Enhancing Rice Yield, Profitability, and Phosphorus Use Efficiency in West Bengal using the Nutrient Expert® Fertilizer Decision Support Tool

By M.K. Mandal, S. Dutta, K. Majumdar, T. Satyanarayana, M. Pampolino, V. Govil, A.M. Johnston, and G.C. Shrotriya

Nutrient Expert®-based fertilizer recommendation helped increase rice productivity and P use efficiency over farmers' fertilization practice.

Rice is the most important food crop of India. Rice is grown under diverse agro-ecological conditions, in a variety of soils, in combination or in sequence with a large number of crops. Rice ranks first in the use of land at > 43 million (M) ha, water resources (> 50% irrigation water), and inputs (38 to 40% of fertilizers and 17 to 18% of pesticides) among the crops cultivated in India (Rice Knowledge Management Portal, http://www.rkmp.co.in). Grown in an area of 43 M ha with an average productivity of 2.5 t/ha, rice contributes to nearly 41% to the total foodgrain production. The demand for rice is projected to increase in the near future with the increase in population in India. A summary of several projections compiled by the Directorate of Rice Research (2011) showed the demand for rice is expected to rise between 107 to 156 M t by 2030 over the current production of 43 M t (FAI, 2014).

Future gains in rice yield is expected to be largely driven by knowledge intensive crop and soil management as compared to the germplasm driven yield gains since the start of Green Revolution. Development of precision nutrient management strategies for rice grown in different ecologies and seasons in India, and their large-scale adoption through innovative extension mechanisms, will be critical to achieve projected production goals in 2030 that are 3 to 4 times the current production level.

Imbalanced fertilizer application in rice has been identified as one of the major reasons for decreasing crop response to fertilizer application and the consequent lower crop production growth rate in India. Chauhan et al. (2012) identified increasing multiple deficiencies of major nutrients (N, P, K, and S) and micronutrients (Zn, Fe and Mn) due to imbalanced fertilization as one of the major reasons for stagnant or declining yield of rice. The lack of appropriate tools and implementation mechanisms, along with government subsidy programs, has

Abbrevations and notes: N = nitrogen; P = phosphorus; K = potassium; Fe = iron; Mn = manganese; Zn = zinc.

A rice farmer of Hoogly District, West Bengal transplanting her crop.

been a major hindrance that restricted wide-scale adoption of balanced fertilization in rice. Hobbs and Morris (1996) suggested that reduced total factor productivity (input-use efficiency) and profit margin, and increasing cultivation costs in rice production, has led to a loss of relevance of the simple agronomic practices that revolutionized rice-wheat cultivation in the Indo-Gangetic Plain.

IPNI and its partner organizations in South Asia have jointly developed a dynamic nutrient management tool, the Nutrient Expert® (NE) for Rice (India), that can generate farm-specific fertilizer recommendation for rice. The tool is based on the site-specific nutrient management (SSNM) principles (Pampolino et al., 2012) and utilizes information of the growing environment to provide balanced fertilizer recommendations for rice that are tailored for a particular location, cropping system, rice ecology, season, and farmer resource availability.

The NE rice tool development in India was followed by a large-scale on-farm validation across different growing environments of rice. The NE-based recommendations were compared to the existing farmers' fertilization practices (FFP). The two treatments were implemented side-by-side in the same farmer's field where each plot size was ≥100 m^2. The current study reports on the pooled data from 323 on-farm trials in high-yielding variety (HYV) rice from 10 districts of West Bengal, covering old and new alluvial soils, and red and lateritic soils. A single fertilizer recommendation was given to multiple farmers in domains where the soils, cropping systems and FFP did not differ significantly to warrant different recommendations. The validation trials were conducted in collaboration with Iffco Kisan Sanchar Ltd. (IKSL) through their farmer network across West Bengal, in the kharif season of 2014.

The NE-based fertilizer recommendation for rice improved the grain yield as compared to FFP (**Figure 1**) across multiple sites in West Bengal. The highest yields achieved using the NE recommendation and FFP were 7,250 kg/ha and 6,200 kg/ha, respectively. The yield variability across sites was higher in the farmers' practices as compared to the NE treatment due to variable management of farmers. Rice yields were far more stable and varied within a short range as the NE recommendation for each individual farmer was designed to achieve the maximum attainable yield of HYV rice in the kharif season. Other studies using NE for maize and wheat also showed significant yield advantage from the tool-based fertilizer recommendation as compared to existing practices (Satyanarayana et al., 2012; Sapkota et al., 2014).

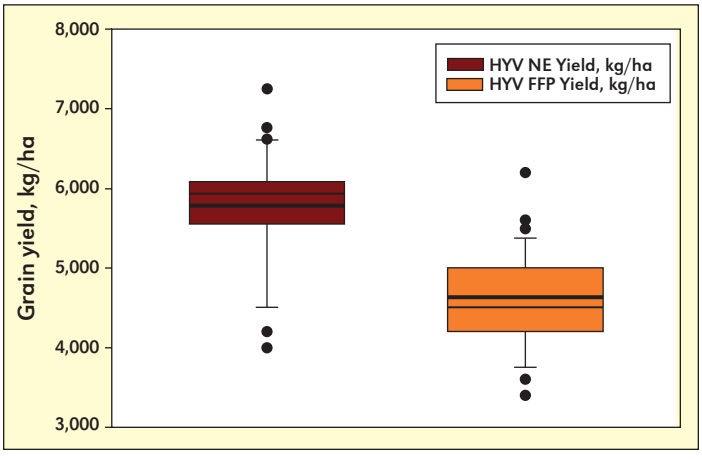

Figure 1. Average high yielding variety (HYV) rice grain yield in Nutrient Expert® (NE) validation trials compared to farmers' fertilization practice (FFP) (n = 323) in West Bengal. Boxes represent data within the first and third quartiles (interquartile range). The thin line denotes the second quartile or median and the thick line represents the mean. Lines extending beyond the interquartile range denote the 10th to 90th percentile of the data. Statistical outliers are plotted as individual points outside these lines.

The NE tool estimates attainable yield in a location based on a constraint analysis that takes into account historical yield data, soil characteristics, and other crop management parameters. In this study, the yield data from the NE treatments were compared with the attainable yields estimated by the NE tool. The analysis showed that 43% of the trials achieved NE estimated attainable yield, yield in 41% trials exceeded the estimated attainable yield, and NE estimated attainable yield was not achieved in 16% of the trials (data not shown).

As mentioned earlier, the NE tool is based on the SSNM principles. SSNM advocates external application of nutrients to bridge the gap between indigenous soil nutrient supply and crop nutrient requirement for a target yield. In smallholder rice fields of West Bengal, farmers' crop and soil management varies widely depending on awareness and resource availability. Such variable management decisions create large spatial and temporal variability in soil nutrient availability. Ideally the fertilizer management in such smallholder landscape should vary and be location-specific to avoid over- or under-use of nutrients. Location specific fertilizer management in such variable landscapes is expected to produce benefits in terms of improved yield, higher nutrient use efficiency or saving of fertilizer and consequent improved economics of production and environmental stewardship of applied nutrients. The comparative data of different treatments from the validation trials for rice are given in **Table 1**.

Table 1. Agronomic and economic performance of Nutrient Expert®-Rice in West Bengal (n = 323).

Parameters	Unit	Farmer Fertilization Practice (FFP)	Nutrient Expert (NE)	NE-FFP	
Grain yield	kg/ha	4,627	5,784	+1,157	***
Fertilizer N	kg/ha	85	111	+26	***
Fertilizer P_2O_5	kg/ha	39	34	-5	*
Fertilizer K_2O	kg/ha	47	49	+2	ns
Fertilizer cost	Rs./ha	3,108	3,270	+162	ns
GRF[1]	Rs./ha	54,273	68,386	+14,113	***

***, **, *: significant at $p < 0.001$, 0.01, and 0.05 level; ns = not significant; [1]GRF = gross return above fertilizer cost; Prices (in Rs./kg): Rice = 14.00; N = 11.40; P_2O_5 = 32.20; K_2O = 18.80.

Averaged over sites, NE tool-based recommendations improved rice yield by 1 t/ha over the farmers' practice. The increased yield in the NE treatment was achieved through a significantly higher application of N and better timing of fertilizer application. Fertilizer cost in the NE treatment was similar to the investment by the farmers. The gross return over fertilizer cost was significantly higher in the NE treatment (**Table 1**), suggesting significantly higher economic return across sites.

One of the major objectives of improved nutrient manage-

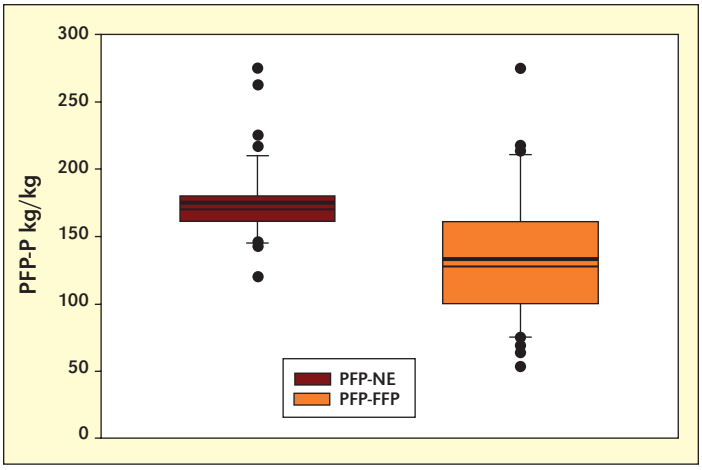

Figure 2. Average Partial Factor Productivity (PFP) for P in rice in the NE validation trials (n = 323) compared to farmers' fertilization practice (FFP) in West Bengal. Boxes represent data within the first and third quartiles (interquartile range). The thin line denotes the second quartile or median and the thick line represents the mean. Lines extending beyond the interquartile range denote the 10th to 90th percentile of the data. Statistical outliers are plotted as individual points outside these lines.

ment is to achieve high nutrient use efficiency at higher yield and farm profitability. The partial factor productivity (PFP) of P was used in this study to assess the efficiency of conversion of fertilizer or soil P to economic parts. The PFP is considered the most important index for on-farm studies, among the different indices of nutrient use efficiency, as it integrates the use efficiency of both indigenous and applied nutrients. The average partial factor productivity (PFP) of P in the NE treatment (175 kg grain/kg P_2O_5) was higher than the FFP treatment (134 kg grain/kg P_2O_5) across sites (**Figure 2**). The PFP of P in the FFP varied over a wide range (56 to 275 kg grain/kg P_2O_5) due to the wide variability in rice yield (3,400 to 6,200 kg/ha) and P application rates (16 to 90 kg/ha). The efficiency of P use was within a narrower range (125 to 275 kg grain/kg P_2O_5) in the NE treatment as the yield variability in the NE treatment was lower (**Figure 1**), P_2O_5 application (24 to 42 kg/ha) recommended by the NE tool was also within a narrow range than the farmers' practices.

The NE for rice validation trials in West Bengal showed that farmers' yield, profitability, and nutrient use efficiency in kharif season rice could be significantly improved by farmer- and site-specific fertilizer recommendations. Wide-scale dissemination of site-specific fertilizer recommendation has been a challenge due to lack of appropriate tools that can help extension agents develop such recommendations quickly. The NE tool is a significant innovation to fill that gap as was verified through the use of the tool by the extension mechanism of IKSL. The unique capability of the NE tool to develop site-specific recommendations in the absence of soil testing provides an opportunity to support the majority of rice farmers who do not have access to soil testing. BCSA

Drs. Mandal and Shrotriya are with IKSL; Drs. Dutta, Majumdar, Satyanarayana, and Mrs. Govil are with IPNI South Asia Program; Dr. Pampolino is with IPNI Southeast Asia Program; Dr. Johnston is Vice President, and Asia & Africa Coordinator of IPNI.

References

Directorate of Rice Research. 2011. Vision 2030. Rajendranagar, Hyderabad.

Hobbs, P.R., and M. Morris. 1996. Natural Resource Group Paper 96-01. Mexico, D.F: CIMMYT.

Chauhan, B.S., G. Mahajan, V. Sardana, J. Timsina, and M.L. Jat. 2012. Advances in Agronomy, DOI: http://dx.doi.org/10.1016/B978-0-12-394278-4.00007-6.

Sapkota, T.B., K. Majumdar, M.L. Jat, A. Kumar, D.K. Bishnoi, A.J. McDonald, and M. Pampolino. 2013. Field Crops Res. 155:233-244.

Satyanarayana, T., K. Majumdar, M. Pampolino, A.M. Johnston, M.L. Jat, P. Kuchanur, D. Sreelatha, J.C. Sekhar, Y. Kumar, R. Maheswaran, R. Karthikeyan, A. Velayutahm, Ga. Dheebakaran, N. Sakthivel, S. Vallalkannan, C. Bharathi, T. Sherene, S. Suganya, P. Janaki, R. Baskar, T.H. Ranjith, D. Shivamurthy, Y.R. Aladakatti, D. Chiplonkar, R. Gupta, B.P. Biradar, S. Jeyaraman, and S.G. Patil. 2012. Better Crops South Asia 6(1): 4-7.

7th International Nitrogen Conference (INI 2016)

The Victorian Government and University of Melbourne are jointly hosting the 7th International Nitrogen Initiative Conference, at the Melbourne Cricket Ground, on December 4 to 8, 2016.

The theme of INI 2016 is **Solutions to Improve Nitrogen Use Efficiency for the World**. The program includes plenary presentations from many of the world's experts in the fields of nitrogen cycling and management, crop and animal production, emissions and environmental impacts with participation from research, industry and policy organizations globally. Further details of the conference are available at ini2016.com. BC

THE CALL FOR PAPERS IS NOW OPEN