Farm Typology-based Phosphorus Management for Maize in West Bengal

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Integrating the farmers' resource endowment capacity into the nutrient management strategy is important for sustainable maize production systems.

Farm typology-based phosphate fertilizer recommendation demonstrated significant increase in agronomic and economic benefit over the existing management practices in maize growing areas of West Bengal.

Maize is an important field crop of West Bengal in terms of acreage, production and utilization for food and feed purposes. The introduction of hybrid maize has increased the production potential of maize systems. However, the present productivity level of maize across eastern India is very low due to several production constraints at the farm level. Widespread nutrient depletion of agricultural soils is one of the most important bio-physical factors limiting small scale maize production across Asia. Literature suggests that the ability of soil to supply nutrients naturally, as well as nutrient recovery for maize, are location-specific (Witt et al., 2009). Therefore, enhancement of maize productivity can largely be achieved through proper supplementation of plant nutrition. However, the recommendation of fertilizer is a challenge to scientists as it should meet both the nutrient demand of the crop and sustain the crop production system.

The 4R Nutrient Stewardship concept, and its implementation through site-specific nutrient management (SSNM), helps to achieve agronomic and economic benefits while maintaining socially and environmentally sustainable crop production systems. However, to provide appropriate recommendations, a SSNM-based nutrient recommendation needs to be integrated with the classification of farmers as per their resource endowment. Grouping farmers within a domain in different resource endowment classes is an essential step in the realistic evaluation of the constraints and opportunities that exists within farm households for appropriate interventions (Banerjee et al., 2014). The present study was initiated to identify different farm typologies of smallholder maize farmers in southern Bengal, followed by the application of Nutrient Expert® (NE) – a decision support tool for precision nutrient management with a special reference to P nutrition.

Rapid Rural Surveys

Farm typologies were determined based on information derived from a Rapid Rural Survey (RRS) conducted in the four West Bengal districts of South 24 Parganas, Paschim Medinipur, Nadia and Murshidabad (**Table 1**). These four districts represent four distinct agro-ecological zones and are representative of a large part of eastern India in terms of farmers' socio-economic conditions and bio-physical characteristics of their farmlands. The idea was to include two emerging (South 24 Parganas and Paschim Medinipur) and two traditional (Nadia and Murshidabad) maize-growing areas in this study.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium.

Experimental field comparing Nutrient Expert® plot (left) and farm practice (right) at Krishnanagar-I block in Nadia districts of West Bengal, India.

Under each district, maize growers were selected randomly from three adjacent villages (**Table 1**). The interview sched-

Table 1. Study locations and number of farmers interviewed.

Districts	Blocks	Villages	Sample
South 24 Parganas	Pathar Pratima	Rakshaskhali, Dakshin Shibjanj	19
	Baruipur	Ghola	13
Paschim Medinipur	Keshpur	Khirishmul, Uchahar, Jorapata	18
	Daspur	Ramdaspur	12
Nadia	Krishnanagar-I	Kulgachhi, Purba Bhat Jangla, Gobindapur, Asannagar	30
Murshidabad	Raghunathganj	Radhakrishnapur	15
	Lalgola	Chanoapara, Champapur	20
		TOTAL	127

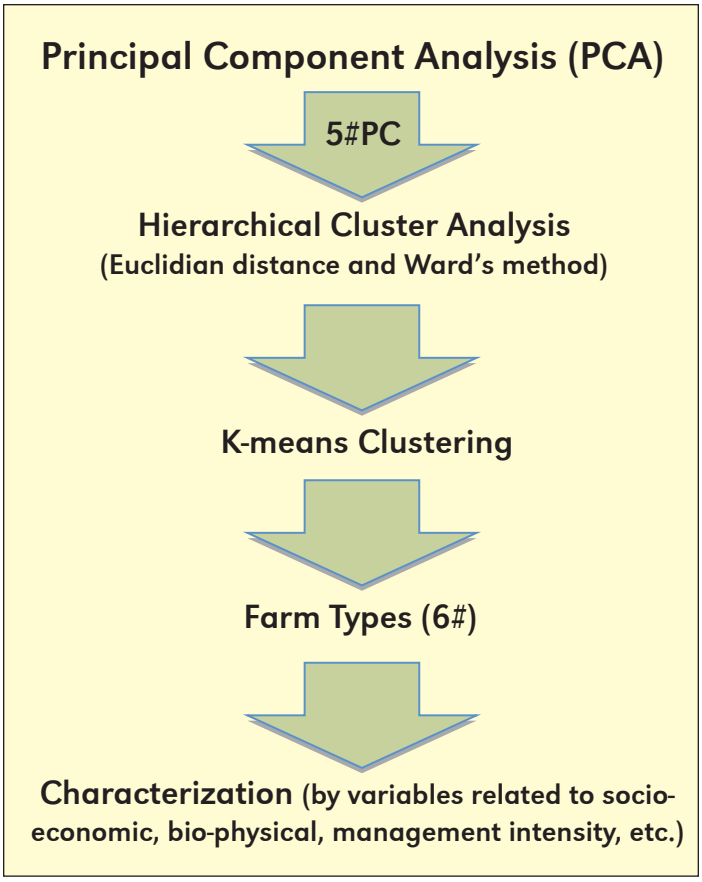

Figure 1. Methodology of farm typology delineation and characterization.

ule was developed and a database was created, manipulated and screened in SPSS, Version 17 (SPSS Inc., Chicago, USA).

Farm Typologies

Multivariate statistical techniques have been widely used for the farm typology and characterization study. Principal Component Analysis (PCA) was used to reduce the number of variables, which was followed by Cluster Analysis to identify typical farm households (Goswami et al., 2014). We used variables related to both socio-economic background and management intensity (labor and input use) of the maize growers in the PCA (**Figure 1**). Then, the five extracted PCs were used to cluster the surveyed farms. A hierarchical cluster analysis using Euclidian distance and Ward's method was used to identify the potential number of clusters (six in our study) and K-means clustering was finally used to classify the surveyed farms. The six farm types were characterized by a host of socio-economic, crop management, and related variables. The distribution of farm types in different districts along with their qualitative description is given in **Table 2**. The identified farm typologies were then used for site-specific nutrient recommendations using NE.

On-farm Trials at Different Locations

A total of 127 trials were conducted during the 2014-15 in the four districts of South 24 Parganas (32), Paschim Medinipur (30), Nadia (30), and Murshidabad (35) to rationalize P use in maize systems. Two maize hybrids namely PAC 740 (Grain purpose) and HQPM 1 (Seed purpose) were given to selected farmers for the growing season December-January to April-May.

Table 2. Characterization of identified farm types (narrative form).

Farm Type	No. of farms	Location (No. of farms)
Farm Type 1: Moderate-resourced commercial maize grower	16	Murshidabad (6) Nadia (8) South 24 Parganas (2)
Farm Type 2: Exclusive cultivators with large holding and large family	9	Paschim Medinipur (2) Murshidabad (0) Nadia (2) South 24 Parganas (5)
Farm Type 3: Low-yielding new maize growers	37	Paschim Medinipur (25) Murshidabad (0) Nadia (2) South 24 Parganas (10)
Farm Type 4: Moderately resourced family farms	16	Paschim Medinipur (3) Murshidabad (0) Nadia (0) South 24 Parganas (13)
Farm Type 5: Traditional maize grower	28	Paschim Medinipur (0) Murshidabad (26) Nadia (1) South 24 Parganas (1)
Farm Type 6: Resource-rich commercial seed producers	21	Paschim Medinipur (0) Murshidabad (3) Nadia (17) South 24 Parganas (1)

In order to rationalize fertilizer P application to support sustained high productivity on one hand and address the environmental and economic concerns on the other, P management is an important parameter (Sanyal et al., 2015). NE for hybrid maize has been used in the present study for nutrient management recommendations. NE provides fertilizer recommendations that are consistent with SSNM strategies for managing P fertilizer along with other nutrients. Based on the knowledge of the maximum attainable yield (Ymax), the actual attainable yield (Ya), yield at farmer's field (Y), and the nutrient-limiting yield from a large number of on-farm trial results, NE utilizes decision rules that provides guidance for fertilizer P application to achieve a pre-determined attainable yield at a location with specific indigenous nutrient supplying capacity. The development process and the decision rules used in NE has been explained in details elsewhere (Pampolino et al., 2012).

Phosphorus Requirement of Maize

Maize requires large quantities of P (along with N and K) for higher yields. Production of 1 t of maize removes almost 18 kg P_2O_5/ha (IPNI Data). Plants obtain much of their P from the soil, crop residues, organic amendments, and irrigation water. But the supply of P from these naturally occurring, indigenous sources is typically insufficient to sustain high maize yield. Supplemental P fertilizers are thus essential for sustaining high and profitable yields of maize without depleting the fertility of the soil. The economic challenges associated with increasing P fertilizer prices in India are driving the increased interest in improving P-use efficiency (Majumdar et al., 2013). Moreover, transfer of soil P from cultivated land through erosion or runoff is a major concern. This necessitates appropriate P management for taking care of native soil P supplies and crop

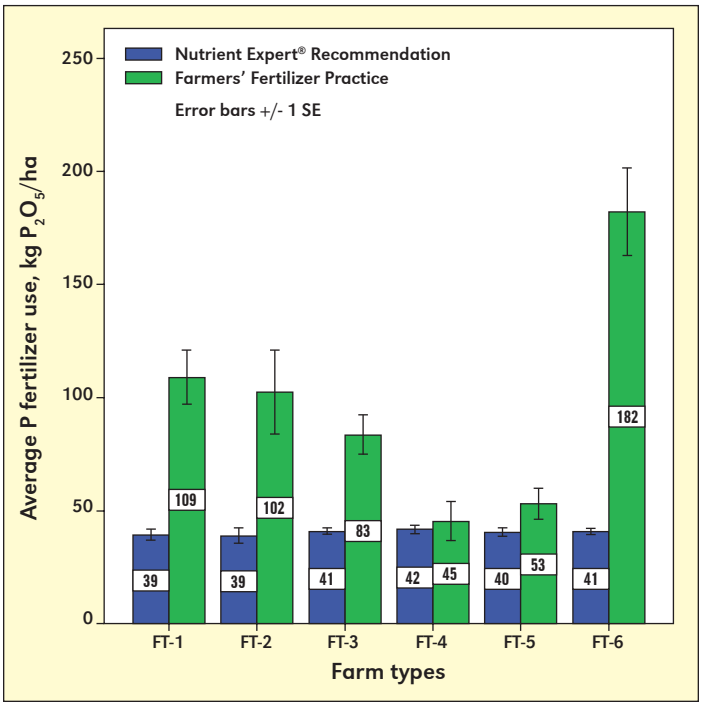

Figure 2. Comparison of P fertilizer use across different farm types, West Bengal.

demands in a growing environment (Sanyal et al., 2015). The SSNM approach advocates the sufficient use of fertilizer P to overcome deficiencies while simultaneously accounting for, to some extent, the nutrient removal with harvested products, to avoid P mining.

Phosphorus Management Strategies and Maize Yield

A comparison of the agronomic and economic performance of NE-based fertilizer recommendation over Farmers' practice (FFP) were carried out to evaluate their performance in smallholder maize growing environments among different farm types across different districts of West Bengal. FFP treatments differed in the amount of P applied among the six farm types. Farmers belonging to farm type 6 demonstrated greater tendencies of applying higher P rates in maize cultivation, followed by farm type 1, 2 and 3. Poor P use was common for growers who belonged to type 4 and 5. The NE tool recommended comparatively lower amounts of P over the FFP across all farm types (**Figure 2**). Compared to FFP, average P use with NE decreased by 178, 164, 105, 9, 32, and 345% from farm type 1 to 6, respectively.

NE and FFP treatments differed in the yield of maize among the six farm types. The NE yields were significantly ($p \leq 0.01$) higher compared to FFP across all the farm types (**Figure 3**). Farmers belonging to farm type 5 achieved the highest maize yields, followed by type 1, 6 and 4. Poor yield was common in growers who belong to type 3 and 2. Compared to FFP, average grain yields in NE-based SSNM increased by 41.7, 47.0, 70.4, 38.3, 55.3, and 62.5% in farm type 1 to 6, respectively. However, it must be pointed out that the yield improvement in the NE treatment was due to the balanced and site-specific application of all limiting nutrients, not only P, at the right time and through use of the right sources. The results showed the potential benefit of using the Nutrient Expert® tool in areas where farmers get lower maize yield due to imbalanced fertilization.

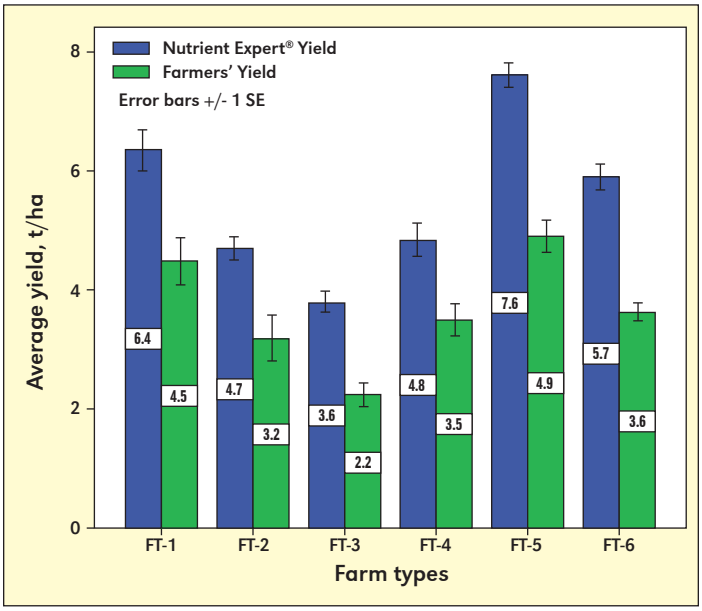

Figure 3. Comparison of yield across different farm types, West Bengal.

Economics of Phosphorus Management

The cost of cultivation in terms of P fertilizer application differed across treatments among the six farm types. Farmers belonging to farm type 6 incurred significantly higher expenditure towards P fertilizer, followed by the farmers on farm types 1, 2 and 3. Maize growers of type 4 and 5 spent comparatively less on P fertilizer. Significantly ($p \leq 0.01$) lesser P fertilizer cost was achieved with NE recommendation across all farm types (**Figure 4**). Compared to FFP, average P fertilizer cost with NE for different farm types decreased to a similar extent to that of P fertilizer use.

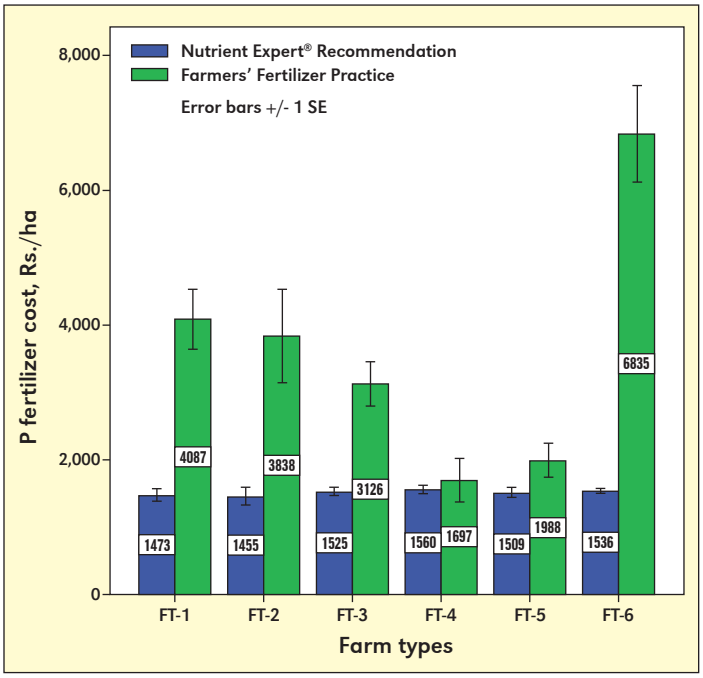

Figure 4. Average P fertilizer cost across different farm types, West Bengal.

IPNI Photo/S. Dutta

Field site inspection by Dr. Dutta (center) standing next to Dr. Banerjee (right in photo) and the site's farmer (left).

Conclusion

Yield and profitability of maize in the favorable tropical environments of eastern India can further be increased with improved nutrient management practices. The farm typology-based nutrient recommendations in this study, in terms of phosphate fertilization, demonstrated a significant increase in agronomic and economic benefit over current farmer fertilizer practices. Nutrient Expert® use in this study supports its wide spread dissemination in support of balanced fertilizer recommendations. BCSA

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