EVALUATION OF FERTILIZER REQUIREMENT FOR RICE IN UNFAVORABLE ECOSYSTEMS OF BANGLADESH

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Abstract

Soil fertility assessment through soil testing is effective in increasing productivity hence considered as the first step to managing soil fertility. But soil test basis (STB) doses of fertilizers may not be equally effective in different ecosystems due to variation in soil properties, climate, natural calamities, etc. To address this constrains, this study was conducted in T. Aman season 2011 at different unfavorable ecosystems (Submergence and Cold area, Drought prone and Cold area, Tidal Flood Ecosystem, Saline and Charland area) of Bangladesh. Eight fertilizer treatments were tested in one farmer's field per site. The treatments were: T_1 = 100 % NPKSZn (STB); $T_2 = T_1$ + 25 % N; $T_3 = T_1$ + 25 % NP; $T_4 = T_1$ + 25 % NK; $T_5 = T_1$ + 25 % PK; $T_6 = T_1$ + 25 % NPK; T_7 = 75 % of T_1 and T_8 = Absolute control (without fertilizer). STB doses of fertilizer performed better in Tidal Flood Ecosystem (AEZ 13) and Saline and Charland area (AEZ 18). But additional fertilizer, N or NK fertilizer, might be beneficial for maximizing rice yield in Submergence area (AEZ 3). Similarly, the highest agronomic efficiency was observed with T_1 treatment in both AEZ 13 and AEZ 18. On the other hand, T_2 and T_4 treatments showed the highest agronomic efficiency in AEZ 3.

Key words: Tidal flood, Saline and Charland, Drought, Submergence, Rice-based cropping systems

Introduction

About 160 million peoples in Bangladesh depend on rice as main food and about 75 percent of agricultural land use to grow rice (Rasheduzzaman, 2013). Most of the people depend on rice as main food all the year especially in Bangladesh as well as Asia. Rice production increases must be achieved at a faster rate than in most other countries, while the land planted to rice is not expanding. In addition, Bangladesh is faced with production constraints such as drought, lack of irrigation facilities, flooding, submergence and salinity of soils, coupled with appropriate fertilizer management technologies. To maintain self-sufficiency in rice, Bangladesh will have to continue to expand rice production by raising yields at a rate that is at least equal to population growth until the demand for rice has stabilized. In Bangladesh, coastal area constitutes about 2.5 million hectares which amount to about 25 percent of the total cropland of the country (Saha *et al*., 2016). Now a days nearly 1.0 million hectares land of Bangladesh are affected by varying intensities of salinity (Karim, 1997) due to the effect of climate change and global warming (rising of sea level, Sidr, Aila etc.). Crop production in this area is dominated by the traditional T. Aman rice with the yield of 2 t ha^{-1} which is very low due to soil salinity problem, drought in the dry season (Karim, 1997), lack of sufficient number of saline tolerant rice cultivars as well as lack of appropriate fertilizer management technologies etc.

Flood-prone rice ecosystem of Bangladesh cover about 2.6 million hectares (Karim, 1997). The devastating flood caused considerable loss of rice crop. The average yield of rice under flood-prone ecosystem is very low (2.5 t ha^{-1}) due to lack of technologies on flood tolerance rice varieties and their appropriate fertilizer management packages etc.

The High Barind-Tract of north-west Bangladesh is drought prone having 1200-1400mm mean annual rainfall from June to October and drought affected area is nearly 2.5 million hectares in Kharif and 1.2 million hectares in the dry season (Karim, 1997). BRRI dhan39 yielded 0.61 to 2.8 t ha^{-1} in the drought prone area from the year 2001 to 2003 (Mazid *et al.*, 2004). This low yield might be due to lack of sufficient water and nutrition management.

The non-saline tidal flood ecosystem of Bangladesh covers about 1.9 million hectares (Saha *et al*., 2016) and the average yield of rice under non-saline tidal flood ecosystem is not more than 3.0 t ha^{-1} due to lack of technologies on appropriate fertilizer management packages etc.

Thus, it is the demand of time to produce more yields by introducing salt, drought and submergence tolerance rice cultivars with the best fertilizer management packages. Keeping all above in view, the present study was carried out to identify the proper fertilizer management packages through inorganic amendments for Boro-Fallow-T. Aman cropping pattern under different unfavorable ecosystems.

Materials and Methods

The experiment was conducted in T. Aman season 2011 at different unfavorable ecosystems of Bangladesh. The locations and characteristics of the study areas are presented in Table 1. Initial soil properties of the experimental sites are presented in Table 3. There were remarkable variations in soil nutritional status at different ecosystems. Initial soil was collected with a core sampler from 0 to 15 cm layer of puddled soil before the application of fertilizer. Nine samplings were done from each farmer's field. Soil samples were air-dried, ground and passed through a 2-mm sieve and prepared for routine analyses of texture, pH, OC, total N, exchangeable K, available P, S and Zn (Islam *et al*., 2013a; Islam *et al*., 2013b; Islam *et al*., 2014; Islam *et al*., 2016a and Saha *et al*., 2016).

The experiment was laid out in a randomized complete block design with three replications. Treatments consisted of options for managing fertilizers in rice of different ecosystem. The treatments were: T_1 = 100 % NPKSZn (Soil Test Basis (STB); according to the BARC FRG, 2005); $T_2 = T_1$ + 25 % N; $T_3 = T_1$ + 25 % NP; $T_4 = T_1$ + 25 % NK; $T_5 = T_1$ + 25 % PK; $T_6 = T_1$ + 25 % NPK; T_7 = 75 % of T_1 and T_8 = Absolute control (without fertilizer). STB dose of NPKSZn was @ 84-5-46-14-1.6, 80-11-14-11-0.64, 64-3-39-8-1.3 and 90-11-30-4-1.5 kg ha^{-1} in Rangpur (AEZ 3), Rajshahi (AEZ 26), Barisal (AEZ 13) and Sonagazi (AEZ 18), respectively. In Rangpur site (AEZ 3), one-third N, 1/2 K and all other inorganic fertilizers were applied at final land preparation. The first top dress (one-third N) was applied at 18 DAT and the rest 1/3 N and 1/2 K was applied at 55 DAT. In other sites, AEZ 13, 18 and 26, one-third N and all other inorganic fertilizers were applied at final land preparation. The first top dress (one-third N) was applied at 20 DAT and the rest 1/3 N was applied at 40 DAT. Unit plot size was 5m × 4m. BRRI dhan52, BRRI dhan56, BRRI dhan44 and BRRI dhan41 were used as tested crop in Rangpur, Rajshahi, Barisal and Sonagazi, respectively. Time of sowing, transplanting and harvesting are presented in Table 2. All plots were surrounded by permanent bunds to prevent transfer of soil and nutrients between plots. In all cases, rice was transplanted and grown on submerged soil. Weeds and insects were controlled to avoid yield losses.

Grain yield was recorded from the central 5 m^2 harvest area in each plot at maturity and reported on 14% moisture basis. At maturity, 16 hills (four hills from each of the four sides of the grain harvest area) were collected at ground level and fresh straw weight was determined after separating the grains. Grain and straw were dried at 70°C to constant weight and dry weights were recorded. The ratio of fresh and oven-dry weights of straw for 16-hill samples was then used to determine straw yields on an oven-dry basis from fresh straw weights (Islam *et al.*, 2015 and Islam *et al.*, 2016b).

Agronomic efficiency of nitrogen (AE_N) was calculated by using following equations (BARC, 2005): $AE_N = \frac{(Y_{NA} - Y_{N0})}{N_{RN}}$

Where, Y_{NA} is the grain yield in fertilized plot (kg ha^{-1}), Y_{N0} is the grain yield in unfertilized plot (kg ha^{-1}), and N_{RN} is the rate of nitrogen applied (kg ha^{-1}). Mean value of grain yield (Table 3) for each treatment was considered for calculation.

Analysis of variance (ANOVA) was performed on yield to determine the effects different treatments using the SPSS program. Least significant difference (LSD) at the 0.05 level of probability was used to evaluate the differences among treatment means.

Results and Discussion

Submergence and Cold area (AEZ 3)

Applied fertilizer significantly influenced the grain and straw yield of T. Aman rice (Tables 4 & 5). The grain yield was higher in the treated plots than that of the control plot (T_8). It might be due to low availability of nutrient in soil. The highest yield of 4.04 t ha^{-1} was obtained with the treatment $T_{2,}$ which was statistical similar to T_4. Treatment T_2 showed the highest agronomic efficiency followed by T_4 (Table 6). There might be a synergistic relation between N and K. Applied nutrients might be lost through surface runoff due to flash flood. As a consequence, additional N or NK might be increased rice yield. Raihan (2014) also reported that additional application of K increased rice yield. Addition of other nutrients, more than STB dose, might be created nutrient imbalance in soil. As a result, it might have negative impact on rice yield (Anonymous, 2016) and agronomic use efficiency. Outside of the experimental plot where other rice varieties (except BRRI dhan52) were cultivated, crops were damaged by the flood. Only BRRI dhan52, submergence tolerant rice variety, survived from the flood but it delayed to maturity. Similar trend was also observed in case of straw yield.

Drought prone and Cold area (AEZ 26)

The grain yield was not significantly influenced by fertilizer treatments due to inundation of levee for several times through heavy rainfall and during flowering stage the experimental plot was affected by the hot-wind (Table 4). As a result grains were largely unfilled (as eye estimation). Agronomic efficiency showed low in all treatments due to nutrient inefficiency for inundation of experimental plots (Table 6). Straw yield was, however, significantly lower in control than other treatments (Table 5).

Tidal Flood Ecosystem (AEZ 13)

Applied fertilizer significantly influenced the grain and straw yield of T. Aman rice (Tables 4 & 5). The highest grain yield (5.78 t ha^{-1}) was obtained with the treatment T_1, which was statistically similar to T_2, T_3, T_4, T_5, T_6 and T_7 (Table 4). So, STB doses of fertilizers are enough to attain maximum rice yield. Rahman (2001) reported that in rice-rice cropping pattern, the highest grain yield of rice was recorded in the soil test basis (STB) NPKSZn fertilizers treatment. The lowest grain yield was observed in the treatment T_8 (control). The similar trend was also observed in case of straw yield (Table 5). In case of agronomic efficiency, STB doses of fertilizer showed the highest efficiency (Table 6). Addition of more nutrients than STB dose might be created nutrient imbalance in soil. As a result, it might have negative impact on rice yield (Anonymous, 2016) and agronomic use efficiency.

Saline and Charland area (AEZ 18)

Applied fertilizer significantly influenced grain and straw yield of T. Aman rice (Tables 4 & 5). The highest grain yield (4.60 t ha^{-1}) was obtained with the treatment T_2, which was statistically similar to T_1, T_3, T_5, T_6 and T_7. STB doses of fertilizers showed the highest agronomic efficiency (Table 6).

Table 1 Characteristics of the study areas

Location/AEZ	GPS Reading	Characteristics	Cropping Pattern
Gongachara, Rangpur (AEZ 3)	25.86° N and 89.24° E	Submergence and Cold area	Boro-Fallow-T. Aman
Tanore, Rajshahi (AEZ 26)	24.54° N and 88.56° E	Drought prone and Cold area	
Babugonj, Barisal (AEZ 13)	22.76° N and 90.30° E	Tidal Flood Ecosystem	
Sonagazi, Feni (AEZ 18)	22.82° N and 91.39° E	Saline and Charland area	

Table 2 Crop calendar of the studied areas

Location/AEZ	Variety	Date of sowing	Date of transplanting	Date of Harvesting
Gongachara, Rangpur (AEZ 3)	BRRI dhan52	05-07-11	10-08-11	15-12-11
Tanore, Rajshahi (AEZ 26)	BRRI dhan56	23-07-11	08-08-11	30-10-11
Babugonj, Barisal (AEZ 13)	BRRI dhan44	03-07-11	22-08-11	07-12-11
Sonagazi, Feni (AEZ 18)	BRRI dhan41	14-07-11	17-08-11	03-12-11

Table 3. Initial soil properties of the experimental sites during T. Aman season, 2011.

Parameters	Locations			
	Rangpur (AEZ 3)	Rajshahi (AEZ 26)	Barisal (AEZ 13)	Sonagazi (AEZ 18)
Texture	Silt Loam	Silt Loam	Silty Clay Loam	Clay Loam
pH (1:2.5)	6.04	7.22	6.55	7.42
Org. C (%)	1.06	1.22	1.74	0.93
Total N (%)	0.11	0.12	0.17	0.09
Avail. P (ppm)	34.8	10.4	20.4	10.8
Exch. K (Cmol kg^{-1})	0.10	0.24	0.13	0.17
Avail. S (ppm)	5.1	11.3	19.1	82.8
Avail. Zn (ppm)	0.4	0.8	0.7	0.4

Table 4. Effect of fertilizer application on the grain yields of T. Aman rice 2011 in different ecosystems.

Treatments	Grain yield (t ha^{-1})			
	Rangpur (AEZ 3)	Rajshahi (AEZ 26)	Barisal (AEZ 13)	Sonagazi (AEZ 18)
T_1=100% NPKSZn (STB)	2.94	2.69	5.78	4.43
T_2= T_1+ 25% N	4.04	2.63	5.22	4.60
T_3=T_1+ 25% NP	2.87	3.05	5.39	4.29
T_4=T_1+ 25% NK	3.91	3.17	5.54	3.85
T_5=T_1+ 25% PK	3.02	3.06	4.95	4.07
T_6=T_1+ 25% NPK	3.39	2.34	5.45	4.24
T_7=75% of T_1	2.55	2.98	5.41	4.07
T_8=Control	2.40	2.42	4.70	3.84
LSD0.05	0.57	-	0.62	0.63
Significant level	**	NS	*	*
CV (%)	10.4	19.6	6.7	8.6

Note: T_1= N_{84} P_5 K_{46} S_{14} $Zn_{1.6}$ (Rangpur), T_1= N_{80} $P_{11}K_{14}$ S_{11} $Zn_{0.64}$ (Rajshahi), T_1= N_{64} P_3 K_{39} S_8 $Zn_{1.3}$ (Barisal), T_1=$N_{90}P_{11}$ K_{30} S_4 $Zn_{1.5}$ (Sonagazi).

Table 5. Effect of fertilizer application on the straw yields of T. Aman rice 2011 in different ecosystems

Treatments	Straw yield (t ha^{-1})			
	Rangpur (AEZ 3)	Rajshahi (AEZ 26)	Barisal (AEZ 13)	Sonagazi (AEZ 18)
T_1=100% NPKSZn (STB)	4.54	6.37	5.97	5.73
T_2= T_1+ 25% N	6.28	5.90	5.54	6.19
T_3=T_1+ 25% NP	5.06	6.26	5.19	5.32
T_4=T_1+ 25% NK	4.49	5.47	6.00	6.10
T_5=T_1+ 25% PK	4.13	5.84	5.42	5.52
T_6=T_1+ 25% NPK	3.48	6.12	5.82	5.87
T_7=75% of T_1	3.24	5.51	5.52	4.91
T_8=Control	2.29	5.34	4.85	4.06
LSD0.05	0.78	0.95	0.91	1.04
Significant level	**	*	*	**
CV (%)	10.6	9.3	9.4	10.8

Note: T_1= N_{84} P_5 K_{46} S_{14} $Zn_{1.6}$ (Rangpur), T_1= N_{80} $P_{11}K_{14}$ S_{11} $Zn_{0.64}$ (Rajshahi), T_1= N_{64} P_3 K_{39} S_8 $Zn_{1.3}$ (Barisal), T_1= $N_{90}P_{11}$ K_{30} S_4 $Zn_{1.5}$ (Sonagazi).

Table 6. Effect of fertilizer doses on agronomic efficiency (kg/kg) under different unfavorable ecosystems in T. Aman 2011.

Treatments	Agronomic efficiency (kg/kg)			
	Rangpur (AEZ 3)	Rajshahi (AEZ 26)	Barisal (AEZ 13)	Sonagazi (AEZ 18)
T_1=100% NPKSZn (STB)	6.43	3.38	16.88	12.00
T_2= T_1+ 25% N	15.62	2.10	6.50	4.62
T_3=T_1+ 25% NP	4.48	6.30	8.62	6.13
T_4=T_1+ 25% NK	14.38	7.50	10.50	7.47
T_5=T_1+ 25% PK	7.38	8.00	3.91	2.78
T_6=T_1+ 25% NPK	9.43	-	9.38	6.67
T_7=75% of T_1	2.38	9.33	14.79	10.52
T_8=Control	-	-	-	-

Note: T_1= N_{84} P_5 K_{46} S_{14} $Zn_{1.6}$ (Rangpur), T_1= N_{80} $P_{11}K_{14}$ S_{11} $Zn_{0.64}$ (Rajshahi), T_1= N_{64} P_3 K_{39} S_8 $Zn_{1.3}$ (Barisal), T_1= $N_{90}P_{11}$ K_{30} S_4 $Zn_{1.5}$ (Sonagazi)

Since STB doses of fertilizers gave similar rice yield with other treatments and also showed highest agronomic efficiency, it might be suitable for rice production in T. Aman season for this area. Rahman (2001) reported that in rice-rice cropping pattern, the highest grain yield of rice was recorded in the soil test basis (STB) NPKSZn fertilizers treatment. The lowest grain yield (3.84 t ha^{-1}) was observed in the treatment T_8 (control). The highest straw yield (6.19 t ha^{-1}) was obtained with the treatment T_2, which was statistically similar to T_1, T_3, T_4, T_5 and T_6. Addition of more nutrients than STB dose might be created nutrient imbalance in soil. As a result, it might have negative impact on rice yield and agronomic use efficiency. The lowest straw yield (4.06 t ha^{-1}) was observed in the treatment T_8 (control), which was statistically similar to T_7.

Conclusion

Soil test basis (STB) fertilizer doses might not be influenced rice yield equally in different ecosystems. STB doses performed better in Tidal Flood Ecosystem (AEZ 13) and Saline and Charland area (AEZ 18). But additional fertilizer, N or NK fertilizers, might be beneficial for maximizing rice yield in Submergence area.

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