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Nutrient management for Rice-Fallow-Rice cropping pattern grown under costal saline area of Satkhira, Bangladesh

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Abstract

Salinity is an environmental stress that limits growth and development in plants. An experiments was conducted at saline area of Satkhira districts (AEZ-13) of Bangladesh for two years to determine fertilizer requirement for crops (var. BRRI dhan 30 for Boro and Binadhan-8 for T.aman) grown in saline area for Boro-Fallow-T.aman cropping pattern. There were eight treatments i.e T_1: 100% NPK (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: Control for both Boro and T.aman rice. The experiment was laid out in randomized complete block design (RCBD) replicated three times. In first year the highest grain (5.50t ha^{-1}) and straw yields (6.71t ha^{-1}) of Boro rice was recorded in treatment T_3 (STB + 25% NP). In second year the highest yields of grain (4.90t ha^{-1}) and straw (6.37t ha^{-1}) were observed in treatment T_4 (STB + 25% NK). Regarding T. aman rice, the highest grain yield (4.56t ha^{-1}) was obtained in treatment T_6 in both the year. The highest straw yield (5.85t ha^{-1}) was found in treatment T_2 in 2012 where as in 2013, the highest straw yield (5.90t ha^{-1}) found in treatment T_1 and T_6, respectively. Based on the most profitable treatment, the recommended doses of fertilizers are N_{120} P_{25} K_{75} S_8 Zn_1 $B_{0.5}$ for Boro rice and N_{72} P_{20} K_{40} S_4 for T. aman rice at Shamnagar, Satkhira, Bangladesh.

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Introduction

Rice (*Oryza sativa* L.) is the major staple food for more than half of the world population and 90% of it is being produced and consumed in Asia. It is the major crop in most flood-prone areas of South and South-East Asia (tropical and sub-tropical regions between 55⁰ North and 36⁰ South) and it plays a major role supporting more than 3 billion people (A. M. Ismail, 2013; G. S. Khush 2005; Brondani *et al*, 2006). Rice is the staple food of Bangladesh with huge population (140 million) and high demand of food with limited arable land (8.56 million hectare) and rice production is 34.7 million metric tons (BBS, 2016).

Salinity is a significant problem affecting agriculture worldwide and the detrimental effects of high salinity on plants can be observed at the whole-plant level in terms of plant death and/or decrease in productivity (Parida & Das, 2005). Salinity is one of the most limiting factors of agricultural crops productivity, with adverse effects on germination, plant vigour and crop yield (R. Munns & Tester, 2008). High salinity affects plants in several ways: water stress, ion toxicity, nutritional disorders, oxidative stress, alteration of metabolic processes, membrane disorganization, reduction of cell division and expansion, genotoxicity (Hasegawa *et al.*, 2000; R. Munns, 2002; Zhu, 2007).

Bangladesh is a deltaic country with total area of 1,47,570km^2. The coastal area covers about 20% of the country and over thirty percent of the net cultivable area. Out of 2.85 million hectares of the coastal and offshore areas about 1.056 million hectare of arable lands are affected by varying degrees of salinity (SRDI, 2009). Agricultural land use in these areas is very poor, which is roughly 50% of the country's average (Petersen & Shireen, 2001). In the coastal areas of Bangladesh, approximately 90% of the arable land remains fallow for 6-7 months after the aman rice harvest because of the shortage of fresh water, salinity of the soil and late draining condition (SRDI, 2001). Saline tolerant rice variety is now introduced to enhance crop production and attention is given to this area for better crop management for sustainable crop production. The fertility status of coastal area is low as well as low in organic matter content.

Proper fertilization effectively improves quality and yield of crop, reduces cost as well as increase farmer's income. Improper fertilization creates adverse effects on the soil environment. Therefore, the objective of the study was to determine appropriate fertilizer package for rice-rice cropping pattern in the coastal saline area of Satkhira district of Bangladesh.

Materials and methods

Nursery bed management

The seedbed was selected in non-saline area of BINA (Bangladesh Institute of Nuclear Agriculture) substation, Satkhira district for the betterment of the seedlings. The seedbed was prepared with cowdung @ 500kg for 1000m^2 (seedbed) and chemical fertilizers were applied as 10kg N, 5kg P and K. Nitrogen was applied 5kg as basal and 5kg as top dressing at 12 days after sowing. In general 35 days old seedlings for Boro season and 30 days old seedlings for T. aman season were used. The seed bed was flooded before uprooting and was carefully pulled the seedlings preventing root damage so that it becomes less vulnerable to salinity. The experiment was conducted at saline area of farmer's field, Shamnagar, Satkhira district of Bangladesh. There were eight treatments i.e T_1: 100% NPK (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: Control (without fertilizer) for both Boro (var. BRRIdhan 30) and T.aman rice (cv. Binadhan-8). The experiment was laid out in randomized complete block design (RCBD) each replicated three times. Each replication represented a block. There were 24 (8 × 3) unit plots. The layout of the experiment was done in accordance with the statistical deign. Full dose of P, K, S, Zn, B fertilizers and 1/3 of N fertilizer were applied at the time of final land preparation. The rest of N fertilizer was applied in two equal split, ie. 30 days of transplanting (DAT) and 55 DAT for Boro season and in T.aman season 25 & 45 DAT. Weeding was done before top dressing of urea application. Irrigations were applied according to the field condition and Furadan 3G was used as insecticide.

Soil and Plant Analysis

Composite soil samples (0-15cm depth) were collected from the experimental plot before setting (Table 1) and after completion of the experiment.

The soil sample was analysis for pH, organic matter, total N, exchangeable K, available P and S. Plant samples (Grain and straw) were collected from the field experiment and analyzed for NPKS content following standard methods (Jackson 1962, Olsen *et al.* 1954, Page *et al.* 1982).

Statistical Analysis

Data on yield components were recorded at 10 hills plot^{-1} and the yield data was on individual plots. Plant height (cm), panicle length (cm), tiller hill^{-1} (nos), 1000 seed weight (g), grain yield (t ha^{-1}) and straw yield (t ha^{-1}) were measured and recorded. The analysis of variance for various crop characters as well as for nutrient concentration and uptake were done following the principle of F-statistics. Mean comparisons of the treatments were adjudged by the Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and discussion

Boro rice

Although salinity level remains high in March-May in Bangladesh, which is the appropriate time for Boro rice (January to May) cultivation but suitable management practice along with using fertilizer efficiently can produced higher rice. Application of fertilizers using different combinations significantly affects the grain and straw yields of Boro rice in 2012 (Table 1). The highest grain yield (5.50t ha^{-1}) of Boro rice was observed in treatment T_3 which was statistically similar to T_1, T_2, T_5 and T_6. Straw yield also found highest (6.71t ha^{-1}) in T_3 treatment which was statistically identical with T_4 and T_6. Lowest yield was recorded in treatment T_8 at both the cases of grain and straw yields. The effect of fertilizers in the second year (2013) of Boro rice (Table 1) was largely similar to that of the first year crop.

The highest yields of grain (4.90 t ha^{-1}) and straw (6.37t ha^{-1}) were observed in treatment T_4 (STB + 25% NK) which was followed by T_3, T_5 and T_6 for grain and only T_6 for straw. In both cases, lowest yields were observed in control (T_8) treatment. In both greenhouse and field studies, Motamed *et al.* (2008) and Clermont-Dauphin *et al.* (2010) found that the number of filled grains per panicle and grain weight are most sensitive yield components to salinity. First year, treatment T_3 obtained highest yield where 25% additional nitrogen and phosphorus fertilizer were needed and in the following second year treatment T_4 produced highest yield. In treatment T_4 25% additional nitrogen and potassium fertilizer were applied which indicated that demand of additional fertilizer exists in those saline areas comparing to that of soil test based nutrient requirement.

T. aman rice

T.aman rice season is considered as the rainy/wet season in Bangladesh. Major portion of rain fall occurs in the July to September which lowers the adverse effect of salinity in the coastal areas of Bangladesh. Appropriate fertilizer management increase T. aman production in saline areas. In 2012 year, the highest grain yield (4.56t ha^{-1}) was obtained in treatment T_6 and the second highest was obtained in treatment T_5. Regarding straw yield, the highest yield was (5.85t ha^{-1}) recorded in treatment T_2. Lowest yield in both the cases were recorded in treatment T_8. In T. aman 2013, the highest grain yield (4.57t ha^{-1}) was obtained in treatment T_6 and highest straw yield was recorded in treatment T_6 and T_1, respectively. Based on the two year experiments, the best treatment for T.aman rice production in saline area is T_6 treatment (N_{90} P_{25} K_{50} S_5, kg/ha) which produced highest yield.

Table 1. Effects of fertilizers on the yield of crops in Boro-Fallow-T.aman rice cropping pattern at farmer's field, Shamnagar, Satkhira.

Treatments	Boro 2012		T.aman 2012		Boro 2013		T.aman 2013	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1=100%(STB)	4.66abc	5.71b	3.75bc	4.54b	4.30cd	5.74bc	4.33a	5.90a
T_2= T_1 + 25% N	4.74abc	5.57b	3.90abc	5.85a	4.50bcd	5.92bc	4.17a	5.53ab
T_3= T_1 + 25% NP	5.50a	6.71a	3.93abc	5.14ab	4.75ab	5.68bc	4.43a	4.93b
T_4= T_1 + 25% NK	4.63bc	5.97ab	3.67bc	5.78a	4.90a	6.37a	4.53a	5.80a
T_5= T_1 + 25% PK	5.13ab	5.83b	4.33ab	5.24ab	4.60abc	5.65c	4.50a	5.86a
T_6=T_1 + 25% NPK	5.04ab	6.35ab	4.56a	5.72a	4.80ab	6.07ab	4.57a	5.90a

Treatments	Boro 2012		T.aman 2012		Boro 2013		T.aman 2013	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_7= 75% of T_1	4.05c	4.74c	3.44c	4.36b	4.20d	5.71bc	3.47b	4.80b
T_8= Control	2.07d	2.57d	1.87d	2.58c	2.50e	4.18d	2.33c	3.27c
CV(%)	9.90	7.66	9.67	8.29	4.31	3.60	5.85	7.65

STB: Boro (BRRIdhan-30) = N_{120} P_{20} K_{60} S_8 Zn_1 $B_{0.5}$ and T.aman (Binadhan-8)= N_{72} P_{20} K_{40} S_4 (kg/ha).

Nutrient uptake

Nutrient uptake by Boro-Fallow-T.aman cropping pattern was influenced due to different treatments (Table 2). The total nitrogen uptake by grain and straw (Boro and T.aman) varied from 66-186kg ha^{-1}. The highest total (186kg ha^{-1}) N uptake was recorded in treatment T_6. The highest P uptake (27kg ha^{-1}) was also recorded in T_6 treatment. The total K uptake varied from 72-181kg ha^{-1}. Potassium application alleviated the stress condition and significantly improved dry matter yield and yield components in rice (Reyhaneh *et al.* 2012). The highest K uptake (181kg ha^{-1}) was recorded in T_6 and T_4 treatments. Saleque *et al.* (1998) reported that K application increased K concentration in rice straw. Potassium uptake increased significantly with increase of K levels in rice (Mitra *et al.* 2001). The total S uptake varied from 9-21kg ha^{-1}. The highest S uptake (21kg ha^{-1}) was recorded in T_6 treatment. The application of gypsum as a source of sulphur improve yield component (Ahmed *et al.* 2016).

The lowest uptake of N (66kg ha^{-1}), P (12kg ha^{-1}), K (72kg ha^{-1}) and S (9kg ha^{-1}) was found in T_8 treatment. It observed that in maximum cases total N, P, K and S uptake was obtained in treatment T_6.

Table 2. Effects of fertilizers on nutrient uptake (kgha^{-1}) by Boro-Fallow-T.aman cropping pattern.

Nutrients Added	Nutrient Uptake (kgha^{-1})			
	Nitrogen	Phosphorus	Potassium	Sulphur
T_1=100%(STB)	153ab	23a	155ab	18a
T_2= T_1 + 25% N	168ab	25a	175a	19a
T_3= T_1 + 25% NP	180a	26a	180a	20a
T_4= T_1 + 25% NK	179a	23a	181a	20a
T_5= T_1 + 25% PK	160ab	24a	180a	19a
T_6=T_1 + 25% NPK	186a	27a	181a	21a
T_7= 75% of T_1	139b	20b	146b	16b
T_8= Control	66c	12c	72c	9c
Range	6-186	12-27	72-181	9-21

Soil Fertility Status

The coastal regions of Bangladesh are quite low in soil fertility. Thus in addition to salinity, plant nutrients in soil affect plant growth. Soil reaction values (pH) range from 7.3-7.8 (Table 3 & 4) and the pH values of the surface soils being lower than those of the sub-surface soils. In places with higher pH values, micronutrients deficiencies may have exits. The top soil organic matter ranged from 2.38 to 2.64%. The total N content of the soils are generally low and mostly around 0.12-0.16%. The available P and S status of the soils ranged from 12.86-13.62 ppm and 17.65-25.89 ppm, respectively. Application of phosphorus to saline soil helps in reducing the chloride toxicity (Singh *et al.* 1999). The potassium content ranged from 0.27-0.34 meq %. The changes in soil parameters compare with the initial value the pH, organic matter, total N, available P and S and exchangeable K content was very low due to the treatments and two year cultivation.

Table 3: Nutrient status of initial soil of the experimental site and nursery bed.

Soil	pH	OM (%)	Total N (%)	P (ppm)	S (ppm)	K (meq%)	EC (ds/m)
Initial Soil	7.8	2.60	0.14	13.6	20.2	0.29	4.6
Nursery bed soil	7.2	1.90	0.10	12.2	21.11	0.23	1.12

Table 4. Soil nutrient status of initial and post harvest soil of the experiment site after two years of cropping.

Treatments	pH	OM (%)	N (%)	P (mgkg^{-1})	K (cmolkg^{-1})	S (mgkg^{-1})
T_1 = 100% (STB)	7.8	2.43	0.16	13.25	0.34	23.24
$T_2 = T_1$ + 25% N	7.3	2.54	0.16	13.44	0.31	20.30
$T_3 = T_1$ + 25% NP	7.5	2.64	0.14	13.44	0.27	17.65
$T_4 = T_1$ + 25% NK	7.7	2.55	0.14	13.25	0.31	21.18
$T_5 = T_1$ + 25% PK	7.4	2.58	0.16	13.25	0.29	25.89
$T_6 = T_1$ + 25% NPK	7.4	2.55	0.14	12.87	0.32	22.95
T_7 = 75% of T_1	7.4	2.42	0.14	13.62	0.31	19.42
T_8 = Control	7.7	2.38	0.12	13.06	0.27	21.47

Economics of fertilizer use

The results of budget analysis of Boro-Fallow-T.aman cropping pattern at Shamnagar, Satkhira (Table 5) demonstrated that the highest net return of Tk 1,33,208/- was obtained in T_6 treatment followed by Tk 1,31,638/- in T_3 treatment. The highest MBCR (3.13) was obtained in T_5 followed by 2.96 in treatment T_7. From two years of study, based on the most profitable treatment, the recommended dosed of fertilizers are N_{150} P_{25} K_{75} S_{10} Zn_1 $B_{0.5}$-N_{90} P_{25} K_{50} S_5 for Boro-Fallow-T.aman cropping pattern to obtain higher yield at Shamnagar, Satkhira.

Table 5. Effects of fertilizers use economy in Boro-Fallow-T.aman rice cropping pattern.

Treatments	Average Yield (2012 & 2013)				Gross Return	Fert. Cost	Net Return	Marginal Return	MBCR
	Boro		T.aman		Tk ha^{-1}				
	Grain	Straw	Grain	Straw					
T_1=100%(STB)	4.48	5.73	4.04	5.22	1,38,750	17,102	1,21,648	49,488	2.89
$T_2 = T_1$ + 25% N	4.62	5.75	4.04	5.69	1,41,340	19,262	1,22,078	49,918	2.59
$T_3 = T_1$ + 25% NP	5.13	6.2	4.18	5.04	1,50,890	20,612	1,30,278	58,118	2.82
$T_4 = T_1$ + 25% NK	4.72	6.17	4.10	5.79	1,44,260	19,812	1,24,448	52,288	2.64
$T_5 = T_1$ + 25% PK	4.87	5.74	4.42	5.55	1,50,640	19,002	1,31,638	59,488	3.13
$T_6 = T_1$ + 25% NPK	4.92	6.21	4.57	5.81	1,54,370	21,162	1,33,208	61,048	2.88
T_7= 75% of T_1	4.13	5.23	3.46	4.72	1,23,800	13,042	1,10,758	38,598	2.96
T_8= Control	2.29	3.38	2.10	2.93	72,160	-	72,160	-	-

Grain = 15 Tk. kg^{-1}; Straw = 1 Tk. kg^{-1}; N = 45 Tk. kg^{-1}; P = 150 Tk. kg^{-1}; K = 50 Tk. kg^{-1}; S = 55 Tk. kg^{-1} and Zn = 102 Tk. kg^{-1}; MBCR = Marginal benefit cost ratio.

Salinity Status

The salinity of the experimental plots has been recorded during the whole growing season. The aman season is considered as wet season and abundant rainfall occurred and creates suitable condition of low salinity in saline areas for crop growth. To reduce adverse effect of salinity, irrigation was an effective management to reduce salinity as well as rainfall was another major cause to low salinity in the growing wet season. But in boro season (November to May) of Bangladesh is considered as dry season and during that period rainfall is almost zero and capillary raise of salt cause salinity up. The salinity status of the experiment site was range from 1.18 to 2.46 dSm^{-1} in T.aman season and 3.18 to 8.35 dSm^{-1} in boro season during 2012. In 2013, the salinity range was 1.51 to 4.32 dSm^{-1} in T.aman and 3.74 to 10.31 dSm^{-1} in boro season, respectively.

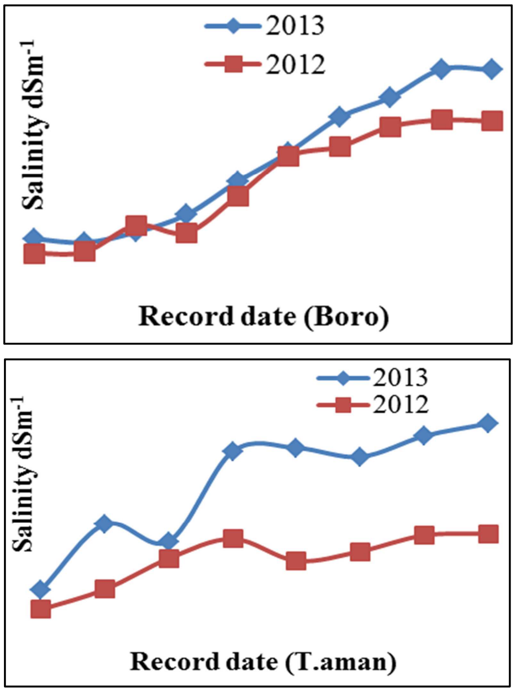

Fig. Salinity record throughout the years (2012 & 2013).

Conclusion

Climate change leads to the spread soil salinity and has impact on agricultural production in the coastal region (Dasgupta *et al.* (2014a). The salient findings of this experiment were raising of healthy and vigorous seedlings by applying balance fertilizer. The highest grain and straw yields of boro rice was obtained in T_3 treatment (T_1 + 25% NP) in 2012 and 2013 the highest yields of grain and straw were observed in T_4 treatment (T_1 + 25% NK). Regarding T.aman rice, treatment T_6 (T_1 + 25% NPK) produced highest grain and straw yields. From the result it might be concluded that (based on economic analysis), treatment T_6 (T_1 + 25% NPK) found to be best for higher rice production in saline area. The changes in soil pH, organic matter, total N, available P, S and echaangeable K contents was very low due to the treatments and two year cultivation. The highest net benefit of Tk ha^{-1} was 1,33,208 which obtained in T_6 treatment. Based on the most profitable (highest net return) treatment, the recommended doses of fertilizer are N_{150} P_{25} K_{75} S_{10} Zn_1 $B_{0.5}$-N_{90} P_{25} K_{50} S_5 (kg ha^{-1}) for Boro-Fallow-T.aman cropping pattern in southern saline area of Shamnagar, Satkhira, Bangladesh.

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