*Bangladesh Agron. J. 2017, 20(2): 1-9*

# SITE-SPECIFIC NUTRIENT MANAGEMENT FOR IRRIGATED RICE IN SOUTH CENTRAL REGION OF BANGLADESH

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(**Received:** 16 November 2016, **Accepted:** 9 December 2017)

**Key words:** irrigated rice, nutrient omission, optimum yield, SSNM

## Abstract

A site-specific nutrient management (SSNM) field trial was conducted for irrigated rice using five fertilizer treatments: i) omission of N, ii) omission of P, iii) omission of K, iv) NPK and v) farmers' practice (FP). Substantial variation in the native N, P, and K supply was found among farmers' fields. The indigenous soil K produced 4.5 to 5.0 t $ha^{-1}$ but native P and N gave only rice yield of 3.5 to 4.0 t $ha^{-1}$. The highest grain yield (6.0 to 7.5 t $ha^{-1}$) was obtained from balanced fertilization, followed by FP (4.0 to 5.0 t $ha^{-1}$).The optimal grain yield at Faridpur was obtained by using N, P and K at 135, 8 and 49 kg $ha^{-1}$; 139, 9 and 42 kg $ha^{-1}$; and 140, 10 and 43 kg $ha^{-1}$ for high, medium and low land rice, respectively. However, for Gopalgonj district fertilizer doses of N, P and K were 140, 11 and 38 kg $ha^{-1}$; 142, 10 and 42 kg $ha^{-1}$; and 138, 10 and 49 kg $ha^{-1}$; and for Madaripur district, 126, 8 and 46 kg $ha^{-1}$; 120, 7 and 38 kg $ha^{-1}$; and 99, 6 and 27 kg $ha^{-1}$ for high, medium and low land rice, respectively. These predicted fertilizer doses increase farmers' income and protect environment from pollution.

## Introduction

Fertilizer is one of the most important inputs and successful production of *boro* rice depends on fertilizer management. Fertilizer accounts for about 20 percent of input costs in rice production - the biggest cost after labor (Clayton, 2010). For modern rice varieties, Bangladesh Agricultural Research Council (BARC) has published a fertilizer recommendation guide and Bangladesh Rice Research Institute (BRRI) *Adhunik Dhaner Chas* booklet (FRG, 2012; BRRI, 2013).

To ensure that essential plant nutrients are provided in optimal amounts and readily available during crop growth, site-specific nutrient management (SSNM) was developed by the International Rice Research Institute (IRRI, 2008). In SSNM, the plant's need for N, P or K fertilizer is determined from the gap between the supplies of a nutrient from indigenous sources, as measured via a nutrient omission plot, and the demand of the rice crop for that nutrient, as estimated from the total nutrient required by the crop to achieve a yield target for average climatic conditions. So, SSNM is a low - tech, plant need - based approach for optimally applying nitrogen, phosphorus and potassium fertilizers to rice when they are needed (IRRI, 2007). The purpose of this research was to recognize spatial variability in soil fertility depending on response of indigenous nutrient elements and calculate the amount of fertilizer correctly for developing site-specific nutrient management package for rice production in Low Ganges River Floodplain of Bangladesh.

## Materials and Methods

Farmers' participatory SSNM experiment was conducted on 72 farmers' fields in Low Ganges River Floodplain of Agro - Ecological Zone (AEZ) -12 of Bangladesh. The common cropping pattern was Boro (January to May) - fallow – T.ama*n* (July to November). Soils of the region are silt loams and silty clay loams on the ridges and silty clay loam to heavy clays on lower sites.

Five fertilizer treatments, i.e., nitrogen omission (PK), phosphorus omission (NK), potassium omission (NP), balanced fertilizer (NPK) and farmers' practice (FP) were used (Table 1)

Table 1. Description of experimental treatments

| No. | Treatment | Applied nutrients | Description |
|---|---|---|---|
| 1. | Nitrogen omission (-N) | PK | PK-based fertilizer recommendation |
| 2. | Phosphorus omission (-P) | NK | NK-based fertilizer recommendation |
| 3. | Potassium omission (-K) | NP | NP-based fertilizer recommendation |
| 4. | Balance fertilizer (NPK) | NPK | NPK-based fertilizer recommendation |
| 5. | Farmers' practice | NPK | Farmers' own fertilizer practice |

Two sites (Site-I and Site-II) within each district (Faridpur, Gopalgonj and Madaripur) were selected for trial. From six sites, four farmers (each farmer represented one replication) were selected from each of high, medium or low land. So, selected numbers of farmer were 24 (12 from site-I and 12 from site-II) from each district. The experimental design was split-split plot (mentioned main and sub plot) with four replications. Farmers cultivated BRRI dhan29 in Faridpur and Gopalgonj but BRRI dhan28 in Madaripur district. The age of seedlings for transplanting varied from 40 to 55 days. Transplanting time ranged from mid-January to last week of February. Blanket doses of other nutrients were included in all treatments to prevent deficiencies other than nitrogen (N), phosphorus (P), or potassium (K). In this trial, N, P and K were used at 147, 20 and 50 kg $ha^{-1}$ in the form of urea, triple super phosphate (TSP) and muriate of potash (MoP). The TSP and MoP were applied during final land preparation but urea was top-dressed in three splits (15, 30 and 50 days after transplanting). Intercultural operation and irrigations were similar in all locations. Monitoring was done through frequent field visits and keeping close contact with respective farmers during the crop-growing period.

### Calculation of Optimum Fertilizer Rates

Optimum N, P and K doses were calculated following Driessen (1996):

$$N = [(Y_{NPK} - Y_{PK}) / N_U] \times 18 \quad [1]$$
$$P = [(Y_{NPK} - Y_{NK}) / P_U] \times 2.5 \quad [2]$$
$$K = [(Y_{NPK} - Y_{NP}) / K_U] \times 20 \quad [3]$$

Where, $Y_{NPK}$ = yield in NPK plots, $Y_{PK}$ = yield in N omission plot, $Y_{NK}$ = yield in P omission plot, $Y_{NP}$ = yield in K omission plot, $N_U$ =N-use efficiency (40%), $P_U$ = P-use efficiency (60%), and $K_U$ = K-use efficiency (80%) (BRRI, 2004).

Grain yield was harvested at maturity and was adjusted to 14% moisture content [GMK-303RS (G-WON HITECH Co., LTD, Korea)] was used. Crop data were analyzed using the CropStat 7.2 software (IRRI, 2015).

## Results and Discussion

### Grain yield

#### Faridpur

Grain yield of rice on different land types (L) was not statistically significantly different. Similar grain yield was obtained from high, medium and low lands. The individual effect of site (S) as well as that of L × S interaction on yield was statistically significant. The highest grain yield was recorded from low land in site-I. The grain yield was the highest in medium land at site-II (Table 2). Effect of fertilizer management (F) was statistically significant on grain yield. The highest grain yield was obtained from balanced fertilization (NPK) that produced about 6-.5 t $ha^{-1}$. In fertilizer omission plots, the highest grain yield was recorded from potassium omission (-K), followed by phosphorus omission plot (-P) but statistically similar yields. The potassium and phosphorus omission plots yielded 4.65 and 4.43 t $ha^{-1}$, respectively. The lowest yield was obtained from nitrogen omission plot (-N) that produced 3.38 t $ha^{-1}$. However, the L × F, S × F and L × S × F interactions were not statistically significant in relation to grain yield (Table 2). On high land, highest yield was recorded from NPK-treated plots, followed by farmers' practice. In nutrient omission plots, the highest yield was obtained from NP (-K) plot.

Table 2. Rice yield as affected by different nutrient management practices at farmers' field at Faridpur district

| Treatments | Grain yield (t $ha^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | High land | | | Medium land | | | Low land | | | Mean |
| | Site-I | Site-II | Mean | Site-I | Site-II | Mean | Site-I | Site-II | Mean | |
| - N (PK) | 3.50 | 3.23 | 3.36 | 3.30 | 3.17 | 3.24 | 3.92 | 3.00 | 3.47 | 3.38 |
| - P (NK) | 4.29 | 4.44 | 4.37 | 4.55 | 4.69 | 4.62 | 4.42 | 4.19 | 4.30 | 4.43 |
| - K (NP) | 4.55 | 4.24 | 4.40 | 4.46 | 4.93 | 4.70 | 5.08 | 4.64 | 4.86 | 4.65 |
| NPK | 6.40 | 6.31 | 6.36 | 6.40 | 7.15 | 6.78 | 6.94 | 6.23 | 6.58 | 6.58 |
| FP | 5.59 | 4.77 | 5.19 | 5.44 | 5.16 | 5.31 | 5.61 | 4.98 | 5.29 | 5.26 |
| Mean | 4.86 | 4.60 | | 4.83 | 5.02 | | 5.19 | 4.61 | | |
| CV (%) | 10.4 | | | | | | | | | |
| $LSD_{(0.05)}$ | | | | | | | | | | |
| Land (L) | NS | | | | | | | | | |
| Site (S) | 0.19 | | | | | | | | | |
| L × S | 0.34 | | | | | | | | | |
| Fertilizer (F) | 0.31 | | | | | | | | | |

NS = not significant, FP = Farmers' practice

#### Gopalgonj

Grain yield was not statistically influenced by the individual effect of site (S) and land type (L) as well as by L × S interaction (Table 3). Statistically similar grain yield was obtained from both sites in all land types. Again, higher grain yield was obtained from high land than from medium land. On the other hand, effect of fertilizer management (F) was statistically significant on grain yield. The highest grain yield was obtained from NPK, followed by farmers' practice. The highest grain yield was recorded from potassium omission plots (-K), followed by phosphorus omission plots (-P). These two treatments produced statistically similar yields. Around 3.37 t $ha^{-1}$ yields were recorded from -N plots, whereas more than 4.0 t $ha^{-1}$ yields was recorded from -P and -K plots. However, the L × F, S × F and L × S × F interaction effects were not statistically significant in relation to grain yield (Table 3). Irrespective of land type, highest grain yield was recorded from balanced fertilizer (NPK)-treated plots. In missing-nutrient plots, the highest yield was obtained from potassium omission (-K) plots, followed by phosphorus omission (-P) plots. The lowest yield was recorded from nitrogen omission (-N) plots in all cases (Table 3).

Table 3. Rice yield as affected by different nutrient management practices at farmers' field at Gopalgonj district

| Treatments | Grain yield (t $ha^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | High land | | | Medium land | | | Low land | | | Mean |
| | Site-I | Site-II | Mean | Site-I | Site-II | Mean | Site-I | Site-II | Mean | |
| - N (PK) | 3.48 | 3.60 | 3.54 | 3.44 | 3.29 | 3.37 | 3.25 | 3.11 | 3.18 | 3.37 |
| - P (NK) | 4.58 | 4.57 | 4.58 | 4.66 | 4.05 | 4.36 | 4.50 | 4.18 | 4.34 | 4.43 |
| - K (NP) | 4.70 | 4.82 | 4.77 | 4.50 | 4.81 | 4.66 | 5.19 | 4.26 | 4.73 | 4.72 |
| NPK | 7.31 | 6.87 | 7.10 | 6.76 | 6.74 | 6.75 | 6.63 | 6.72 | 6.68 | 6.85 |
| FP | 5.09 | 5.38 | 5.24 | 5.22 | 5.33 | 5.28 | 5.16 | 5.50 | 5.33 | 5.29 |
| Mean | 5.04 | 5.05 | | 4.91 | 4.84 | | 4.95 | 4.76 | | |
| CV (%) | | | | | 9.6 | | | | | |
| $LSD_{(0.05)}$ | | | | | | | | | | |
| Land (L) | | | | | NS | | | | | |
| Site (S) | | | | | NS | | | | | |
| L × S | | | | | NS | | | | | |
| Fertilizer (F) | | | | | 0.26 | | | | | |

NS = not significant, FP = Farmers' practice

**Madaripur**

The effect of land type (L) on grain yield was not significant but site (S) effect was significant. The L × S interaction was not statistically significant for grain yield (Table 4). The highest grain yield was obtained from site-I in all land types. More than 4.5 t $ha^{-1}$ grain yields were recorded from site-I but less than 4.0 t $ha^{-1}$ from site-II. Effect of fertilizer management (F) on grain yield was statistically significant. The highest grain yield was obtained from balanced fertilization (NPK), which produced more than 5.5 t $ha^{-1}$. In nutrient omission plots, the highest grain yield from potassium omission plots (-K) was followed by phosphorus omission plots (-P). Both the treatments produced more than 4.0 t $ha^{-1}$. Around 3.0 t $ha^{-1}$ yields were recorded from -N plots, whereas more than 4.0 t $ha^{-1}$ yield was recorded from -P and -K plots. The L × F, S × F and L × S × F interaction effects were statistically significant for grain yield. The highest yield was obtained from balanced fertilizer in all land types, followed by FP. In fertilizer omission plots, the highest yield was obtained from -K, followed by -P plots. In high land, highest yield was obtained from NPK fertilizer that yielded 7.08 and 4.84 t $ha^{-1}$ at site-I and II, respectively. Potassium omission plots produced the second highest yield in high land, followed by -P plots. In medium and low lands, highest yield was recorded from NPK plots. Around 6.0 t $ha^{-1}$ grain yield was obtained from NPK fertilizer and 4.5 -5.0 t $ha^{-1}$ from -K plot. The lowest yield was recorded from nitrogen omission plots (-N) in all cases. This trend was also true for low land.

Table 4. Rice yield as affected by different nutrient management practices at farmers' field at Madaripur district

| Treatments | Grain yield (t $ha^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | High land | | | Medium land | | | Low land | | | Mean |
| | Site-I | Site-II | Mean | Site-I | Site-II | Mean | Site-I | Site-II | Mean | |
| - N (PK) | 3.26 | 3.02 | 3.15 | 3.34 | 2.71 | 3.03 | 3.58 | 2.97 | 3.27 | 3.15 |
| - P (NK) | 4.32 | 3.74 | 4.03 | 4.17 | 3.65 | 3.91 | 4.44 | 3.85 | 4.15 | 4.03 |
| - K (NP) | 4.56 | 3.72 | 4.14 | 4.84 | 3.54 | 4.19 | 4.87 | 3.91 | 4.39 | 4.25 |
| NPK | 7.08 | 4.84 | 5.96 | 6.29 | 5.08 | 5.69 | 5.97 | 5.00 | 5.48 | 5.71 |
| FP | 5.07 | 4.14 | 4.61 | 5.56 | 4.18 | 4.87 | 4.49 | 4.07 | 4.28 | 4.59 |
| Mean | 4.87 | 3.89 | | 4.86 | 3.83 | | 4.67 | 3.96 | | |
| CV (%) | | | | | 10.3 | | | | | |
| $LSD_{(0.05)}$ | | | | | | | | | | |
| Land (L) | | | | | NS | | | | | |
| Site (S) | | | | | 0.14 | | | | | |
| L × S | | | | | NS | | | | | |
| Fertilizer (F) | | | | | 0.22 | | | | | |
| L × F | | | | | 0.39 | | | | | |
| S × F | | | | | 0.32 | | | | | |
| L × S × F | | | | | 0.55 | | | | | |

NS = not significant, FP = Farmers' practice

The NPK treatment produced the highest grain yield at all locations. The balanced fertilizer treatment plots gave 95, 49, 42 and 25% higher grain yield at Faridpur (Table 2); 103, 55, 45 and 29% at Gopalgonj (Table 3) and 81, 42, 34 and 24% at Madaripur (Table 4) than omission of N (PK), P (NK), K (NP) and FP, respectively. The highest grain yield was obtained to balanced fertilization (optimum N, P and K) that produced more tillers and number of panicles per square meter and highest thousand- grain-weight as compared with PK, NK, and NP treatments. Pham *et al.* (1999) reported that more balanced fertilization increased N-uptake and N-use efficiencies. Nath *et al.* (2012) was also found that NPK fertilizer-treated plots gave higher grain yield due to more panicles $m^{-2}$ and thousand grain weight compared with omission of N, P and K-treated plots.

Among omission plots, the highest grain yield was recorded from K omission plots. The response of soil native potassium was mentionable (4.5 to 5.0 t $ha^{-1}$) and thus in K omission treatment; yield was the second highest (Tables 2 to 4). So, the response of soil native potassium was better than phosphorus and nitrogen omission plot. Nath *et al.* (2012) also reported that the response of soil native potassium was remarkable and produced yield similar to that of NPK-treated plots. To produce one ton of rice, 20 kg K $ha^{-1}$ is required (Dobermann and White, 1999). The plots without application of P fertilizer gave lower grain yield than NPK and K omission plots. Phosphorus promotes tillering, root development, early flowering and ripening. To produce one ton of rice grain, 2.5 kg P $ha^{-1}$ is required (Dobermann and White, 1999). Lower grain yield in P-omission plots might be as a result of production of minimum number of panicles $m^{-2}$ and less grains $panicle^{-1}$. The N omission plots produced the lowest grain yield, which was around 3.0 t $ha^{-1}$. Insufficient N supply did not meet the crop demand for other nutrients, such as P, K and other micro- and secondary nutrients. To produce one ton of rice, 18 kg N $ha^{-1}$ is required (Dobermann and White, 1999). BRRI dhan29, a long duration variety, produced around 6.0 t $ha^{-1}$ at Faridpur and Gopalgonj (Tables 2 to 4). In contrast to, BRRI dhan28, a short duration variety, yielded around 5.0 t $ha^{-1}$ at Madaripur (Tables 2 to 4).

**Response of Initial Soil Nutrient to Grain Yield**

The relationship between initial soil N and grain yield in N omission plots (PK) was significant ($P<0.00$) and positive at all locations. So, with the increases of soil N, regression analysis showed increased grain yield in missing-N plots (Fig 1). The relationships between soil N and yield of N omission plots were:

Faridpur : Grain yield = 11.103 soil N + 2.2157, $R^2 = 0.4993^{**}$
Gopalgonj : Grain yield = 10.269 soil N + 2.2207, $R^2 = 0.3976^{**}$
Madaripur : Grain yield = 16.574 soil N + 1.378, $R^2 = 0.522^{**}$

For phosphorus omission plots, a significant and positive relationship was obtained between soil P and yield of P missing plot ($P<0.01$). Regression analysis demonstrated increased grain yield was obtained with increases in soil P (Fig 2). The relationships between yield and soil P were:

Faridpur : Yield = 0.0994 soil P + 3.7441, $R^2 = 0.4216^{**}$
Gopalgonj : Yield = 0.0624 soil P + 3.5376, $R^2 = 0.3553^{**}$
Madaripur : Yield = 0.0731 soil P + 3.3352, $R^2 = 0.3968^{**}$

The grain yield response in K omission plots was statistically significant. With increases in soil K, regression analysis showed increased grain yield (Fig 3). The relationships between yield responses with soil K were:

Faridpur : Yield = 11.305 soil K + 2.035, $R^2 = 0.5243^{**}$
Gopalgonj : Yield = 5.5439 soil K + 3.3888, $R^2 = 0.3507^{**}$
Madaripur : Yield = 26.162 soil K + 0.8939, $R^2 = 0.5464^{**}$.
All the b values were significant ($P<0.01$).

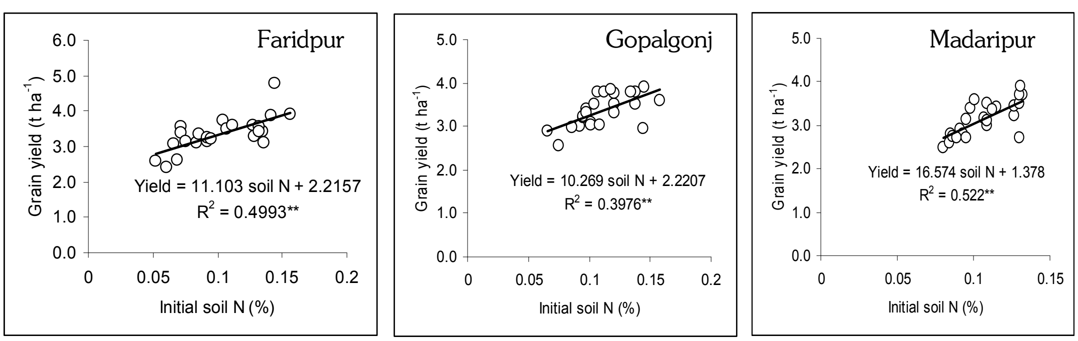


Fig. 1. Relationship between grain yield in nutrient omission plot and indigenous soil N supply during Boro season
** = Significant at 1% level.

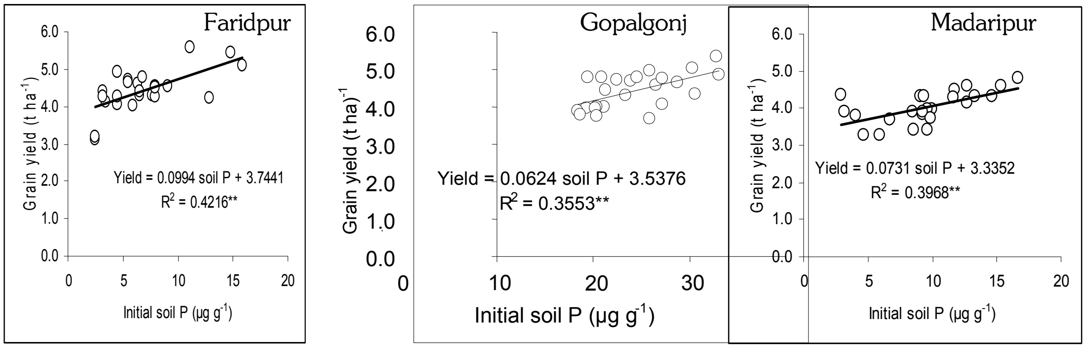


Fig. 2. Relationship between grain yield in nutrient omission plot and indigenous soil P supply during Boro season

** = Significant at 1% level.

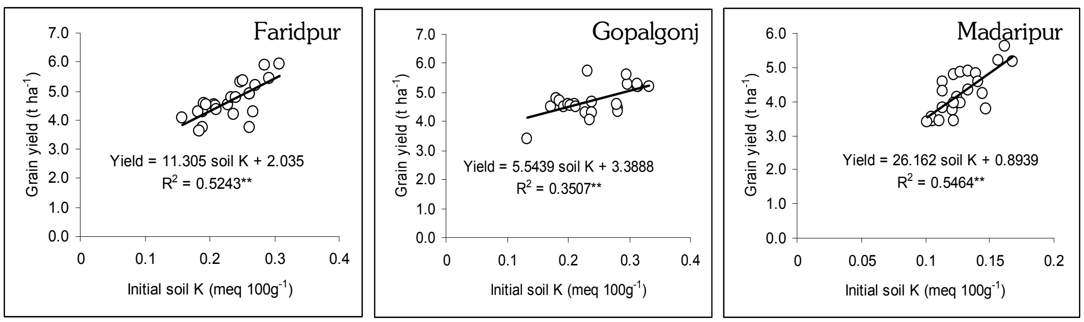


Fig. 3. Relationship between grain yield in nutrient omission plot and indigenous soil K supply during Boro season

** = Significant at 1% level.

## Calculation of Optimum Fertilizer Doses

Using formulae 1, 2 and 3, optimum fertilizer doses were calculated for cultivating *boro* rice. The calculated doses of N, P and K were 135, 8 and 49 kg ha$^{-1}$; 139, 9 and 42 kg ha$^{-1}$; and 140, 10 and 43 kg ha$^{-1}$ for high, medium and low land, respectively, at Faridpur (Table 5). The required fertilizer doses of N, P and K were 140, 11 and 38 kg ha$^{-1}$; 142, 10 and 42 kg ha$^{-1}$; and 138, 10 and 49 kg ha$^{-1}$ for high, medium and low land, respectively, at Gopalgonj. The calculated optimum N, P and K dose were 126, 8 and 46 kg ha$^{-1}$; 120, 7 and 38 kg ha$^{-1}$; and 99, 6 and 27 kg ha$^{-1}$ for high, medium and low land, respectively, at Madaripur. The calculated doses of N, P and K were lower than applied fertilizer doses at all locations. However, the differences were more prominent in Madaripur than that of Faridpur and Gopalgonj. This might be due to cultivation of BRRI dhan28 (short-duration) at Madaripur but BRRI dhan29 (long-duration) at Faridpur and Gopalgonj districts. However, calculated N and K doses were higher (10 to 20 Kg ha$^{-1}$) than farmers' practice but P was lower (Table 5). Moreover, farmers' application of fertilizer was not sufficient for proper plant growth and yield. Imbalanced fertilization during *boro* rice cultivation depletes soil nutrients, leading to a decline in production. Therefore, using SSNM fertilizer management practice, farmers could get more profit and also reduce environmental pollution.

Table 5. Calculated optimum doses of nutrients under various soil types during *Boro* season

| Nutrients | Amount of nutrients (kg ha$^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|---|
| | | High land | | Medium high land | | Low land | |
| Faridpur | | | | | | | |
| | Applied | To be applied† | FP | To be applied† | FP | To be applied† | FP |
| N | 147 | 135 | 105 | 139 | 112 | 140 | 136 |
| P | 20 | 8 | 20 | 9 | 30 | 10 | 40 |
| K | 50 | 49 | 27 | 42 | 25 | 43 | 30 |
| Gopalgonj | | | | | | | |
| N | 147 | 140 | 151 | 142 | 120 | 138 | 153 |
| P | 20 | 11 | 24 | 10 | 21 | 10 | 32 |
| K | 50 | 38 | 28 | 42 | 27 | 49 | 35 |
| Madaripur | | | | | | | |
| N | 147 | 126 | 143 | 120 | 126 | 99 | 130 |
| P | 20 | 8 | 26 | 7 | 31 | 6 | 27 |
| K | 50 | 46 | 25 | 38 | 35 | 27 | 32 |

†Calculated optimum amount of NPK, FP = Farmers' practice

## Conclusion

Depending on the response of grain yield to the indigenous soil nutrients, it could be concluded that rice soils of Faridpur, Gopalgonj and Madaripur showed spatial variability in availability of N, P and K. However, nitrogen and phosphorus were the most limiting nutrients to increased grain yield in the experimental sites. For optimum grain yield of *boro* rice, recommendation for farmers of Faridpur could be use of N, P and K at 135, 8 and 49 kg ha$^{-1}$; 139, 9 and 42 kg ha$^{-1}$; and 140, 10 and 43 kg ha$^{-1}$ for high, medium and low land, respectively. However, required fertilizer doses of N, P and K were 140, 11 and 38 kg ha$^{-1}$; 142, 10 and 42 kg ha$^{-1}$; and 138, 10 and 49 kg ha$^{-1}$ at Gopalgonj; and 126, 8 and 46 kg ha$^{-1}$; 120, 7 and 38 kg ha$^{-1}$; and 99, 6 and 27 kg ha$^{-1}$ at Madaripur for high, medium and low land, respectively. A mentionable portion of fertilizer can be saved through adopting site-specific nutrient management (SSNM) technology which can ensure efficient use of nutrients.

## Acknowledgements

This research was supported by USAID funded Extension of Cereal system Initiative for South Asia (CSISA) in Bangladesh project of International Rice Research Institute (IRRI). The authors are grateful to the farmers of Singria and Khapura of Faridpur; Podderer char and Gobra of Gopalgonj; Char Doulath Khan and Char Doulath Khan South of Madaripur district for their patience and excellent cooperation through-out the on-farm experiments.

## References

BRRI. 2004. Bangladesh Rice Research Institute. Soil Science Division, Bangladesh Rice Research Institute internal review report for 2003-2004. pp. 25-27.

BRRI. 2013. Bangladesh Rice Research Institute. "*Adhunik Dhaner Chash," 17th edition*, pp.10–72.

Clayton, S. 2010. "50 years of rice science for a better world – and it's just the start!" Rice Today, IRRI.

Dobermann, A. and P. F. White. 1999. Strategies for nutrient-management in irrigated and rainfed lowland rice systems. Nut. Cycl. Agro-ecosystem 53: 1-18.

FRG. 2012. Fertilizer Recommendation Guide, Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 1215, pp. 01-02.

IRRI. 2007. International Rice Research Institute. Site-specific nutrient management [online]. Available at www.irri.org/irrc/ssnm.

IRRI. 2015. International Rice Research Institute. http://cropstat-for-windows.software.informer.com/7.2/

IRRI. 2008. International Rice Research Institute. http://www.knowledgebank.irri.org/ericeproduction/IV.4_SSNM.htm

Nath, D., F. Haque, M. S. Islam and M. A. Saleque. 2012. Farmers' Participatory Site Specific Nutrient Management in Ganges Tidal Floodplain Soil for High Yielding *Boro* Rice International Conference on Environment, Agriculture and Food Sciences (ICEAFS'2012) August 11-12, in Phuket, Thailand.