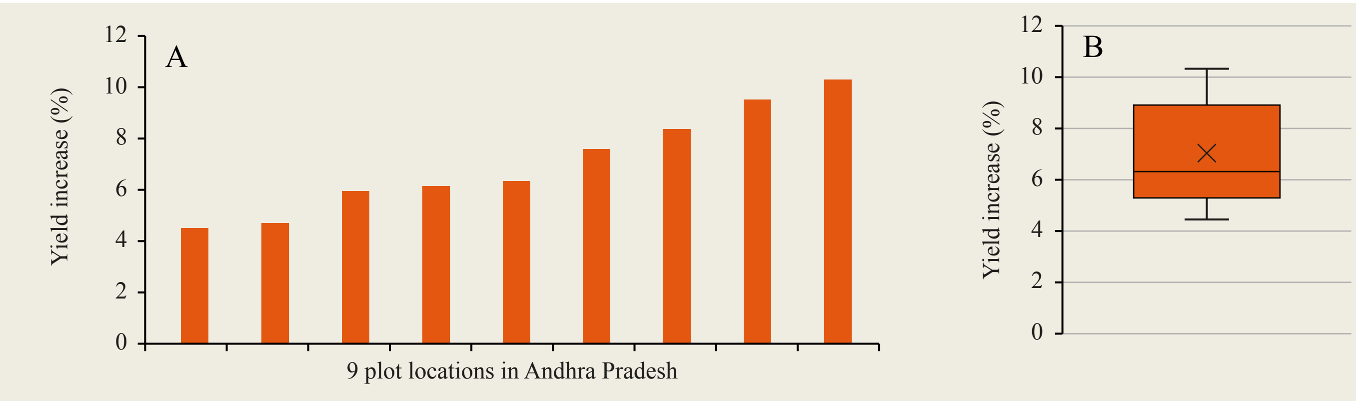

Fig. 7. Maize yield increase in 9 plot pairs across Andhra Pradesh obtained in 2015-2016. Relative yield increase (A) in plots fertilized with potash in comparison to control plots with no potash fertilization. Boxplot diagram (B) illustrates the distribution of the data.

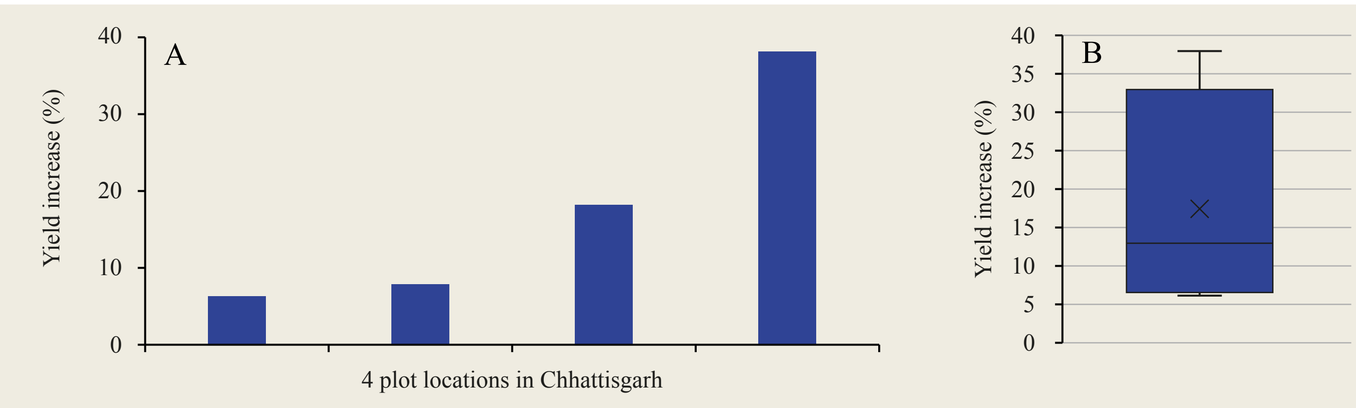

Fig. 8. Maize increase in 4 plot pairs across Chhattisgarh obtained in 2015-2016. Relative yield increase (A) in plots fertilized with potash in comparison to control plots with no potash fertilization. Boxplot diagram (B) illustrates the distribution of the same data.

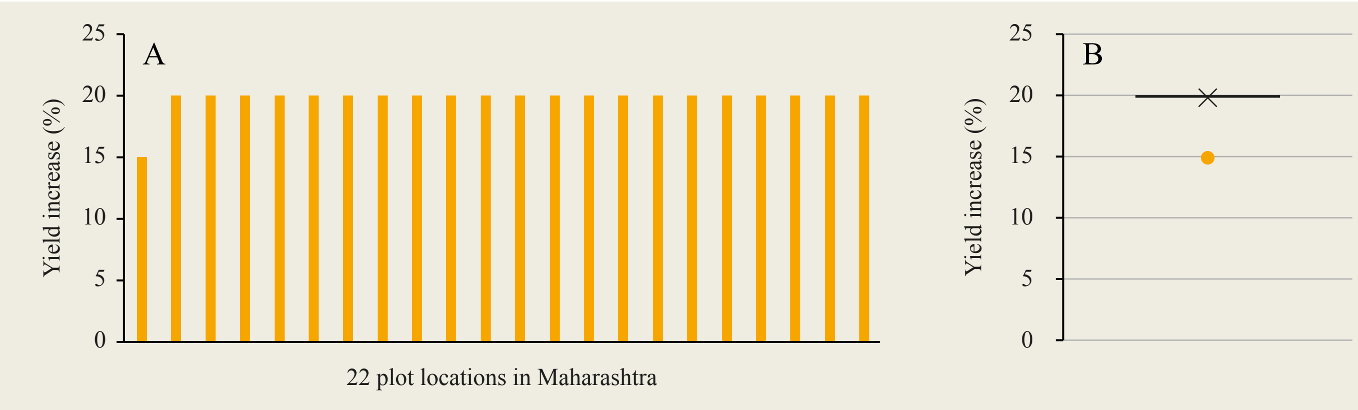

Fig. 9. Maize yield increase in 22 plot pairs in Maharashtra obtained in 2015-2016. Relative yield increase (A) in plots fertilized with potash in comparison to control plots with no potash fertilization. Boxplot diagram (B) illustrates the distribution of the data. In the boxplot the middle line represents the median, the upper and lower edge of the box represent the 25th and the 75th percentiles respectively. The mean is signified by the x-marker. The bars reach the maximum and minimum values, outliers excluded, which are signified by small coloured circles. However, due to extremely uniform results, no box edges or bars are discernable, as they have the same value as the median, which is why all these parameters are displayed as the flat line in the graph.

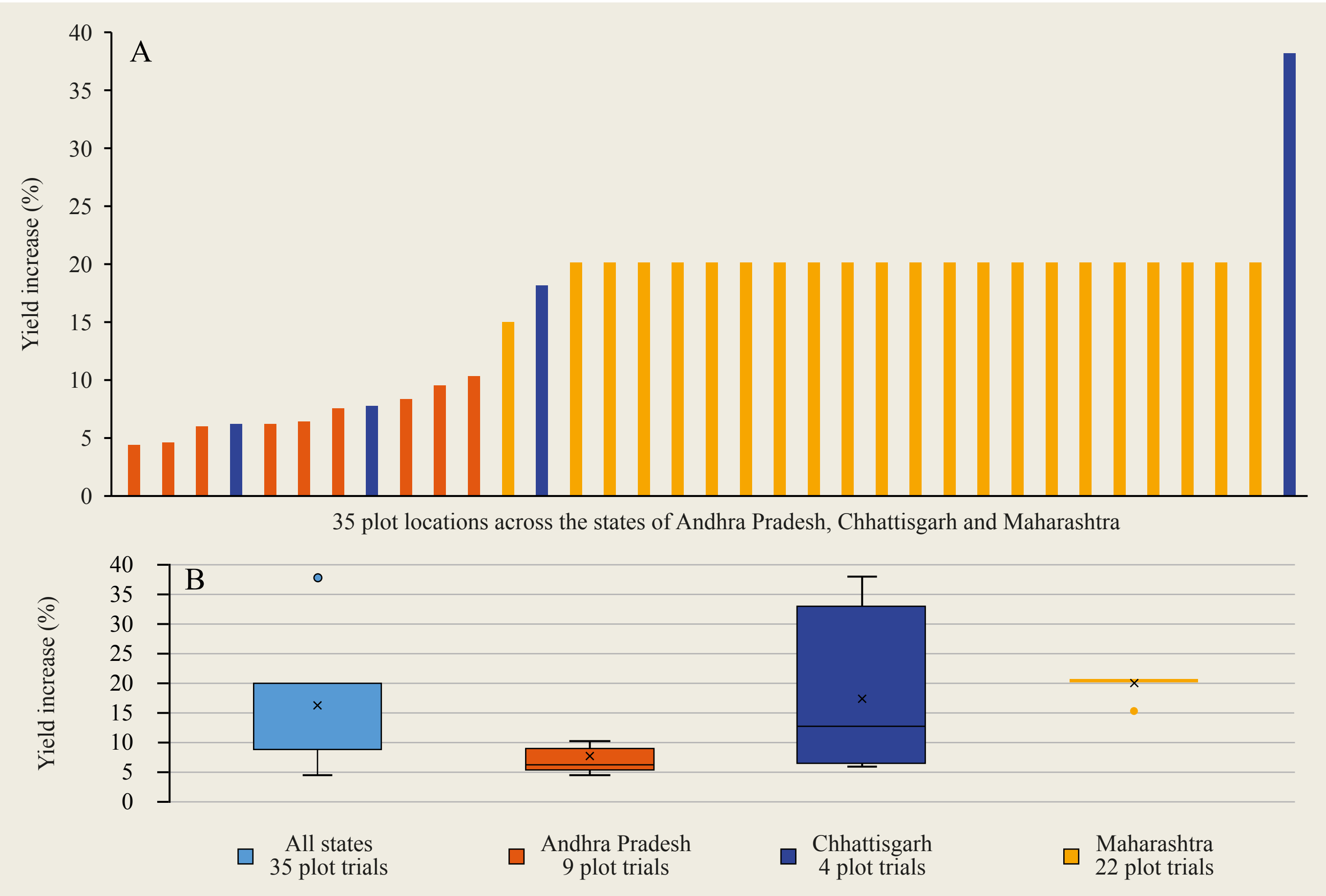

Fig. 10. Relative yield increase (A) in plots fertilized with potash in comparison to control plots with no potash fertilization across the states of Andhra Pradesh, Chhattisgarh and Maharashtra. Boxplot diagram (B) illustrates the distribution of the data.

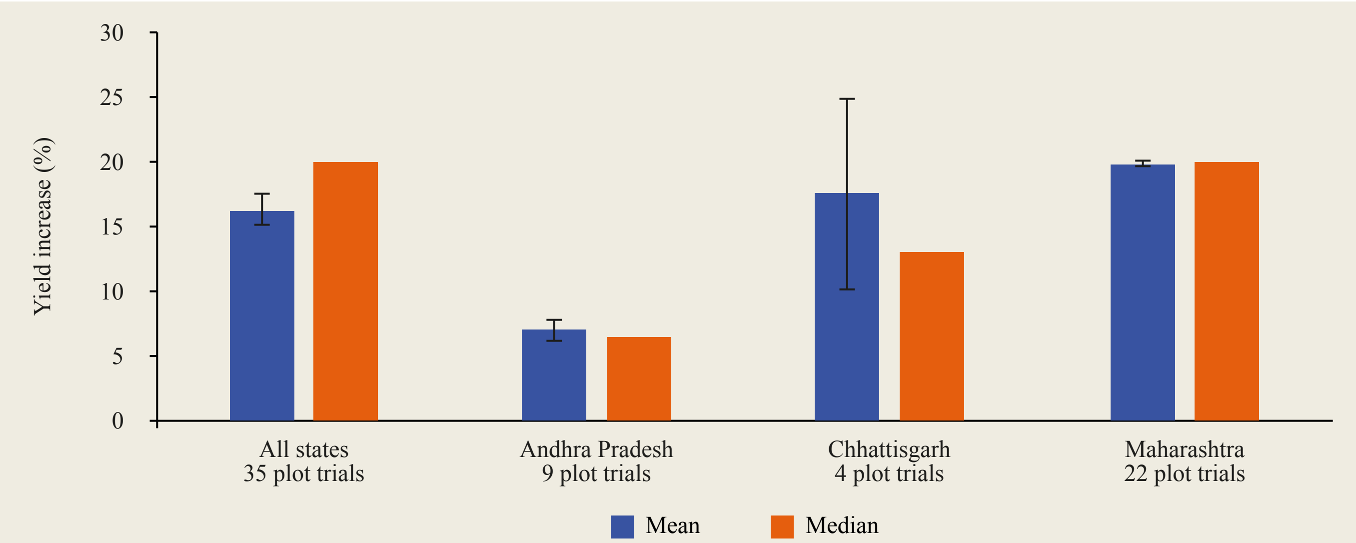

Fig. 11. Average maize yield increase illustrated both as mean and median in Andhra Pradesh, Chhattisgarh and Maharashtra.

Results and discussion

Absolute yield increase

Application of MOP over and above urea, DAP and manure gave an average grain yield increase of 406, 1,052 and 664 kg ha^{-1} and additional net profit of Rs. 4,568, 12,997 and 7,662 ha^{-1}, in the states of Andhra Pradesh, Chhattisgarh and Maharashtra, respectively. This clearly demonstrated to the maize-growing farmers the benefits accruing from the MOP application (Table 3 and 4). Yield increases were statistically significant in the states of Andhra Pradesh and Maharashtra; however, for Chhattisgarh, yield increases were not significant. Perhaps the small sample size and larger variance in Chhattisgarh were responsible for the observed lack of significance. Average values in Andhra Pradesh and Maharashtra were found to be stable, and are representative of the datasets (Fig. 1, 2, 3 and 4). This is clearly indicated by a low standard error of the means, and the proximity between the median and mean values (Table 3; Fig. 5 and Fig. 6).

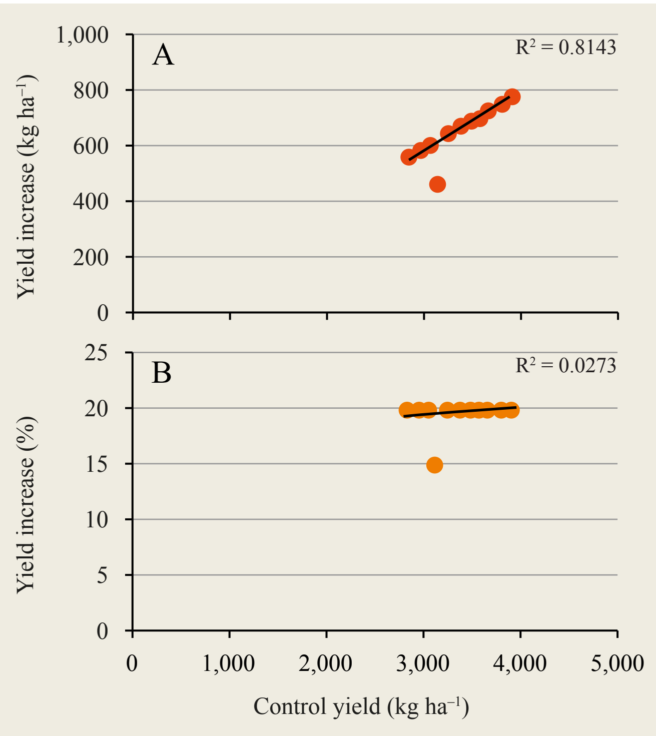

Fig. 12. Absolute (A) and relative (B) yield increase plotted as a function of the control yield. The circles represent the data points of the plot. The linear regression line is illustrated in black, and the R^2-value is specified.

Yield response to muriate of potash in Andhra Pradesh roughly ranged from 250 to 550 kg ha^{-1}. The corresponding range for Chhattisgarh and Maharashtra was 200 to 2,300 and 470 to 770 kg ha^{-1}, respectively. In Andhra Pradesh, the yield increase was evenly distributed between the lowest to the highest response value, almost exhibiting a linear relationship (R^2 = 0.93). The slope of this increase was moderate (Fig. 1A), which is also illustrated by the proximity of the upper and lower quartiles in the boxplot diagram (Fig. 1B). For Maharashtra, distribution was different. It was approximately linear (R^2 = 0.91) but uniform, with only a slight distribution slope (Fig. 3A). This is also illustrated by the close proximity of the whole boxplot distribution to the average value (Fig. 3B).

For Chhattisgarh no trend can be established due to the small sample size and the large variation. Comparison of the results pooled for the states indicates that the upper response values from Chhattisgarh are outliers (Fig. 4A). Otherwise there is a clear even response distribution, and a uniform response range for the states. This is also clear from the boxplot comparison (Fig. 4B), in which the upper

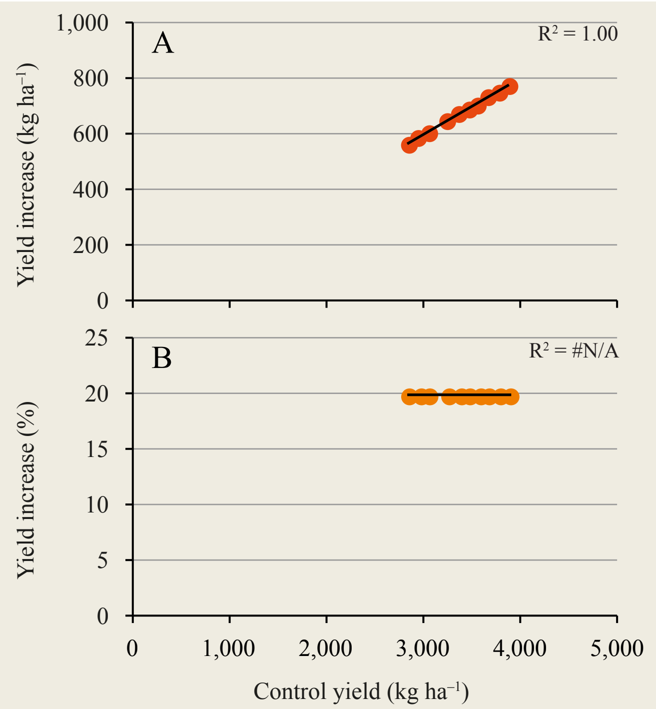

Fig. 13. Absolute (A) and relative (B) yield increase plotted as a function of the control yield for the plot trials conducted in Solapur district, Maharashtra.

outliers correspond to the two upper response values in Chhattisgarh. The mean yield increase levels were similar for Andhra Pradesh and Maharashtra (Fig. 5). In spite of the high variance, the same pattern was also observed for Chhattisgarh. It is also clear that the differences between the mean and the median values tend to be low, as do the differences in the standard error of the mean (Fig. 6).

Relative yield increase

In relative terms, the application of K (MOP) caused an average maize yield increase of 7.0, 19.0 and 19.8% in the states of Andhra Pradesh, Chhattisgarh and Maharashtra, respectively, giving an average benefit:cost (B:C) ratio of 5:1, 13:1 and 6:1 in these states. All average relative yield increase values were stable and representative of the datasets (Fig. 7, Fig. 8, Fig. 9 and Fig. 10), which is indicated by a low standard error of the means, and the proximity between the median and the mean values (Fig. 11, Table 3). Differences between the average relative yield increases associated with K application were statistically verifiable for Andhra Pradesh and Maharashtra.

In both Andhra Pradesh and Maharashtra, there were clear trends in the response pattern to the MOP application. In Andhra Pradesh the pattern was similar to the absolute yield increase trend; the relative yield increase was evenly distributed, and increased from the lowest to the highest response value almost linearly ($R^2 = 0.97$) with a moderate slope (Fig. 7). In Maharashtra the relative yield increase response trend was virtually constant; all plot trials except one in Latur district had the same response (Fig. 9).

Comparison of the results for the three states shows that only the upper response values from Chhattisgarh deviated from the other results (Fig. 10A). The rest of the results fell into a moderate and well-defined response range (4 to 20%). This is also clear from the boxplot comparison (Fig. 10B), in which the upper outlier corresponded to the highest response value in Chhattisgarh.

For Andhra Pradesh and Chhattisgarh, no clear cut relationship between control yield and yield increase response could be established. However, for Maharashtra, a very clear correlation was observed; yield increase response was almost a linear function of the control yield (Fig. 12). When adjusted for districts, the linear regression was perfect in the district of Solapur ($R^2 = 1.00$) (Fig. 13).

Observed trends and their implications

Application of MOP produced statistically significant and quantifiable increases in maize yields which implies that the soils of the experiment locations have undergone nutrient depletion. These results give us confidence to effectively popularize the use

Photo 3: Impact of K application on maize from plot in Maharashtra, India. Photo by the authors.

of MOP to increase maize productivity and profitability in the states of Andhra Pradesh and Maharashtra. Overall response trends, with reasonably narrow response range and stable yield increase response averages from Andhra Pradesh are significant and provide a reliable economic incentive to include MOP application in maize production (Fig. 1, Fig. 7; Table 3, Table 4). For Maharashtra, the benefits are even more significant, with higher and narrower response ranges (Fig. 3, Fig. 9; and Table 4). In relative terms, the average yield increase is both high and stable (19.8 ± 0.2%). For Chhattisgarh, no statistically justified conclusions can be drawn because of the paucity of data.

Inferences of practical significance

It can be easily extrapolated that if a maize farmer in Andhra Pradesh applies MOP according to the PFL recommendations, he would get a yield increase of about 260 to 540 kg ha^{-1}. Given the average B:C ratio of 5:1, this turns out to be a profitable proposition. In Maharashtra, the corresponding figures would be between 610 and 720 kg ha^{-1} and a B:C ratio of 6:1. It is really impressive indeed.

Conclusions

Application of muriate of potash in addition to the commonly applied N and P fertilizers had an unequivocal effect in increasing the maize yields in Andhra Pradesh and Maharashtra. These results indicate that there is a critical need for the development of K fertilization practices for maize in these states. As an immediate measure, the dose successfully employed in this study should be recommended to the maize farmers for maximizing their yields and profits.

Acknowledgements

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References

Anonymous. 2018. About Maize. Available at Farmers' Portal, Ministry of Agriculture and Farmers Welfare, Government of India, https://farmer.gov.in/M_cropstaticsmaize.aspx [Accessed on 24/12/2018].

APEDA. 2018. Maize. Available at the website of Agriculture and Processed Food Products Exports Authority, Ministry of Commerce and Industry, Government of India, http://apeda.gov.in/apedawebsite/SubHead_Products/Maize.htm [Accessed on 24/12/2018].

FICCI. 2014. Summit Report: Maize in India, India Maize Summit 2014. Available at the website of Federation of Indian Chambers of Commerce and Industry (FICCI), http://ficci.in/spdocument/20386/India-Maize-2014_v2.pdf [Accessed on 24/12/2018].

Ranjit Kumar, K. Srinivas, N.K. Boiroju and P.C. Gedam. 2014. Production Performance of Maize in India: Approaching an Inflection Point. International Journal of Agricultural and Statistical Sciences 10:241-248.

The paper "Response in Maize to Applied Potassium: Results from Field Demonstrations in the States of Andhra Pradesh, Chhattisgarh and Maharashtra" also appears on the IPI website.

We dedicate this paper to the memory of Dr. Bhisham Pal.

Dr. Pal was deeply involved in the 'Potash for Life' project under which this research was carried out.

He provided valuable advice and timely guidance on the agronomic activities of the project, always with a smile and great professionalism. His tremendous enthusiasm, endless dedication and his knowledge and experience will be missed by those in India – and from further afield – who knew and worked with him.