ISSN 0258-7122 (Print), 2408-8293 (Online)
Bangladesh J. Agril. Res. 42(3): 521-529, September 2017

DETERMINATION OF OPTIMUM AND ECONOMIC DOSES OF FERTILIZERS FOR RICE PRODUCTION IN SALINE AND CHARLANDS ECOSYSTEM

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Abstract

On-farm experiment was carried out for four consecutive seasons: *Boro* (dry season) 2011-12, Transplanted Aman (T. Aman, wet season) 2012, Boro 2012-13 and T. Aman 2013 at the farmer's field in Londonipara, Sonagazi, Feni to develop fertilizer recommendation for rice-based cropping systems in saline and charland ecosystem in Bangladesh. The experiments were designed with eight treatments and laid out in randomized complete block design (RCBD) with three replications. The treatment combinations 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. Results indicated that application of different fertilizers significantly affected the grain yield at all of the seasons. In Boro 2011-12, the highest grain yield was found in treatment T_1 (100% STB) while T_3 (T_1 + 25% NP) gave highest grain yield in Boro 2012-13. Statistically identical yield was observed in Boro 2011-12 with all treatments except control (T_8). Highest grain yield was found with T_6 (T_1 + 25% NPK) treatments in both of T. Aman 2012 and 2013 seasons. Annual straw yield was found more in T_6 (T_1 + 25% NPK) treatment. All the treatment combinations gave significantly higher yield over the control in all seasons. However, on the basis of yield performance, economic analysis and nutrient absorption, the treatment $T_6 = T_1$ + 25% NPK ($N_{225}P_{30}K_{17.5}S_{15}Zn_4$ for Boro and $N_{121}P_{15}K_9S_{10}Zn_3$ for T. Aman) performed the best among the treatments.

Keywords: AEZ-18, crop cycle, cropping system, added return, gross return

Introduction

Applying nutrients to the crop is essential in managing soil fertility so the plants grow and develop normally. A number of crop problems can be related to inefficient management of nutrients and nutrient imbalances in the field. Fertilizer should be applied based on a soil test and the desired yield. Salinity causes unfavorable environment and hydrological situation that restrict normal crop production throughout the year. The freshly deposited alluviums from upstream in the coastal areas of Bangladesh become saline as it comes in contact with the sea water and continues to be inundated during high tides and ingress of sea water through creeks. The factors which contribute significantly to the

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development of saline soils are, tidal flooding during wet season (June-October), direct inundation by saline or brackish water and upward or lateral movement of saline ground water during dry season (November-May). 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, lack of sufficient number of saline tolerant rice cultivars as well as lack of appropriate fertilizer management technologies etc. Increased pressure of growing population demand more food. Thus, it has become increasingly important to explore the possibilities of increasing the potential of these (saline) lands for increased production of crops. To meet the food grain requirement for a growing population with limited land resources, an increasing pressure on the land is taking place without adequate compensation of the plant nutrient taken up from the soil. Nutrient mining is one of the major causes for stagnation or decline in yield of major crops of Bangladesh. If this problem of nutrient depletion is not corrected it will cause a serious damage of the soil and to the welfare of mankind. Relatively higher amount of fertilizers need to be used in HYV of different crop cultivation. Fageria *et al.* (1991) stated that supplying of mineral nutrients to crops in adequate amounts is one of the most important factors in achieving higher productivity. Fertilizer has now become a very costly commodity of agriculture in Bangladesh. A huge amount of foreign currency is needed to import different fertilizers in the country. It is, therefore, urgently needed to develop fertilizer management packages in such a way that it suits farmers' resource constraints for ensuring the high use efficiency of fertilizers. Information based on soils, crops and cropping pattern, BARC prepared Fertilizer Recommendation Guide to adopt balanced fertilization for sustaining crop production in the country. This National Fertilizer Recommendation Guide needs to be further updated and verified for different dominant cropping patterns at different AEZs. Therefore, an attempt was made to develop the proper fertilizer management packages for Rice-Fallow-Rice and rice-based cropping systems in saline and charland ecosystem under AEZ 18.

Materials and Method

Experimental sites and seasons: The study was conducted in continuous rice–rice cropping systems for four consecutive seasons, *Boro* (dry season) 2011-12, T. Aman (wet season) 2012, Boro 2012-13 and T. Aman 2013 at the farmer's field in Londonipara, Sonagazi, Feni (22.8183'N latitude, 91.38613'E longitude). Two rice crops were grown annually in two seasons known as T. Aman and Boro. T. Aman was the wet season (June–July to November–December) in which transplanted rice was grown under partially irrigated conditions in the study area. Boro was the dry season (December–January to April–May) in which transplanted rice was grown under fully irrigated conditions. Semi-dwarf, high-yielding rice varieties were grown in the study area; BRRI dhan46 with 150 days duration was grown in T. Aman, and BRRI dhan47 (salt tolerant)/BRRI dhan28 with 152/140 days duration was grown in Boro season. The field belongs to agroecological zone (AEZ) number 18 known as Young Meghna Estuarine Floodplain. The clay loam soil having pH 6.79, organic carbon 0.71%, total N 0.07%, available P 9.5 mg kg^{-1}, exchangeable K 0.27 cmol kg^{-1} and available S 13.1 mg kg^{-1} was used in the experiment (Table 1).

Experimental design and treatments: The experiment was established in farmer's fields in a randomized complete block design with one complete set of treatments and three replications. Treatments consisted of options for managing fertilizers in rice of saline and char lands ecosystem. The treatments were: T_1 = 100 % N P K S Zn (Soil Test Basis; according to the BARC, 2005); $T_2 = T_1$ + 25 % N; $T_3 = T_1$ + 25 % N P; $T_4 = T_1$ + 25 % N K; $T_5 = T_1$ + 25 % PK; $T_6 = T_1$ + 25 % N P K; T_7 = 75 % of T_1 and T_8 = Absolute control (without fertilizer). In Boro season, NPKSZn were applied @ 180-24-14-15-4, 225-24-14-15-4, 225-30-14-15-4, 225-24-17.5-15-4, 180-30-17.5-15-4, 225-30-17.5-15-4, 135-18-10.5-11.25-3 and 0-0-0-0-0 kg ha^{-1} in T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 treatments, respectively. In T. Aman season, NPKSZn were applied @ 97-12-7-10-3, 121.25-12-7-10-3, 121.25-15-7-10-3, 121.25-12-8.75-10-3, 97-15-8.75-10-3, 121.25-15-8.75-10-3, 72.75-9-5.25-7.5-2.25 and 0-0-0-0-0 kg ha^{-1} in T_1, T_2, T_3, T_4, T_5, T_6, T_7 and T_8 treatments, respectively. The total amounts of P as triple superphosphate, K as KCl, S as gypsum, and Zn as zinc sulfate were applied as basal-immediately before transplanting of rice. In the recommended practice for rice, N was applied as urea in three equal splits at basal, 25-30 days after transplanting (DAT) and 5-7 days before PI stage and at basal, 20-25 DAT and 5-7 days before PI stage in Boro and T. Aman season, respectively. Unit plot size was 4 × 5 m^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 with irrigation. Weeds and insects were controlled to avoid yield losses.

Soil and plant sampling and analysis: Initial soil was collected with a core sampler from the 0 to 15 cm layer of puddled soil before the application of fertilizer. Nine samplings were done from farmer's field. Soil samples were air-dried, ground and passed through a 2 mm sieve and prepared for routine analyses of texture, pH, EC, OC, total N, exchangeable K, available P, S and Zn (Olsen *et al.,* 1954, Page *et al.,* 1982, Islam *et al*., 2014; Islam *et al*., 2016 and Saha *et al*., 2016).

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). Dry grain and straw from the 16-hill samples were ground to pass through a 0.5-mm sieve and analyzed for total N, P and K following standard procedure. The N, P and K contents in grain plus straw were taken as the measure of total N, P and K uptake.

Table 1. Initial Soil Properties of the Experimental Sites

Texture	pH (1:2.5)	Org. C (%)	Total N (%)	Available P (mg kg^{-1})	Exchangeable K (cmol kg^{-1})	Available S (mg kg^{-1})	Available Zn (mg kg^{-1})	EC (dS/m)
Clay Loam	6.79	0.71	0.07	9.5	0.27	13.1	Trace	0.65

Table 2. Effect of different fertilizer packages on the yield of rice (t ha^{-1}) in a Boro-Fallow-T. Aman cropping pattern

Treatments	2011-12						2012-13					
	Boro (BRRI dhan47), 2011-12		T. Aman (BRRI dhan46), 2012		Annual yield (t ha^{-1}crop-cycle^{-1})		Boro (BRRI dhan28), 2012-13		T. Aman (BRRI dhan46), 2013		Annual yield (t ha^{-1}crop-cycle^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1= NPKSZn (STB)[1]	5.88	6.51b	3.19	2.60	9.07	9.11	4.67	4.78	4.09	4.35	8.76	9.13
T_2= T_1+ 25% N	5.79	7.27	2.82	2.48	8.61	9.75	5.68	5.24	3.79	4.03	9.47	9.27
T_3= T_1+ 25% NP	5.22	6.21	2.60b	3.07	7.82	9.28	6.62	5.25	3.74	3.91	10.36	9.16
T_4= T_1+ 25% NK	4.99	6.10	2.80	3.13	7.79	9.23	5.53	4.96	4.23	4.70	9.76	9.66
T_5= T_1+ 25% PK	5.82	6.06	2.97	3.00	8.79	9.06	5.36	5.36	4.15	4.37	9.51	9.73
T_6= T_1+ 25% NPK	5.05	7.05	3.82	3.18	8.87	10.23	5.16	4.98	4.67	4.84	9.83	9.82
T_7 = 75% of T_1	5.81	6.04	3.01	2.87	8.82	8.91	5.32	5.30	3.45	3.77	8.77	9.07
T_8 = Control	3.10	4.27	2.05	2.31	5.15	6.58	3.68	4.44	2.58	3.02	6.26	7.46
$LSD_{0.05}$	0.85	0.60	0.69	0.64	-	-	0.62	0.47	0.45	0.55	-	-
Significant level	**	**	**	*	-	-	**	**	**	**	-	-
CV (%)	9.3	5.6	13.5	12.9	-	-	6.7	5.4	6.6	7.7	-	-

[1]Nutrient rates for T_1= N_{180} P_{24} K_{14} S_{15} Zn_4 (Boro) and T_1= N_{97} P_{12} K_7 S_{10} Zn_3 (T. Aman)

** = Significant at 1% level; * = Significant at 5% level.

Total N was determined following Micro Kjeldahl method (Steam distillation method, Bremner 1965). Plant samples were digested using the HNO_3-$HClO_4$ (5:2) di-acid mixture. Phosphorous was determined colorimetrically by spectrophotometer (model-V-630, Jasco) and potassium was determined by flame photometer (model-410, Sherwood) according to the procedure described by Yoshida *et al.* (1976).

Data analysis: Analysis of variance (ANOVA) was performed on yield and N, P and K uptake to determine the effects different treatments using the IRRISTAT software version 4.1 (IRRI, 1998). Least significant difference (LSD) at the 0.05 level of probability was used to evaluate the differences among treatment means. Economic analyses were done using standard procedure.

Results and Discussion

Yield: Applied fertilizer significantly influenced the grain and straw yield of Boro and T. Aman rice (Table 2). In Boro season (2011-12), the highest grain yield (5.88 t ha^{-1}) was observed in the treatment T_1, which was statistically similar to the treatments T_2, T_3, T_4, T_5, T_6 & T_7. There were no positive or negative effects on additional fertilizers. The lowest grain yield (3.10 t ha^{-1}) was found in the treatment T_8 (control). The highest straw yield (7.27 t ha^{-1}) was observed in the treatment T_2, which was statistically similar to the treatments T_6. The lowest straw yield (4.27 t ha^{-1}) was found in the treatment T_8 (control).

In Boro season (2012-13), the highest grain yield (6.62 t ha^{-1}) was obtained with the treatment T_3. The lowest grain yield (3.68 t ha^{-1}) was observed in the treatment T_8 (control). Significantly highest straw yield (5.36 t ha^{-1}) was obtained with the treatment T_5, which was statistically similar to T_2, T_3, T_4, T_6, and T_7. The lowest straw yield (4.44 t ha^{-1}) was observed in the treatment T_8 (control), which was statistically similar to T_1 (Table 2).

In T. Aman season (2012), the highest grain yield (3.82 t ha^{-1}) was obtained with the treatment T_6, which was statistically similar to T_1. Ali *et al*. (2014) observed the same results on rice yield. The lowest grain yield (2.05 t ha^{-1}) was observed in the treatment T_8 (control), which was statistically similar to T_3. The highest straw yield (3.18 t ha^{-1}) was obtained with the same treatment T_6 followed by T_4 (3.13 t ha^{-1}), which were statistically similar to T_1, T_2, T_3, T_5 and T_7. The lowest straw yield (2.31 t ha^{-1}) was observed in the treatment T_8 (control), which was statistically similar to T_1, T_2, T_3, T_5 and T_7.

In T. Aman season (2013), like first year (T. Aman 2012), the highest grain yield (4.67 t ha^{-1}) was obtained with the same treatment T_6, which was statistically similar to T_4. The lowest grain yield (2.58 t ha^{-1}) was observed in the treatment T_8 (control). The highest straw yield (4.84 t ha^{-1}) was obtained with the same treatment T_6, which was statistically similar to T_1, T_4 and T_5. The lowest straw yield (3.02 t ha^{-1}) was observed in the treatment T_8 (control). In first crop-cycle, the highest annual grain yield (9.07 t ha^{-1} crop-cycle^{-1}) was obtained with the treatment T_1 while in 2nd crop-cycle, it was obtained with the treatment T_3 (10.36 t ha^{-1} crop-cycle^{-1}).

Economic analysis: The estimated total variable cost (TVC), gross return, total value of extra production (added return) and marginal benefit cost ratio (MBCR) are presented in Table 3. Economic analysis was done considering the following: fertilizer cost, fertilizer application cost and labor cost for the additional product including by products due to fertilizer application. The application of fertilizer increased the gross and added return in all the treatments (Table 3). The gross return from the control plot per crop-cycle/ha was only about Tk.1,40,643/- and the application of fertilizer increased the gross return, which ranged from Tk 2,07,658/- ha^{-1} crop cycle^{-1} in T_7 to Tk.2,23,100/- ha^{-1} crop cycle^{-1} in T_6. The highest added-return of Tk. 82,458/- ha^{-1} crop-cycle^{-1} was obtained with T_6 followed by T_5 (75,608/- ha^{-1} crop-cycle^{-1}). The MBCR of all treated plots ranged from 2.43 (T_4) to 3.40 (T_7), which were higher than the permit able limit (2.00).

Table 3. Average yield (t ha^{-1}) and fertilizer use economy as affected by nutrient combinations

Treatment	Average yield (2011-12 & 2012-13)				Gross return** (Tk ha^{-1} crop-cycle^{-1})	Total Value of Extra production (Tk ha^{-1} crop-cycle^{-1})	TVC* (Tk ha^{-1} crop-cycle^{-1})	MBCR
	Boro (BRRI dhan47& 28)		T. Aman (BRRI dhan46)					
	Grain	Straw	Grain	Straw				
T_1= NPKSZn (STB)	5.28	5.65	3.64	3.48	210528	69885	25249	2.77
T_2= T_1+ 25% N	5.74	6.26	3.31	3.26	214790	74148	28359	2.61
T_3= T_1+ 25% NP	5.92	5.73	3.17	3.49	214265	73623	29395	2.50
T_4= T_1+ 25% NK	5.26	5.53	3.52	3.92	209563	68920	28307	2.43
T_5= T_1+ 25% PK	5.59	5.71	3.56	3.69	216250	75608	26647	2.84
T_6= T_1+ 25% NPK	5.11	6.02	4.25	4.01	223100	82458	29826	2.76
T_7 = 75% of T_1	5.57	5.67	3.23	3.32	207658	67015	19715	3.40
T_8 = Control	3.39	4.36	2.32	2.67	140643	0	0	-

* Total variable cost (TVC) included fertilizer cost (chemical fertilizer), fertilizer application cost and labor cost for additional product.

Price (Taka/kg): Urea=20.00; TSP=22.00; MP=16.00; Gypsum=12.00; $ZnSo_{4=}$ 180.00.

Labor wage rate = Tk.230/day

**Price (Taka/kg): Paddy=18.50; straw=5.00.

Two additional man-days/ha are required for applying fertilizer and four man-days/ha for per ton additional products including byproducts.

Table: 4. Effect of different fertilizer packages on the nutrient uptake (kg ha^{-1}) by rice in a Boro – Fallow – T. Aman cropping pattern

Treatments	Boro, 2011-12			T. Aman, 2012			Total nutrient uptake (kg ha^{-1} $crop\text{-}cycle^{-1}$)		
	Nutrient uptake (kg ha^{-1})			Nutrient uptake (kg ha^{-1})					
	N	P	K	N	P	K	N	P	K
T_1=NPKSZn (STB)[1]	81.17	15.26	144.80	41.88	4.68	61.38	123	20	206
$T_2 = T_1$+25% N	92.68	15.20	129.90	42.06	4.15	64.07	135	19	194
$T_3 = T_1$+25% NP	74.98	13.82	180.15	36.91	4.31	74.88	112	18	255
$T_4 = T_1$+25% NK	77.53	12.72	154.31	39.68	4.45	79.44	117	17	234
$T_5 = T_1$+25% PK	82.11	13.71	178.85	42.79	4.75	77.03	125	18	256
$T_6 = T_1$+25% NPK	76.05	14.17	180.52	56.26	5.68	84.21	132	20	265
T_7 = 75% of T_1	74.06	13.79	167.20	39.04	4.67	76.31	113	18	244
T_8 = Control	50.15	8.64	66.36	25.62	3.42	56.17	76	12	123
$LSD_{0.05}$	13.05	1.95	36.31	9.74	0.91	16.96	-	-	-
Significant level	**	**	**	**	**	*	-	-	-
CV (%)	9.8	8.3	13.8	13.7	11.5	13.5	-	-	-

[1]Nutrient rates for $T_1 = N_{180} P_{24} K_{14} S_{15} Zn_4$ (Boro) and $T_1 = N_{97} P_{12} K_7 S_{10} Zn_3$ (T. Aman)

** = Significant at 1% level; * = Significant at 5% level

Table: 5. Effect of different fertilizer packages on the nutrient uptake (kg ha^{-1}) by rice in a Boro – Fallow – T. Aman cropping pattern

Treatments	Boro, 2012-13		
	Nutrient uptake (kg ha^{-1})		
	N	P	K
T_1=NPKSZn (STB)[1]	70	15	134
$T_2 = T_1$+25% N	85	19	149
$T_3 = T_1$+25% NP	94	19	140
$T_4 = T_1$+25% NK	73	18	127
$T_5 = T_1$+25%PK	82	17	152
$T_6 = T_1$+25% NPK	68	17	145
T_7 = 75% of T_1	75	16	145
T_8 = Control	57	12	125
$LSD_{0.05}$	8	2	NS
Significant level	**	**	NS
CV (%)	6.1	6.7	8.9

[1]Nutrient rates for $T_1= N_{180} P_{24} K_{14} S_{15} Zn_4$ (Boro) and $T_1= N_{97} P_{12} K_7 S_{10} Zn_3$ (T. Aman)

** = Significant at 1% level;

Effect on nutrient uptake: Applied fertilizer significantly influenced the nutrient uptake by Boro and T. Aman rice of the cropping pattern (Tables 4 and 5). The highest total N, P and K uptake (kg ha^{-1} crop-cycle^{-1}) was observed in the treatment T_2, T_1 and T_6, respectively. The lowest total nutrient uptake (kg ha^{-1} crop-cycle^{-1}) was observed in the treatment T_8 (Table 4).

Conclusion

On the basis of yield performance, economic analysis and nutrient absorption the treatment $T_6 = T_1$+25% NPK ($N_{225} P_{30} K_{17.5} S_{15} Zn_4$ for Boro season and $N_{121} P_{15} K_9 S_{10} Zn_3$ for T. Aman season) performed the best among the treatments in saline and char lands ecosystem. From the result it is observed that present recommended dose of fertilizer is not sufficient to obtain optimum yield. So, 25% more NPK fertilizer is required to obtain better yield in this ecosystem.

Acknowledgement

We are very much thankful to the authority of “NATP” for providing all facilities and support to meet our study requirements. We are grateful to the farmers of saline and char land ecosystem for their patience and excellent cooperation in conducting the on-farm experiments.

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