Improved Nutrient Management in Rice-Maize Cropping Systems: A Case Study

By J. Timsina and K. Majumdar

On-farm variability in maize yield responses and agronomic efficiencies of N, P, and K across three districts in Bangladesh were evaluated. The results support the adoption of a site-specific nutrient management approach to tackle the challenge of stagnating or declining maize yields in Bangladesh.

Maize is commonly grown in Bangladesh in a rice-maize (R-M) system, and maize yields in Bangladesh are currently among the highest in the tropics (Timsina et al., 2010, 2011). However, signs of stagnation and decline in maize yields have started to emerge in the last few years. This has led to rising concerns that continuous production of high yielding maize will lead to a depletion of mineral nutrients from soils. Soil nutrient depletion is often accelerated with maize versus rice or wheat because of the higher biomass production, greater nutrient requirements, and increased nutrient removal by the maize crop. Many farmers, however, mostly apply unbalanced fertilisers, particularly low amounts of P, K, S and other micronutrients. In a R-M experiment, Ali et al. (2009) found highly negative nutrient balance for N and K (-120 to -134 and -80 to -109 kg/ha, respectively) but a positive balance for P (15 to 33 kg/ha). There are indications that grain yields have been decreasing where maize has been grown on the same land for the last 5 to 10 years. Thus, there is a need to understand nutrient related constraints affecting maize yields in Bangladesh. Also, given the complexity of the R-M system, through it's anaerobic-aerobic cycles, it is important to understand both nutrient balance and nutrient use efficiency under the existing practices, and how these practices could be improved to maintain sustainability of this cropping system.

This case study shows results from an on-farm trial in 2009-10 with *rabi* maize grown in three districts/sites (Comilla [12 farms], Rajshahi [9 farms], and Rangpur [4 farms]) of Bangladesh to demonstrate attainable yield of maize, agronomic response, and nutrient use efficiencies in farmer fields across the three districts. The experiment had the following treatments: -N (no N), -P (no P), -K (no K), NPK, NK with low dose of P (low P), NP with low dose of K (low K), and N with low doses of P and K (low PK). The N, P_2O_5, and K_2O rates used in the full NPK treatment were 240, 170, and 240 kg/ha, respectively. The low P and low K rates were 100 and 170 kg/ha of P_2O_5 and K_2O, respectively.

Soils in Comilla and Rangpur were acidic (pH 5.6), while in Rajshahi they were slightly alkaline (pH 7.6). Organic C was higher in Rajshahi (0.88%) than in the other two districts (0.75 to 0.78%). Soil total N in all districts was quite low with 0.1% in Comilla and 0.06% in the other two districts. Available P content in all the three districts was higher (27 to 47 mg/kg) than the critical level of 14 mg/kg. Exchangeable soil K concentrations in Comilla and Rajshahi were 0.15 and 0.19 cmol/kg, which were more than the critical level of 0.1 cmol/kg for lowland rice, but were less than the critical level of 0.2 cmol/kg for upland crops such as maize, while in Rangpur, the soil K concentration was higher (0.32 cmol/kg) than the critical value.

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulphur; C = Carbon; AE_N = agronomic efficiency of nitrogen; AE_P = agronomic efficiency of phosphorus; AE_K = agronomic efficiency of potassium.

Dr. Timsina (left) **and Dr. Majumdar** (second from far right) along with cooperating farmers.

Results

Maize grain yields in all treatments varied considerably across the three sites (**Table 1**). Omission of K decreased maize yield significantly more than the omission of P at Comilla, while the opposite was true for Rajshahi and Rangpur sites. At Rajshahi, either low P or low K applications reduced maize yields significantly, while at all the three sites omission of any of the three nutrients reduced maize yields significantly. Omission of N reduced maize yields more in Rangpur, while omission of K had more pronounced effect in Comilla than at other sites. Reduced yield in K-omitted or low-K plots at Comilla and Rajshahi was due to inherently low soil K at these sites.

At Comilla, maize responded to N and K applications better than to P application (**Table 2**). Yield

Table 1. Effect of nutrient omission/reduction from an ample NPK treatment on grain yield of rabi maize in 2009-10 at three locations in Bangladesh.

	- - - - - Grain yield, t/ha - - - - -		
Treatment	Comilla (n = 12)	Rajshahi (n = 9)	Rangpur (n = 4)
-N	5.9	6.6	4.2
-P	7.3	7.4	6.6
-K	5.1	7.8	7.1
NPK	8.7	9.3	8.1
NK and low P	8.3	8.2	7.4
NP and low K	8.1	8.5	7.5
N low PK	7.9	8.8	6.9
LSD (p = 0.05)	0.97	0.64	1.15
CV (%)	16.3	8.4	11.3

Farmers preparing the maize planter for their field trials.

Table 2. Number of farmers' fields showing yield response to N, P, and K in three districts of Bangladesh in 2009-10.

Yield gain, t/ha	--- Comilla ---			--- Rajshahi ---			--- Rangpur ---		
	N	P	K	N	P	K	N	P	K
< 1	3	4	1	1	1	3	0	1	2
1 to 2	2	4	3	3	6	4	0	3	1
2 to 3	3	4	0	2	1	1	0	0	1
3 to 4	1	0	2	0	0	1	3	0	0
4 to 5	2	0	2	2	1	0	1	0	0
> 5	1	0	4	1	0	0	0	0	0

gain due to K application was > 5 t/ha in 4 of the 12 farmer fields at this site. In Rajshahi, maize responded to all three nutrient (NPK) applications, while in Rangpur, N seemed to have a more significant effect on maize yields.

Grain yields in N, P, and K omission plots were not well correlated with the native soil N, P, and K contents, respectively (data not shown). Soil N content across the three sites varied from less than 0.03 to 0.13%, and the grain yield in -N plots varied from 3 to 8 t/ha. But soil N showed poor correlation with the yield of maize in N omission plots across sites. Similar results were obtained for P and K where soil available P and soil test K poorly explained maize yields in the -P and -K treatment plots.

The agronomic use efficiencies for N, P, and K in maize varied widely across districts as well as across farmer fields within a district (**Table 3**). The maximum AE_N observed in Comilla, Rajshahi, and Rangpur were 28.2, 20.5, and 18.2 kg grain/kg N, respectively, which represents a "reasonable" value for soils containing about 1% organic C. However, the mean and median of AE_N in all the three districts was poor. The maximum AE_P was observed in Rajshahi, while the maximum AE_K was observed in Comilla. The results corroborated well with the yield responses to P and K at these two sites.

Given the large variability in yield responses of N, P, and K across locations and deficient grain content of these nutrients in all sites, a site-specific nutrient management strategy

Table 3. Agronomic use efficiencies of N (AE_N), P (AE_P), and K (AE_K) in rabi maize grown in three districts of Bangladesh in 2009-10.

Attribute	Minimum	Maximum	Mean	Median
Comilla (n = 12)				
AE_N, kg grain/kg N	0.3	28.2	10.6	10.3
AE_P, kg grain/kg P	-5.2	38.9	18.2	20.9
AE_K, kg grain/kg K	1.9	28.5	18.0	20.1
Rajshahi (n = 9)				
AE_N, kg grain/kg N	3.0	20.5	10.6	8.3
AE_P, kg grain/kg P	13.4	61.3	25.4	20.6
AE_K, kg grain/kg K	3.8	16.6	7.4	6.1
Rangpur (n = 4)				
AE_N, kg grain/kg N	12.9	18.2	15.5	15.5
AE_P, kg grain/kg P	9.0	26.7	20.6	23.3
AE_K, kg grain/kg K	0.6	11.2	5.0	4.1

based on indigenous nutrient supply and nutrient requirement for particular yield targets needs to be adopted for sustaining productivity of R-M systems in Bangladesh.

Conclusions

There were variable yield responses of maize to N, P, and K across the three experimental districts in Bangladesh. Likewise, the agronomic efficiencies of N, P, and K also varied across the three sites. Grain yields in N, P, and K omission plots were not well-correlated with native soil N, P, and K contents, respectively. BC-SA

Dr. Timsina is a Consultant, International Rice Research Institute, Philippines; e-mail: j.timsina@irri.org and Dr. Majumdar is Director, IPNI South Asia program, Gurgaon, Haryana.

References

Ali, M.Y., S.R. Waddington, J. Timsina, D. Hodson, and J. Dixon. 2009. J. Agric. Sci. & Tech. 3(6):35-53.

Timsina, J., R.J. Buresh, A. Dobermann, and J. Dixon. 2011. Rice-maize systems in Asia: current situation and potential. IRRI-CIMMYT, Sept 2011. 235 p.

Timsina J., M.L. Jat, and K. Majumdar. 2010. Plant & Soil 335:65-82.