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SYSTEM YIELDS AND NUTRIENT BUDGET FOR LENTIL-MUNGBEAN-T. AMAN RICE CROPPING SYSTEM IN TERRACE SOILS OF BANGLADESH

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ABSTRACT: *Background and aims Nitrogen (N), phosphorus (P), potassium (K), sulphur (S), zinc (Zn) and boron (B) nutrition of the lentil-mungbean-T. aman rice system are important for increasing system productivity and improving soil fertility. Experiments on lentil-mungbean-T. aman rice cropping system were conducted in terrace soils of Gazipur, Bangladesh to measure the system yields, nutrient concentration, uptake and apparent balances.Methods We considered four fertilizer treatments viz. absolute nutrient control (T_1); farmer's practice (T_2); AEZ basis fertilizer application (T_3) and soil test basis fertilizer application (T_4). The treatments were compared in a randomized completely block design with three replications over two consecutive years. Results The average yields of lentil, mungbean and T. aman rice ranged from 891 to 1341 kg ha^{-1}, 1006 to 1494 kg ha^{-1} and 3478 to 4526 kg ha^{-1}, respectively showing T_4 as the best treatment. Soil test basis fertilizer application (T_4) exhibited the highest nutrients uptake by all tested crops. The apparent balance of N and K was negative; however it was less negative for T_2 and T_3 treatment. The apparent P balance was positive in T_2, T_3 and T_4 but negative in T_1. Positive S balance observed in T_3 &T_4 but negative in T_1 and T_2. Zinc and B balance in the system was positive in case of T_3 and T_4.Conclusion Considering highest yield, gross margin and soil fertility have been recommended that the soil test basis fertilizer application is profitable for lentil-mungbean-T.aman rice cropping system in terrace soils of Bangladesh.Future research The study clearly indicate an opportunity for the re-adjustment of the N, P, K, S and micronutrients (Zn & B) fertilizer doses for the different rice-based cropping systems in different agro-ecological zone of Bangladesh.*

KEYWORDS: System yields, nutrient concentration, nutrient uptake and balance, lentil-mungbean-T. aman rice, terrace soil.

INTRODUCTION

Terrace soils under the agro-ecological zone-Madhupur Tract comprises parts of greater Dhaka and Mymensingh districts and extends through isolated tracts in Comilla and Noakhali towards south in Chittagong (Rashid 2001). Rice is the staple crop in Terrace soils of Bangladesh next important cereal crop is wheat (Ghosh 2011; Sheikh et al. 2009). But some

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farmers are grown mustard, lentil and vegetables in Rabi and vegetables in Kharif season (FRG 2012). Lentil (*Lens culinaris*), mungbean (*Vigna radiata*) and T. aman rice (*Oryza sativa* L.) grown sequentially in an annual rotation constitute a lentil-mungbean-T. aman cropping system (Iqbal et al. 1990).

Nitrogen (N), phosphorus (P), potassium (K), sulphur (S), zinc (Zn) and boron (B) nutrition of the lentil-mungbean-T. aman rice systems are important for increasing crop productivity and improving soil fertility. Soil nutrients (N, P, K, S, Zn and B) play an important role for regulating the supply of nutrients to plant (Konrad et al. 2001). Several studies have shown that intensive rice-based cropping system including rice-wheat (RW), rice-rice cause's remarkable depletion of soil nutrients and threat to crop productivity (Timsina and Connor 2001). Besides the farmers are following imbalanced use of fertilizers for crop production which leads to degrade soil fertility (Ali et al. 2010). Farmers generally use fertilizers on single crop basis, not the cropping system. Cropping intensity and high yielding varieties of crops uptake higher amount of nutrients from soils resulting in depletion of soil organic matter and deterioration of soil fertility, poses a great threat to sustainable crop production (Kumar and Singh 2009). Moreover, continuous cropping without adequate replacement of removed nutrients and nutrient loss through erosion, leaching, and gaseous emission have caused depletion soil fertility as well as soil organic matter (Yu et al. 2014; Tirol-Padre et al. 2007). Furthermore, low levels of plant nutrients (macro and micro) in terrace soil accompanied with improper nutrient management are constraints for food security and malnutrition. Plant nutrition research can be helped to eliminate the constraints and sustaining food security and well-being of people without affecting the environment (Hossain 2007).

The bulk of literature indicates that, apart from residue management, cropping system productivity may become sustainable through integrated use of organic and inorganic sources of nutrients (Singh and Yadav 1992). Hence, monitoring of crop yields, nutrient concentration, nutrient uptake and balance that to assist for understanding of plant and soil nutrients status and to identify appropriate fertilizer management strategies for both individual crop and a cropping system in specific agro-ecological zone. In Bangladesh, quantification of the nutrients removal or addition under different cropping system has been less attended. Nutrient balance is an important tool for assessing the fate of native and added nutrients in soils (Bindraban et al. 2000; Smaling et al. 1993). Negative nutrient balance may limit crop yield and deplete soil fertility and positive nutrient balance shows nutrient accumulation (Paul et al. 2014). It is hypothised that the current fertilizer recommendation could be improved for a definite cropping system. Thus, the aim of this study was to compare system crop yields and nutrient budget (nutrient uptake and balance) for the lentil-mungbean-T. aman rice cropping system with varying fertilizer management practices.

MATERIALS AND METHODS

Site description

The two years experiment on lentil-mungbean-T. aman cropping systems were conducted at the research field of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur (24° 0′ 13″ N latitude and 90° 25′ 0″ E longitude) lies at an elevation of 8.4 m above the sea level.

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The terrace soils of Gazipur is medium high land with fine-textured (clay loam) belongs to Chhiata series (Soil taxonomy: Udic Rhodustalf) under the agro ecological zone - Madhupur Tract (AEZ-28). The climates of this area are sub-tropical, wet and humid. Heavy rainfall occurs in the monsoon and scanty in others (October to March). Average temperature ranged from 13.0-36.1^0 C and average annual rainfall varied from 1500-2200 mm around the year (Alam 2011; Rashid 2001).

Experiment set-up

The experiments were carried out over the three crop seasons such as Rabi (mid October to mid March), Kharif-I (mid March to mid June) and Kharif-II (mid June to mid October).

Experimental design and treatment

The experiment consisted of four treatments for each crop-absolute nutrient controls (T_1); farmer's practice (T_2); AEZ basis fertilizer application (T_3) and soil test basis fertilizer application (T_4). Descriptions of the different treatments are given in Table 1.

Table 1. Rates of fertilizers (kg ha^{-1}) for lentil, mungbean and T.aman rice

Treatments	Lentil	Mungbean	T. aman rice
Control (T_1)	Control	Control	Control
F. practice (T_2)	$N_{20}P_{30}K_{25}$	$N_6P_5K_4$	$N_{60}P_6K_{20}$
AEZ (T_3)	$N_{12}P_{22}K_{25}S_{10}Zn_1B_1$	$N_7P_7K_5$	$N_{65}P_7K_{28}S_8Zn_1$
STB (T_4)	$N_{18}P_{25}K_{35}S_{15}Zn_2B_{1.5}$	$N_{15}P_{20}K_{10}S_6Zn_1B_1$	$N_{70}P_{12}K_{40}S_{10}Zn_1B_1$

The experiment was laid out in a randomized complete block design with three replications. The unit plot size was 4 m × 3 m for all crops having the spacing of 30 cm × 05 cm for lentil, 30 cm × 10 cm for mungbean and 20 cm × 15 cm for T.aman rice. The layout was kept undisturbed for the cropping sequence over two years.

Fertilizers application and seed sowing

Full amount of fertilizers, except urea in rice was applied to respective plot during final land preparation. Urea was applied in three equal splits for T.aman rice. The sources of N, P, K, S, Zn and B were urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid, respectively. The first crop lentil (var. BARI Masur-6) were sown on mid November, 2nd crop mungbean (BARI Mung-6) were sown on end of March and the 3rd crop T. aman rice (var. BRRI dhan33) seedlings (30 days old) were transplanted on mid July.

Intercultural operation, data collection and statistical analysis

Intercultural operations like irrigation, weeding and plant protection measures (insecticides and fungicides) were done as and when required. The transplanted rice seedlings were nursed properly in the seedbed. The crops were harvested after maturity. Data on yield contributing characters of all test crops were recorded from 10 randomly selected plants/hills from each plot. Data on yields (kg ha^{-1}) were recorded from whole plot technique. Analysis of variance (ANOVA) for

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the yield and yield contributing characters and different nutrient content was done following the principle of F-statistics and the mean values were separated by Duncan's Multiple Range Test (DMRT) (Gomez and Gomez 1984) using MSTAT-C software.

Soil and plant samples analysis

Soil samples at 0-15 cm were collected before establishing the experiment and after completion of two cycles of the cropping system from each treatment plot. Plant samples (straw and grain) against each treatment plot were oven-dried at 70° C for 48 h and finely ground.

The initial and final soil samples were analyzed for soil pH and organic matter by Nelson and Sommers (1982) method; total N by Microkjeldahl method (Bremner and Mulvaney 1982); exchangeable K by 1N NH_4OAc method (Jackson 1973); available P by Olsen and Sommers (1982) method; available S by turbidity method using $BaCl_2$ (Fox et al. 1964); available Zn by DTPA method (Lindsay and Norvell 1978); available B by azomethine-H method (Page et al. 1982).

Ground plant samples were digested with di-acid mixture (HNO_3-$HClO_4$) (5: 1) as described by Piper (1966) for the determination- concentration of N (Micro-Kjeldahl method), P (spectrophotometer method), K (atomic absorption spectrophotometer method), S (turbidity method using $BaCl_2$ by spectrophotometer), Zn (atomic absorption spectrophotometer method) and B (spectrophotometer following azomethine-H method).

Soil solution, rain and irrigation water samples analysis

Soil solutions were collected at intervals of 15 days starting from the date after transplantation to harvest of rice crop with the help of 50 ml plastic syringe and analyzed for determined nutrient leaching loss. The samples were brought to the laboratory immediately after collection, filtered through Whatman No. 42 filter paper and preserved for the determination of P, K, S, Zn and B. Rain water was collected by rain sampler after each rain event. Irrigation water was measured by V-Notch method (Khurmi 1987). Collected rain and irrigation water were preserved for determining the nutrients (P, K, S, Zn and B). Soil solution, rain and irrigation water samples were analyzed for concentration of P, K, S, Zn and B followed same as plant samples analysis method.

Hydraulic conductivity

We determined the saturated hydraulic conductivity in the laboratory by constant head method (Klute 1965). Soil samples were collected from 0-15 cm depth using core samplers in triplicate. The hydraulic conductivity was calculated by using Darcy's equation as $K_w = -\frac{QL}{AT\Delta H}$ cm hr^{-1} Where, K_w= Saturated hydraulic conductivity (cm hr^{-1}), A= Cross sectional area of the sample in cm^2, T= Time in minute, Q= Quantity of water (ml) passing through the sample in time 'T', L= Length of the sample in cm, ΔH= Hydraulic head difference (Length of sample+ height of water above the sample) in cm.

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Nutrient leaching loss estimation

Nutrient loss was calculated from the results of percolation water and nutrient concentration in soil solution. In calculating percolation water (L m^{-2}) the formula $Q =-K_w AT.\Delta\Psi_h/\Delta z$ given by Hanks and Ashcroft (1980) was used. Where, Q = Quantity of water, K_w= Hydraulic conductivity, A = Area, T = Time, H = Difference in hydraulic potential and Z = Difference between two points taking 0 to downward as negative.The hydraulic potential was again calculated by adding the component potentials as $\Psi_h= \Psi_m+ \Psi_p+ \Psi_z$ where h, m, p, and z represent hydraulic, metric, pressure and gravitational potentials. Negative Q was considered as downward movement of water.

Nutrient uptake and apparent balance calculation

Crop nutrient uptake was calculated from the nutrient (N, P, K, S, Zn and B) concentration and the straw and grain yields (Quayyum et al. 2002). Apparent nutrient balance for the lentil-mungbean-T. aman rice cropping system (average of two years) was computed as the difference between nutrient input and output (Paul et al. 2014). The inputs were supplied from (i) fertilizer (ii) rainfall (iii) irrigation water (iv) BNF (biological nitrogen fixation) and the outputs were estimated from crop uptake and leaching loss in a cycle.

Economic analysis

Added cost and added benefit were calculated. Besides, the gross return was calculated on the basis of different treatments which were directly related to the price of product. Cost of cultivation was involved with wage rate (land preparation, weeding, seed sowing and fertilizers application), pesticides, irrigation and fertilizers cost. Land used cost or rental value of land was not considered here. Marginal benefit cost ratio (MBCR) is the ratio of marginal or added benefit and cost. To compare different treatments combination with one control treatment the following equation was applied (Rahman et al. 2011).

$$MBCR\ (over\ control) = \frac{Gross\ return\ (Ti) - Gross\ return\ (To)}{VC\ (Ti) - VC\ (To)}$$

$$= \frac{Added\ benefit\ (over\ control)}{Added\ cost\ (over\ control)}$$

Where, $T_i = T_2$, ... T_4 treatments; T_0 = Control treatment; VC= Variable cost; and

Gross return = Yield × price

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RESULTS

Yields

The grain and stover yields of lentil and mungbean exhibited significant variation due to different fertilizer management practices in the consecutive two years (Table 2). The grain yields (mean of two years) ranged from 891 to 1341 kg ha^{-1} in lentil and 1006 to 1494 kg ha^{-1} in mungbean. The highest grain yields of lentil (1341 kg ha^{-1}) and mungbean (1494 kg ha^{-1}) was recorded from soil test basis fertilizer application (T_4) followed by AEZ basis fertilizer application (T_3) treatment. The control (T_1) treatment gave the lowest grain yield of 891 and 1006 kg ha^{-1} in lentil and mungbean, respectively. In case of stover yields both of lentil and mungbean, the effects of treatments were statistically differed with some exception and significantly highest value found in T_4 treatment. The lowest stover yields of lentil and mungbean were found in control T_1 treatment in both the years.

The grain and straw yields of T. aman rice (3rd crop) affected significantly to different fertilizer management practices in both the years (Table 2). The grain yield recorded from the AEZ basis fertilizer application (T_3) and soil test basis fertilizer application (T_4) was statistically identical in both the years and significantly higher than that of farmer's practice (T_2) and control treatment although T_4 treatment gave dominated yield over T_3 treatment. In case of straw yield, the treatments AEZ basis fertilizer application (T_3) and soil test basis fertilizer application (T_4) differed significantly in 1st year but in 2nd year they were statistically alike while soil test basis fertilizer application gave dominated straw yield over T_3. The lowest grain and straw yields were found in the control treatment. The grain yield (2 years' average) of T. aman rice varied from 3478 to 4526 kg ha^{-1}.

Soil test based fertilizer treatment gave the highest yields among the treatments and the increased grain yield to 51% in lentil, 49% in mungbean and 30% in T. aman rice over control (T_1) treatment. On the other hand this increased was 10 and 33% in lentil, 13 and 29% in mungbean and 14 and 20% in T. aman rice, respectively in T_2 and T_3 (Table 2).

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Table 2. Effect of fertilizer management practices on grain and stover yields of lentil-mungbean-T. aman rice cropping system

Treatment	Grain yield (kg ha^{-1})				Stover yield (kg ha^{-1})		
	1st year	2nd year	mean	% of increase over control	1st year	2nd year	mean
	Lentil						
Control (T_1)	900d	882d	891	-	1963c	1935d	1949
F. practice (T_2)	965c	992c	978	10	2196b	2261c	2229
AEZ (T_3)	1161b	1211b	1186	33	2750b	2834b	2792
STB (T_4)	1324a	1359a	1341	51	3056a	3092a	3074
CV (%)	3.34	3.41	-	-	4.03	3.27	-
$LSD_{0.05}$	160.1	167.2	-	-	108.3	183.6	-
	Mungbean						
Control (T_1)	1022c	990c	1006	-	2202c	2124c	2163
F. practice (T_2)	1128c	1140b	1134	13	2299c	2325b	2312
AEZ (T_3)	1270b	1320ab	1295	29	2412b	2489ab	2451
STB (T_4)	1450a	1538a	1494	49	2568a	2654a	2611
CV (%)	4.69	7.61	-	-	4.86	7.93	-
$LSD_{0.05}$	339.6	230.7	-	-	387.1	588.7	-
	T. aman rice						
Control (T_1)	3497d	3460c	3478	-	3672d	3659c	3666
F. practice (T_2)	3905c	4045b	3975	14	4100bc	4155b	4128
AEZ (T_3)	4099ab	4222a	4160	20	4268b	4337a	4303
STB (T_4)	4473a	4578a	4526	30	4652a	4772a	4712
CV (%)	5.67	4.49	-	-	4.65	5.56	-
$LSD_{0.05}$	289.3	242	-	-	189.9	255	-

Values within the same column with a common letter do not differ significantly ($P<0.05$)

Nutrient concentration and deficiency detection

Grain nutrient concentration (mean of two years) of test crops- lentil, mungbean and T. aman rice and critical values are presented in Tables 3. The nutrients concentration of lentil due to different fertilizer management practices ranged from 3.81 to 3.93% N, 0.20 to 0.23% P, 0.70 to 0.76% K, 0.10 to 0.13% S, 49.9 to 52.5 ppm Zn and 22.5 to 24.5 ppm B. In case of mungbean, nutrient concentration varied in different treatment from 3.19 to 3.26% N, 0.19 to 0.23% P, 1.42 to 1.46% K, 0.09 to 0.11% S, 28.5 to 31.5 ppm Zn and 12.8 to 15.8 ppm B. Further in T. aman rice, concentration also ranged due to fertilizer treatments from 1.43 to 1.48% N, 0.23 to 0.27% P, 0.21 to 0.25% K, 0.07 to 0.10% S, 51.0 to 52.7 ppm Zn and 18.3 to 19.6 ppm B. Comparisons between test crops nutrients values through fertilizer management practices and critical limits showed in Table 3. Different nutrient management practices exhibited the deficiency of N in lentil, mungbean and T. aman rice. The highest N deficiency (critical limit minus grain concentration) showed 0.19% in lentil, 0.44% in mungbean, and severe N deficiency 1.57% in T. aman rice, respectively for T_1 treatment. The

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minor N deficiency found in lentil and mungbean for T_3 and T_4 treatment, respectively. Phosphorus detected minor deficiency in lentil and mungbean, but rice crop showed slightly sufficiency due to different treatment. Severe deficiency of K in lentil and T. aman rice, but in mungbean showed minor K deficiency in all the treatment. The highest K deficiency was calculated from T_1 and lowest was T_4 treatment in all test crops (Table 3). Different treatment showed deficiency of S in lentil, mungbean and T. aman rice. There was affected of Zn in lentil and T. aman rice but moderately affected of Zn in mungbean due to different treatments. Mungbean showed deficiency of B in all the treatments while the highest B deficiency found in T_1 and lowest in T_4 treatment. The 1^{st} and 3^{rd} crop (lentil and T. aman rice) both were showed B sufficiency in all the treatments (Table 3).

Table 3. Comparison between the grain nutrients concentration of lentil, mungbean and T. aman with critical values due to different fertilizer management practices

Treatment	N	P	K	S	Zn	B
Lentil	**(%)**				**ppm**	
Control (T_1)	3.81	0.20	0.70	0.10	49.9	22.5
F. practice (T_2)	3.89	0.22	0.74	0.11	50.2	22.5
AEZ (T_3)	3.93	0.22	0.74	0.12	51.5	23.6
STB (T_4)	3.93	0.23	0.76	0.13	52.5	24.5
Critical limit	4.00	0.30	1.80	0.20	60.0	20.0
Mungbean						
Control (T_1)	3.19	0.19	1.42	0.09	28.5	12.8
F. practice (T_2)	3.22	0.21	1.43	0.09	28.7	13.1
AEZ (T_3)	3.25	0.22	1.44	0.10	30.5	15.7
STB (T_4)	3.26	0.23	1.46	0.11	31.5	15.8
Critical limit	3.63	0.26	1.75	0.20	35.0	27.0
T. aman rice						
Control (T_1)	1.43	0.23	0.21	0.07	51.0	18.3
F. practice (T_2)	1.45	0.24	0.23	0.08	51.3	18.5
AEZ (T_3)	1.46	0.25	0.24	0.09	52.0	19.3
STB (T_4)	1.48	0.27	0.25	0.10	52.7	19.6
Critical limit	3.00	0.23	1.20	0.15	60.0	15.0

Nutrient critical values source: Kalra (1998); Bell and Kovar (2000); Plant analysis handbook (2017), Grain legume handbook (2017).

Nutrient uptake

Different fertilizer management practices have made significant effect to uptake of N, P, K, S, Zn and B by lentil, mungbean and T.aman rice in both the years (Table 4). The soil test basis fertilizer application (T_4) showed significantly higher nutrients uptake by all the test crops over the other treatments. The second highest uptake was observed in T_3 which was followed by T_2. The nutrient uptake followed the order: N>K>P>S>Zn>B. The lowest nutrient uptake was observed in control (T_1) treatment by all the test crops in both the years.

The total uptake of nutrients by the crops (lentil+mungbean+T.*aman*) ranged from 181 to 261 kg N ha^{-1}, 18.5 to 30.7 kg P ha^{-1}, 110 to 156 kg K ha^{-1}, 8.69 to 16.6 kg S ha^{-1}, 0.57 to 0.83 kg

Zn ha^{-1} and 0.25 to 0.40 kg B ha^{-1}. Maximum total uptakes of all nutrients were found in STB (T_4) followed by AEZ (T_3). Minimum uptake was estimated in control (T_1) (Figures 1 & 2).

Table 4. Effect of fertilizer management practices on nutrient uptake by the crops of lentil-mungbean-T. aman rice (grain+stover) cropping system

Treatment	N		P		K		S		Zn		B	
	Kg ha^{-1}											
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
	Lentil											
Control (T_1)	54.0d	52.4d	4.41d	4.05d	22.2d	21.6d	2.17b	1.57c	0.13c	0.12d	0.07c	0.07c
F.practice (T_2)	60.5c	61.6c	5.22c	5.04c	25.1c	25.4c	2.70b	2.35bc	0.15c	0.14c	0.09c	0.08c
AEZ (T_3)	75.2b	77.1b	6.81b	6.53b	31.7b	32.5b	3.59ab	3.32b	0.19b	0.18b	0.11b	0.10b
STB (T_4)	85.4a	86.1a	8.14a	7.61a	36.0a	36.4a	4.47a	4.10a	0.21a	0.20a	0.13a	0.12a
CV (%)	3.87	3.55	4.43	4.66	2.84	3.32	11.5	9.37	5.02	4.80	5.36	5.67
$LSD_{0.05}$	4.53	4.10	1.11	1.00	1.63	1.91	0.94	0.64	0.02	0.019	0.02	0.019
	Mungbean											
Control (T_1)	64.9d	59.0d	4.78c	3.80d	48.1d	44.1d	2.39c	1.60c	0.09c	0.08d	0.06d	0.05c
F.practice (T_2)	71.2c	73.9c	5.50b	5.12c	51.7c	52.9c	2.57c	2.19b	0.10bc	0.10c	0.07c	0.06b
AEZ (T_3)	78.6b	80.2b	6.12ab	5.87b	56.1b	56.3b	3.43b	2.73ab	0.11b	0.12b	0.08b	0.08ab
STB (T_4)	84.5a	87.6a	6.91a	6.76a	59.9a	61.4a	4.04a	3.36a	0.12a	0.15a	0.10a	0.09a
CV (%)	4.62	4.29	7.42	4.85	3.54	3.25	9.35	9.78	8.21	5.50	3.89	7.68
$LSD_{0.05}$	5.23	5.13	1.00	1.08	4.35	4.12	0.64	0.67	0.019	0.02	0.02	0.019
	T. aman rice											
Control (T_1)	67.3d	64.2d	10.6d	9.4c	43.3d	41.2d	5.37d	4.27c	0.37d	0.36d	0.13d	0.13d
F.practice (T_2)	76.4c	77.0c	12.6c	11.8b	50.0c	49.6c	6.84c	6.26bc	0.41c	0.42c	0.15c	0.14c
AEZ (T_3)	80.2b	81.1b	13.7b	13.2ab	53.4b	53.5b	7.12b	6.49b	0.43b	0.45b	0.16b	0.17b
STB (T_4)	89.4a	89.0a	16.3a	15.7a	59.1a	59.7a	8.74a	8.48a	0.48a	0.51a	0.19a	0.18a
CV (%)	4.32	3.68	4.56	7.01	4.47	5.21	5.31	6.88	3.87	4.33	4.5	5.12
$LSD_{0.05}$	5.69	4.74	1.22	2.30	5.01	5.36	1.03	1.00	0.02	0.019	0.019	0.02

Values within the same column with a common letter do not differ significantly ($P<0.05$)

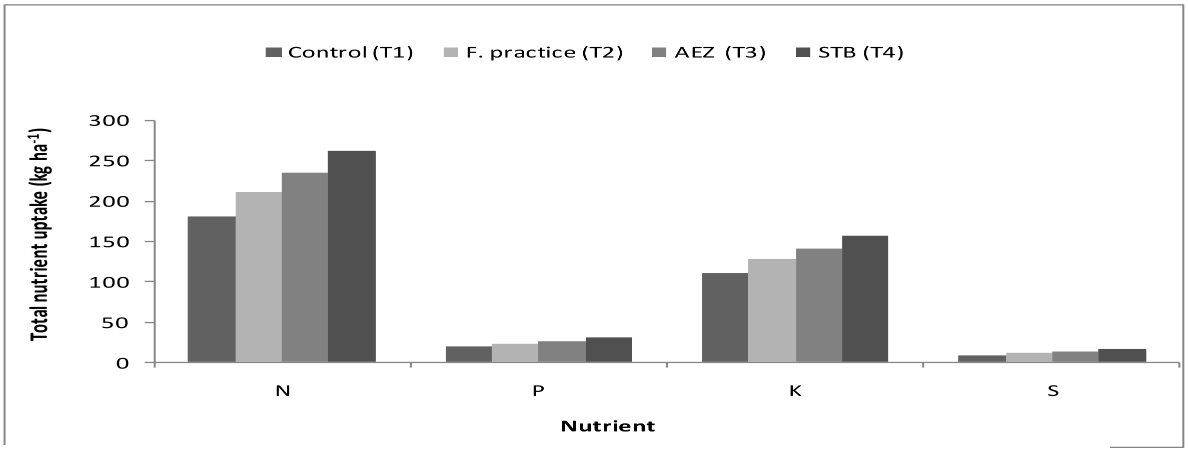

Figure 1. Effect of fertilizer management practices on nutrients uptake by crops under lentil mungbean-T. aman rice cropping system

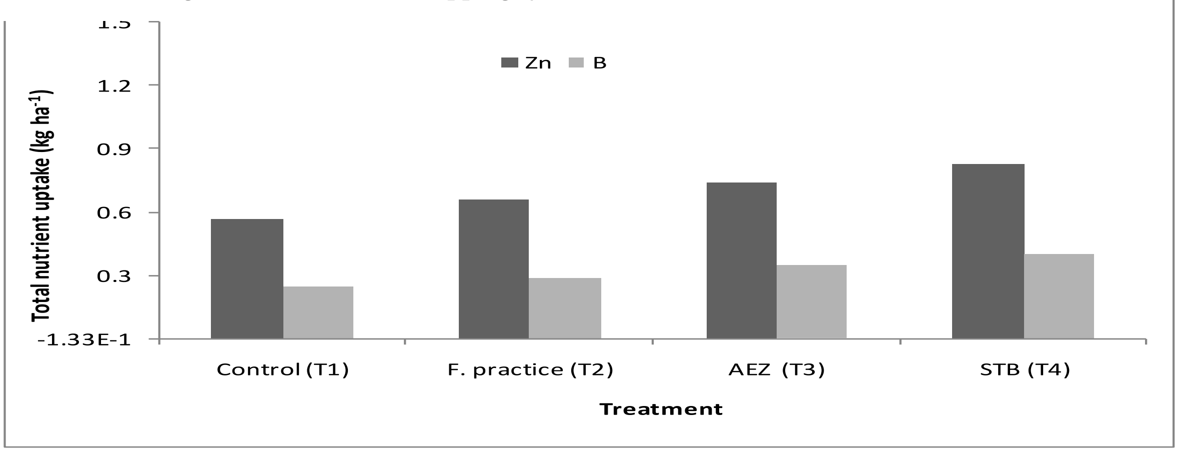

Figure 2. Effect of fertilizer management practices on zinc and boron uptake by crops under lentil-mungbean-T. aman rice cropping system

Leaching of nutrients

Leaching loss was estimated only for T.aman rice not for lentil and mungbean due to both crops are cultivated in dry land condition. Nutrient loss was calculated from the results of percolation water and nutrient concentration in soil solution. Nitrogen loss was ignored due to very low concentration in soil solution. Different nutrient management practices significantly favoured the loss of P, K, S, Zn and B element through leaching. The loss of nutrients (mean of two years) through leaching ranged from 0.180 to 0.425 kg P ha^{-1}, 2.41 to 8.46 kg K ha^{-1}, 1.13 to 2.50 kg S ha^{-1}, 0.030 to 0.080 kg Zn ha^{-1} and 0.050 to 0.280 kg B ha^{-1}. The highest leaching loss of nutrients were estimated from T_4 treatment which was significantly different with others treatment but statistically identical to T_3 andT_2 treatment only S nutrient loss. The lowest nutrients loss values found in T_1 treatments (Table 5).

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Table 5. Effect of fertilizer management practices on nutrient loss through leaching under lentil-mungbean-T. aman rice cropping system (mean of two years)

Treatment	P	K	S	Zn	B
	kg ha^{-1}				
Control (T_1)	0.180d	2.41d	1.13b	0.030c	0.050c
F. practice (T_2)	0.375c	6.22c	1.89a	0.030c	0.055c
AEZ (T_3)	0.400b	7.98b	2.35a	0.070b	0.205b
STB (T_4)	0.425a	8.46a	2.50a	0.080a	0.280a
CV (%)	3.47	3.25	15.7	5.16	8.16
$LSD_{0.05}$	0.024	0.406	0.619	5.41	0.024

Values within the same column with a common letter do not differ significantly (P<0.05)

Nutrients added through rain water

Data on mean concentration and addition of nutrients to soil through rain water are presented in Table 6. The mean concentrations of P, K, S, Zn and B in rain water during Rabi season were estimated of 0.04, 1.25, 0.94, 0.011 and 0.07 mg L^{-1}, respectively. The concentration of P, K, S, Zn and B in rain water during Kharif-I were found 0.05, 1.26, 0.95, 0.012 and 0.08 mg L^{-1}, respectively. Again, the concentrations of P, K, S, Zn and B in rain water during Kharif-II (T.aman rice) season were estimated 0.03, 0.72, 0.42, 0.005 and 0.04 mg L^{-1}, respectively (Table 6). On the other hand, addition of P, K, S, Zn and B to the soil of 0.0034, 0.10, 0.08, 0.001 and 0.006 kg ha^{-1}, respectively during Rabi season. We calculated the addition amount of P, K, S, Zn and B to the soil of 0.03, 0.92, 0.69, 0.008 and 0.05 kg ha^{-1}, respectively during Kharif-I. In case of Kharif-II (T.aman rice) season the addition amount of P, K, S, Zn and B to the soil of 0.20, 5.55, 3.22, 0.04 and 0.26 kg ha^{-1}, respectively (Table 6).

It appeared from the results that the concentrations of all nutrients remain almost same during Rabi and Kharif-I and lower in Kharif-II (T.aman rice) season. The Rabi season was almost rain less or sometimes small rainfall (0-15 mm) occurred during this period. The rainfall increase in Kharif-I season and tremendously increase in T.aman rice season over Rabi season (data not present). During the Rabi season the sky remain clear and the air also remain free of dust due to the after effect of post monsoon period. During the Kharif-I period the wind speed increases after winter which makes the air dirty through the windblown dust particles. The emitted dust particles increase the chemical composition (high nutrient concentration) of precipitation (Gllles et al. 1989; Andreae et al. 1990). Though the nutrient concentration was lower in Kharif-II but the precipitation increased tremendously hence the Table 6 appeared increase addition amount of nutrients to soil.

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Table 6. Nutrients concentration in rain water and addition to soil during Rabi, Kharif-I and Kharif-II (T.aman rice) seasons under lentil-mungbean-T. aman rice cropping system (mean of two years)

Growing seasons	P	K	S	Zn	B
Concentration	**mgL^{-1}**				
Rabi	0.04	1.25	0.94	0.011	0.07
Kharif-I	0.05	1.26	0.95	0.012	0.08
Kharif-II (T.aman rice)	0.03	0.72	0.42	0.005	0.04
Addition	**kg ha^{-1}**				
Rabi	0.0034	0.10	0.08	0.001	0.006
Kharif-I	0.03	0.92	0.69	0.008	0.05
Kharif-II (T.aman rice)	0.20	5.55	3.22	0.04	0.26

Nutrients added through irrigation water

Nutrient concentration and addition of nutrients to soil through irrigation water data are presented in Table 7. The concentrations of P, K, S, Zn and B in irrigation water were estimated of 0.185, 1.86, 1.13, 0.068 and 0.08 mg L^{-1}, respectively. Nitrogen concentration ignored due to low concentration in irrigation water. We calculated the addition amount of P, K, S, Zn and B to the experimental plot of 0.245, 2.47, 1.50, 0.09 and 0.10 kg ha^{-1}, respectively (Table 7).

Table 7. Nutrients concentration in irrigation water and addition to soil during Kharif-II (T.aman rice) seasons under lentil-mungbean-T. aman rice cropping system (mean of two years)

Growing seasons		P	K	S	Zn	B
Kharif-II (T.aman rice)	Concentration	**mgL^{-1}**				
		0.185	1.86	1.13	0.068	0.08
	Addition	**kg ha^{-1}**				
		0.245	2.47	1.50	0.09	0.10

Total input and output of nutrients

The nutrient input mainly from fertilizer but in this estimate, the nutrients supply from fertilizer, rainfall, irrigation and N by symbiotic fixation were considered. We assumed 30 kg N ha^{-1} yr^{-1} added by symbiotic fixation. Annual input of N hence varied from 30 to 133 kg ha^{-1} yr^{-1}, P input ranged from 0.48 to 57.5 kg ha^{-1} yr^{-1}, and K input was on average 9.06 to 94.1 kg ha^{-1} yr^{-1}.The S input was average 5.49 to 38.4 kg ha^{-1} yr^{-1} and input of Zn varied from 0.14 to 4.14 kg ha^{-1} yr^{-1}. Boron input was estimated 0.33 to 3.84 kg ha^{-1} yr^{-1} (Table 8).

The output of nutrients (mean of two years) ranged from 181 to 261 kg N ha^{-1}, 18.7 to 31.1 kg P ha^{-1}, 112 to 164 kg K ha^{-1}, 9.73 to 19.1 kg S ha^{-1}, 0.60 to 0.91 kg Zn ha^{-1} and 0.30 to 0.68 kg B $ha^{-1.}$ The highest outputs of all nutrients were found in T_4 treatment and the lowest were in control (T_1) treatment (Table 8).

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Table 8. Total nutrients (N, P, K, S, Zn and B) input (fertilizer, ranfall, irrigation & BNF) and output (crops uptake & leaching loss) by lentil-mungbean-T.aman cropping system due to different fertilizer management practices

Treatment	N	P	K	S	Zn	B
Nutrients input	**kg ha^{-1}yr^{-1}**					
Control (T_1)	30.0	0.48	9.06	5.49	0.14	0.33
F. practice (T_2)	116	41.5	58.1	6.01	0.14	0.34
AEZ (T_3)	114	36.5	67.1	25.9	2.14	1.34
STB (T_4)	133	57.5	94.1	38.4	4.14	3.84
Nutrient output	**kg ha^{-1}yr^{-1}**					
Control (T_1)	181	18.7	112	9.73	0.60	0.30
F. practice (T_2)	210	22.9	133	13.4	0.69	0.35
AEZ (T_3)	236	26.5	149	15.7	0.81	0.56
STB (T_4)	261	31.1	164	19.1	0.91	0.68

Apparent nutrients balance

An apparent nutrient balance was calculated considering the amount of added nutrient through fertilizer, rain, irrigation water and N supply by symbiotic fixation minus the amount of nutrient removed by crops and leaching loss. However, the nutrient balance did not account for the addition of N from rainfall, irrigation water, or gaseous losses. Apparent balance of N, P, K, S, Zn and B are shown in Figures 3 & 4. The balance was mainly affected by different fertilizer management practices. The apparent balance of N was negative in all the treatment and the soil depletion ranged from −94.0 to −151 kg N ha^{-1} yr^{-1}. In case of P balance which was negative in control treatment (T_1) and the P balance was positive in all the other treatment where P containing fertilizer was utilized. The balance of K was negative in all the treatments where the K mining ranged from −69.9 to −103 kg K ha^{-1} yr^{-1}. The highest K mining was recorded from control treatment followed by AEZ basis fertilizer treatment (T_3) and the lowest K mining was found in STB basis fertilizer treatment (T_4). The negative S and Zn balance was observed in T_1 and farmers practice (T_2) ranged from –4.33 to –7.39 and –0.47 to –0.54 kg ha^{-1} yr^{-1}, respectively. Remaining treatments showed positive balance ranged from 10.1 to 15.1 and 1.33 to 3.23 kg ha^{-1} yr^{-1}, respectively. The maximum positive balance of S and Zn was observed in STB (T_4) treatment. Only control plot along with farmers practice treatments showed negative balance. Apparent balance for B was found negative only in T_2 and others treatment including control (T_1) were showed positive B balance. The highest positive balance B (3.16 kg ha^{-1} yr^{-1}) got from STB treatment (T_4) (Figures 3 & 4).

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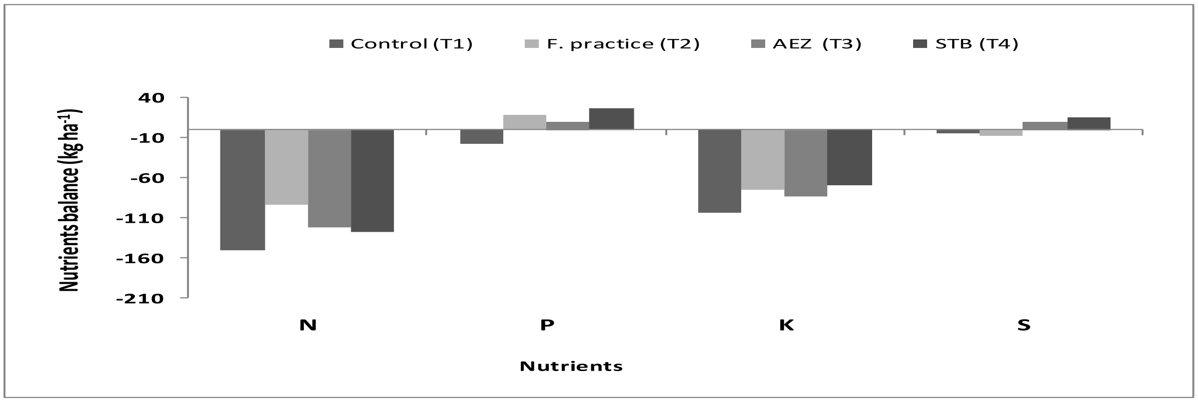

Figure 3. Effect of fertilizer management practices on apparent nutrient balance of N, P, K and S in soil under lentil-mungbean-T. aman rice cropping system

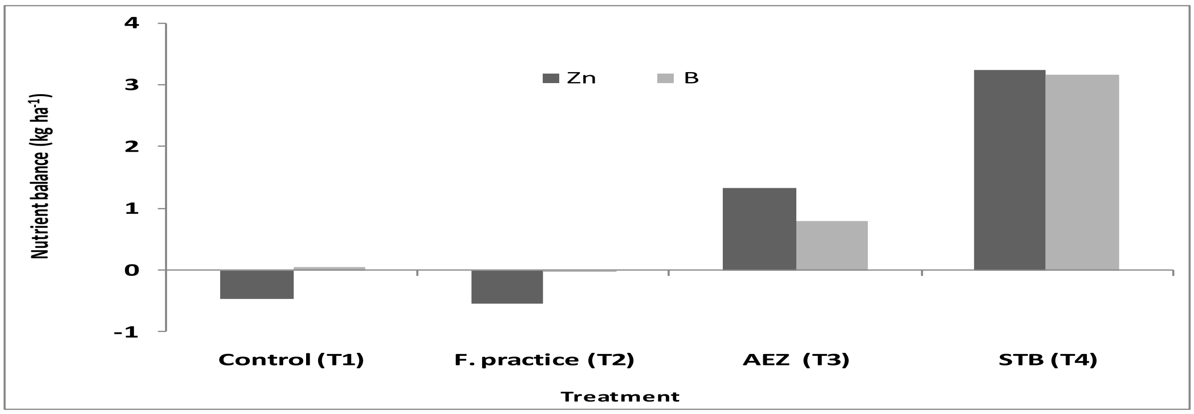

Figure 4. Effect of fertilizer management practices on apparent balance of zinc and boron in soil under lentil-mungbean-T. aman rice cropping system

Soil fertility

Initial soil samples were collected from the experimental field and post harvest soil samples were also collected from each treated plot after two cycles of lentil-mungbean-T. aman rice cropping system for analyzing different soil properties viz. soil pH, organic matter, total N and available P, K, S, Zn and B. The initial and post harvest soil results are presented in Table 9. Initially the soil pH was 6.1, but after completion of two crop cycles and incorporation of mungbean stover and other crop residues in soil, the pH remained unchanged although minor variation existed. A minor change in soil fertility occurred from initial status due to different fertilizer management practices over two years. Soil test basis fertilizer application (T_4) tended to maintain the initial fertility or increased slightly (Table 9). The treatment T_4 showed an encouraging effect on organic matter, N, P, S, Zn and B only. Potassium (K) slightly decreased in T_1 & T_2 treatments and static in T_3 & T_4 plots over the initial status. The available S, Zn and B content of the soil slightly decreased when they were not applied (T_1 and T_2), but remained almost static or increase when applied (Table 9).

Table 9. Initial and postharvest soil fertility status after two cycles of lentil-mungbean-T. aman rice cropping system due to different fertilizer management practices

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Treatment	pH	OM (%)	Total N (%)	K	P	S	Zn	B
				meq. 100 g^{-1}	µg g^{-1}			
Initial	6.1	1.38	0.061	0.15	15.0	17.1	1.36	0.19
Control (T_1)	6.1	1.40	0.061	0.14	15.0	16.5	1.35	0.18
F. practice (T_2)	6.1	1.44	0.062	0.14	16.1	17.2	1.35	0.18
AEZ (T_3)	6.0	1.46	0.064	0.15	16.2	17.7	1.38	0.20
STB (T_4)	6.0	1.52	0.067	0.15	17.0	18.6	1.40	0.22

Economic analysis

Gross returns varied in different treatments under lentil-mungbean-T. aman rice cropping system which were directly related to the price that received from the product. The gross returns were highest (Tk. 257313 ha^{-1} yr^{-1}) in the treatment T_4 followed by T_3 and T_2 and the lowest was in control treatment (Table 10). Cost of cultivation was involved with plowing, wage rate, pesticides, irrigation and fertilizers cost. Data on cost and return analysis showed that the maximum gross margin (Tk. 55666 ha^{-1} yr^{-1}) over control was calculated from T_4 and minimum from T_2. The gross margin by T_4 was increased three fold over farmer practice (T_2) due to get higher crop yield. The highest marginal benefit cost ratio (4.55) was obtained from T_3 followed by T_4 (3.66). Considering the marginal benefit cost ratio (MBCR) T_3 treatment showed ranked first followed by T_4. However, the cost of production of T_3 (Tk. 69298 ha^{-1} yr^{-1}) was lower than T_4 (Tk. 78705 ha^{-1} yr^{-1}) (Table 10).

Table 10. Economic analysis of lentil-mungbean-T. aman rice cropping system affected by different fertilizer managements practices

Treatment	Variable cost	Gross return	Added cost over control	Added benefit over control	Gross margin over control	MBCR
		Tk. ha^{-1} yr^{-1}				
Control(T_1)	57800	180742	-	-	-	-
F. practice(T_2)	66502	207921	8702	27179	18477	3.12
AEZ (T_3)	69298	233114	11498	52372	40874	4.55
STB (T_4)	78705	257313	20905	76571	55666	3.66

Input prices: Urea= Tk. 12 kg^{-1}, T.S.P= Tk. 22 kg^{-1}, MoP= Tk. 20 kg^{-1}, Gypsum= Tk. 6 kg^{-1}, Zinc sulphate= Tk. 120 kg^{-1}, Boric acid= Tk. 300 kg^{-1}, Rovral fungicide= Tk. 250 100 $^{-g}$, Bavistin fungicide = Tk. 200 100^{-g}, Ripcord insecticide= Tk. 105 100^{-ml}, Karate insecticide = Tk. 450 500^{-ml} , Plowing= Tk. 1400 ha^{-1}(one pass), Labour wage= Tk. 125 day^{-1}, Lentil seed= Tk. 65 kg^{-1}, Mungbean seed= Tk. 60 kg^{-1}, T. aman rice seed= Tk. 35 kg^{-1}.

Output price: Lentil= Tk. 60 kg^{-1}, Mungbean= Tk. 55 kg^{-1}, T.*aman* rice= Tk. 19 kg^{-1}, Straw rate (lentil) = Tk. 1 kg^{-1}, Rice straw= Tk. 1.25 kg^{-1}.

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DISCUSSION

Different fertilizer management practices favoured significant contribution to obtain yield of lentil, mungbean and T. aman rice. Among the treatment, we found that the highest yield of lentil got from soil test basis balanced fertilization (T_4). Singh et al. (2013) also found that the maximum lentil grain yield (1243 kg ha^{-1}) recorded from combined application of 30 kg sulphur and 6 kg Zn fertilizers. Lentil needs adequate amount of balanced fertilizations for stimulating growth, pod formation and grain setting (Mondal et al. 2010; Quddus et al. 2014; Singh et al. 2004). Mungbean yield showed similar trend of lentil. Singh et al. (2014) reported that application of recommended balance fertilization led to a better grain yield of mungbean. The third crop rice also yielded higher from the soil test basis fertilizer treatment (T_4). Timsina et al. (2006) found the highest grain yield with STB nutrient in T. aman rice on rice-wheat system. Similar results are also reported by many of researchers (Quayyum et al. 2001 and 2002; Chowdhury et al. 2002; Basak et al. 2008; Roy et al. 2008; Ali et al. 2009).

We observed that lentil, mungbean and T. aman rice yields of second year were relatively higher in T_3 and T_4 treatments than that of first year. Initially the soil fertility status of this study was very low to low. Comparatively higher yield was observed in second year probably due to incorporation of crop residues in addition with fertilization**.** Result of soil analysis was done after two crop cycles showed an increasing trend of soil fertility although some exception existed. With the inclusion of legumes in cropping system, the crop residues left back in the field contain nutrients especially nitrogen (Kumar and Singh 2009; Nawab et al. 2011; Aggarwal et al. 1997).

In this study we compared the grain nutrient concentrations with critical limits collected from different published articles (Kalra1998; Bell and Kovar; Grain legume handbook 2017; Plant analysis handbook 2017). Our observations revealed that, K and S deficiency showed more pronounced in lentil, mungbean and T. aman rice. Nitrogen deficiency detected more in T. aman rice. In case of P showed slightly deficient in lentil and mungbean but slightly sufficient in rice for all the treatment. Similar observations were made by Timsina et al. (2006); Saleque et al. (2006); Panaullah et al. (2006). Zinc deficiency detect in all crops for all the treatment. Lentil and T. aman rice maintained adequate levels of B in grain but deficiency of B detect severe in mungbean for all the treatment. The results are supported by the observation of Bell and Kovar (2000) and Kalra (1998).

We found that the uptakes of N, P, K, S, Zn and B by the crops in this system were significantly variation among the treatments. In this study, the maximum N uptake was found in STB (270 kg $ha^{-1}yr^{-1}$) followed by AEZ (T_3) and minimum was in control (T_1). This finding is in line with Timsina et al. (2006) who reported that N uptake was consistently and significantly greater due to STB fertilizer management. The treatment STB showed highest phosphorus uptake (31.2 kg ha^{-1} yr^{-1}) and second by AEZ (26.4 kg $ha^{-1}yr^{-1}$). The lowest uptake was found in control (16.8 kg ha^{-1} yr^{-1}). Tarafder et al. (2008) observed that an uptake of P ranged from 160 to 202 kg ha^{-1} yr^{-1} in potato-boro-T. aman rice cropping system. Increasing rate of K application through STB contributed great K uptake (158 kg ha^{-1} yr^{-1}). Shrestha and Ladha (2001) found different amount of K uptake by sweet pepper–fallow–rice

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(203 kg ha^{-1}); sweet pepper–indigo–rice (318 kg ha^{-1}); sweet pepper–indigo + mungbean–rice (303 kg ha^{-1}); sweet pepper–corn–rice (467 kg ha^{-1}). Among the treatments, maximum S uptake was observed in STB (15.8 kg ha^{-1} yr^{-1}) followed by AEZ (13.2 kg ha^{-1} yr^{-1}) and the minimum was in control treatment (7.90 kg ha^{-1} yr^{-1}). Haque et al. 2002) reported that sulphur uptake in wheat-T. aus-T.aman cropping system varied from 20 to 47 kg ha^{-1} yr^{-1}. The uptake of other nutrients (Zn and B) due to different nutrients management practices followed almost the same trend of N uptake. Zinc and B uptake results confirmed by Hossain et al. (2008) and Debnath et al. (2011).

We observed in this system that the balance of N, P, K, S, Zn and B affected significantly by different fertilizer treatment. The annual nutrients input had come from fertilizer, rainfall, irrigation water and biological nitrogen fixation. Balance calculation exhibited that removal of N and K exceeded input for all treatments but P, S, Zn and B was not exceeded the input for T_3 and T_4 treatment (Table 9). Under different fertilizer management practices, removals of nutrients (N and K) are substantial (Yadvinder et al. 2005). Study revealed that higher N mining was occurred in control plot as no fertilizers were used and less mining was observed in farmer practice (T_2) and AEZ basis fertilizer treated plot. More N was added in soil through fertilizer as well as added mungbean biomass and other crop residues. Hence, the farmer practice and AEZ basis fertilizer treatment (T_3) showed lesser mining of N. Kumar and Goh (2000) also found minimum N mining from balanced fertilization. On the other hand, in this study apparent balance of N was negative in all the treatment and the depletion ranged from −94.0 to −151 kg N ha^{-1} yr^{-1}. In rice-maize systems in Bangladesh, the apparent nutrient balance showed highly negative for N (–120 to –134 kg ha^{-1} yr^{-1}) (Timsina et al. 2010). Phosphorus balance was positive in all P treated plots except control treatment (T_1) with the highest positive value in soil test basis fertilization (T_4) than the other treatments. This result is agreements with the findings of Jahan et al. (2015a). In rice-maize system in Bangladesh, the apparent P balance was found positive (15 to 33 kg ha^{-1}) (Ali et al. 2009). Positive balance of P showed adequate in soil but plant tissue (lentil and mungbean) showed inadequate even under the high-fertilizer (STB) treatments (Yoshida 1981; Reuter et al. 1997). Our result P showed sufficiency in plant tissue (rice grain).Yoshida (1981); Dhage et al. (1984) also showed the P deficiency was nonexistent in rice. Constraints for achieving adequate P concentration in tissue and uptake could include unavailability of the applied P (due to chemical fixation, or inadequate moisture in the fertilizer zone) or inadequate rates; understanding the cause will require further investigation. The P deficiency in lentil or mungbean may be attributed to increase P sorption and reduced P availability and uptake during the lentil or mungbean season. Similar opinion of Saleque et al. (2006) that P deficiency in wheat or maize may be attributed to increase P sorption and reduced P availability and uptake. The STB fertilization seemed to contribute to slight P build-up in soil, but the low-P concentrations in grain of lentil and mungbean suggest the need for an increased dosage of P fertilizer. Phosphorus nutrition has also been reported to be an important factor in increasing the leaf magnesium (Mg) and Ca concentrations in wheat (Reinbott and Blevins 1991). In this study, the K balance was negative in all the treatments where the highest mining was in control plot and second in AEZ basis fertilizer treatment. The negative K balance depends on crop uptake and leaching loss of nutrient. The K negative balance builds up higher mainly crops uptake and found greater than that of leaching loss. The STB dose contributed

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lesser mining of K from soil for increased dosages of K fertilizer. Lesser negative value of K was also found in STB dose by Yadvinder et al. (2005). The results confirmed the declining trends in available soil K in many treatments and they are comparable with many other long-term studies in rice–rice and rice–wheat systems of Asia (Ladha et al. 2003). Biswas et al. (2006) found that the apparent average annual K balances were all negative and ranged from –179 kg ha^{-1} yr^{-1} in jute–rice–rice to –39 kg ha^{-1} in rice–potato–sesame. The control and farmer practice treatments resulted negative S balance while AEZ (T_3) and STB (T_4) treatments maintained a positive balance. The AEZ (T_3) and STB (T_4) treatments seemed to contribute S build up in soil but low S detection in lentil, mungbean and T. aman rice which suggest an increased dosage of S fertilizer (Yoshida 1981; Reuter et al. 1997). Alam et al. (2000) reported that S was in positive balance for both sole and integrated application of fertilizer and manure. Jahan et al. (2015a) corroborated that the negative balance was observed in control and farmers practice treatments was –1 to –8 kg $ha^{-1}yr^{-1}$. In this study the zinc balance found positive in AEZ (T_3) and STB (T_4) treatment that indicated currently used of this fertilizer. Similar results corroborated by Jahan et al. (2015b) in a monocrop cultivation of T.aman rice where –0.08 to –0.31 kg Zn ha^{-1} yr^{-1} was in control and farmers practice and positive balance (1.12 to 1.61 kg Zn ha^{-1} yr^{-1}) was in AEZ and STB treatment. Deficiency detection of Zn in lentil, mungbean and T. aman rice in this system suggested for application of Zn fertilizer or further monitoring (Bell and Kovar 2000; Kalra 1998). The apparent balance for B was negative in farmers practice and almost static in control due to no B fertilizer was used, but in AEZ (T_3) and soil test based treatments (T_4) the balance was positive because of B fertilization. Other study has also showed positive balance of B in maize-mungbean-rice system when this was added (Hossain et al. 2008). In this study deficiency detection of B in lentil and mungbean grain and sufficiency detection in rice grain. Our observation suggests for increase B fertilization. Some researchers concluded excess B supply may influence as inhibitor and balanced B supply may influence as regulator (Tanada 1983; Alvarez-Tinant et al. 1979; Corey and Schulte 1973).

Our observation on economic analysis that the gross return and gross margin by T_4 was highest over other treatment but considering the marginal benefit cost ratio (MBCR) T_3 treatment showed ranked first and second in T_4. We found in this system the fertilizer dose under T_3 were low however, the cost of production of T_3 (Tk. 69298 ha^{-1} yr^{-1}) was lower than T_4 (Tk. 78705 ha^{-1} yr^{-1}) (Table 10). Therefore, the gross return, gross margin and soil fertility indicate the treatment T_4 is preferable to T_3. Similar results corroborated by Malika et al. (2015) he found that the highest marginal benefit-cost ratio of 3.656 in T_1 (100% RFD) and second in T_3 (75%RFD + PM 3 t ha^{-1}). Ali et al. (2003) and Rahman et al. (2004) also observed in cropping system that highest benefit cost ratio in the soil test basis balanced fertilization.

The above discussions suggest that soil test based of nutrients (N, P, K, S, Zn and B) recommendation need to be monitored, taking into account plant testing to obtain higher productivity.

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CONCLUSION

Yields of tested crops in the system showed higher through soil test basis fertilization. The nutrient uptake by lentil, mungbean and T. aman rice were found to be higher in soil test basis treatment. Nutrients balances at the end of the cycle showed different results depending on the nutrient. The magnitude of negative balance of N and K was greater among the major nutrients. Nitrogen and K mining occur remarkably from the soil. So, the rates of application of these two nutrients should be increased. Considering the gross return, gross margin and soil fertility the soil test basis fertilizer management practice (STB) is economically profitable and viable for achieving sustainable crop yield in terrace soils of Bangladesh. Results of the present study clearly indicate a possibility for the re-adjustment of the N, P, K, S and micronutrients (Zn & B) fertilizer doses for the different rice-based cropping systems in different agro-ecological zone of Bangladesh.

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Conflicts of interest- There are no potential conflicts of interest.

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