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System Yields, Nutrient Uptake and Balance of Mustard-Mungbean-T. Aman Rice Cropping Systems in Terrace Soils of Bangladesh

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Abstract: Conducted experiments on mustard-mungbean-T. aman rice cropping system to measure the system yield, nutrient uptake and apparent balance in terrace soils of Gazipur. Four fertilizer treatments were considered viz. absolute nutrient control (T_1); farmer's practice (T_2); AEZ basis fertilizer application (T_3) and soil test basis fertlizer application (T_4). The treatments were compared in a randomized completely block design with three replications over two consecutive years. The average yields of mustard, mungbean and T. aman rice ranged from 798 to 1543 kg ha^{-1}, 995 to 1489 kg ha^{-1} and 3270 to 4521 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_4 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_4 but negative in T_1, T_2 and T_3. Zinc and B balance in the system was positive in case of T_3 and T_4. Highest yield, gross margin and soil fertility have been recommended that the soil test basis fertilizer application is profitable for mustard-mungbean-T. aman rice cropping system in terrace soils. The study indicate clearly an opportunity for the re-adjustment of the N, P, K, S and miconutrients (Zn & B) fertilizer doses for the different rice-based cropping systems in Bangladesh.

Keywords: System Yield, Nutrient Uptake, Nutrient Balance, Mustard-Mungbean-T. Aman Rice, Terrace Soil

1. Introduction

Terrace soils under the agro-ecological zone-Madhupur Tract which belongs to Dhaka, Gazipur, Tangail, Narshingdi, Narayangonj and Kishorgonj districts of Bangladesh. Rice is the staple crop in Terrace soils of Gazipur, but some farmers are grown mustard and vegetables in Rabi season [1]. Mustard (*Brassica napus*), mungbean (*Vigna radiata*) and T. aman rice (*Oryza sativa* L.) grown sequentially in an annual rotation constitute a mustard-mungbean-T. aman cropping system. Several studies have shown that intensive rice-based cropping system including rice-wheat (RW) causes remarkable depletion of soil nutrients and threat to crop productivity [2]. Besides the farmers are following imbalanced use of fertilizers for crop production which leads to degrade soil fertility [3]. Farmers generally use fertilizers on single crop basis, not the cropping system. 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. 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 [4].

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 [5]. Hence, it is important to develop a cropping system based fertilizer dose for specific agro-ecological zone. Quantification of the loss or gain of nutrients under different cropping system has been less attended. Nutrient balance is an important tool for assessing the nutrient reserve in soils. Crop nutrient balance is a difference between nutrients applied to soil in relation to its removal by crops and leaching loss. Negative nutrient balance may limit crop yield and deplete soil fertility and positive nutrient balance shows nutrient accumulation and creates a risk of water and air pollution [6]. 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 yields, nutrient uptake and nutrient balance for the mustard-mungbean-T. aman rice cropping system with varying fertilizer management practices.

2. Materials and Methods

2.1. Site Description

The two years (2009-10 and 2010-11) experiment on mustard-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. 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).

2.2. 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).

2.2.1. Treatment and Layout

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

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

Treatments	Mustard	Mungbean	T. *aman*
T_1	Control	Control	Control
T_2	$N_{100}P_{15}K_{20}$	$N_6P_5K_4$	$N_{60}P_6K_{20}$
T_3	$N_{85}P_{20}K_{55}S_{15}Zn_0B_1$	$N_7P_7K_5$	$N_{65}P_7K_{28}S_8Zn_1$
T_4	$N_{105}P_{24}K_{60}S_{20}Zn_2B_2$	$N_{15}P_{20}K_{10}S_6Zn_1B_1$	$N_{70}P_{12}K_{40}S_{10}Zn_1B_1$

The experiment was laid out in 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 × 10 cm for mustard, 30 cm × 10 cm for mungbean and 20 cm × 15 cm for T. aman rice.

2.2.2. Fertlizer Application and Seed Sowing

Full amount of fertilizers, except urea in mustard and rice was applied to respective plot during final land preparation. Urea was applied in two equal split for mustard and 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 mustard (var. BARI Mustard-14) were sown on mid November, 2nd crop mungbean (BARI Mung-6) were sown end of March and the third crop T. aman rice (var. BRRI dhan-33) seedlings (30 days old) were transplanted mid July.

2.2.3. Intercultural Operation, Data Collection and Statistical Analysis

Intercultural operations were done as and when required. The crops were harvested after maturity. Data on yields (kg ha^{-1}) of all tested crops were recorded from whole plot technique. Analysis of variance (ANOVA) for the yields and different nutrient content was done following the principle of F-statistics and the mean values were separated by DMRT [7] 1984) using MSTAT-C software.

2.3. 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 [8] method; total N by Microkjeldahl method [9]; exchangeable K by 1N NH_4OAc method [10]; available P by Olsen and Sommers [11] method; available S by turbidity method using $BaCl_2$ [12]; available Zn by DTPA method [13]; available B by azomethine-H method [14]. Ground plant samples were digested with di-acid mixture (HNO_3-$HClO_4$) (5: 1) as described by Piper [15] 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).

2.4. Soil Solution, Rain and Irrigation Water Samples Analysis

Soil solutions were collected at intervals of 15 days starting from the date after transplantation with the help of 50 ml plastic syringe and analyzed for determined nutrient leaching loss. Soil solution was 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. 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 and irrigation water were collected and analyzed for determining the nutrients (P, K, S, Zn and B) added to the soil. Soil solution, rain and irrigation water samples were analysed for concentration of P, K, S, Zn and B same as plant samples analysis method.

2.5. 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 [16] 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.

2.6. 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 [17]. Apparent nutrient balance for the mustard-mungbean-T. aman rice cropping system (average of two years) was computed as the difference between nutrient input and output [6]. The inputs were supplied from (i) fertilizer (ii) rainfall and (iii) irrigation water and the outputs were estimated from crop uptake and leaching loss in a cycle.

2.7. Physiological Efficiency (PE)

Physiological efficiency (PE) was calculated according to Equation-

$$\text{PE} = \frac{Y - Y_0}{U - U_0}$$

Where Y is the yield of the fertilized plot, Y_0 is the yield of the unfertilized plot, U is the total nutrient uptake in above ground crop biomass with fertilized plot and U_0 is the total nutrient uptake in above ground crop biomass with unfertilized plot [6].

2.8. 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 [18].

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

$$MBCR(\text{over control}) =$$

$$\frac{Gross\ return(T_i) - Gross\ return(T_0)}{VC(T_i) - VC(T_0)}$$

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

$$\text{Gross return} = \text{Yield} \times \text{price}$$

3. Result

3.1. Crops Yields

Table 2. *Effect of fertilizer management practices on grain and straw/stover yields of crops in mustard-mungbean-T. aman cropping system.*

Treatment	Grain yield (kg ha^{-1})				Straw/stover yield (kg ha^{-1})		
	1st year	2nd year	mean	% of increase over control	1st year	2nd year	mean
	Mustard						
Control (T_1)	818^d	779^d	798	-	2100^d	2020^d	2060
F. practice (T_2)	1124^c	1140^c	1132	42	2900^c	2924^c	2912
AEZ (T_3)	1300^b	1330^b	1315	65	3610^b	3651^b	3630
STB (T_4)	1534^a	1552^a	1543	93	4172^a	4210^a	4191
CV (%)	3.55	3.27	-	-	2.94	2.97	-
$LSD_{0.05}$	98.9	101	-	-	146	159	-
	Mungbean						
Control (T_1)	1049^c	940^c	995	-	2238^d	2110^d	2174
F. practice (T_2)	1170^b	1242^b	1206	21	2341^c	2397^c	2369
AEZ (T_3)	1332^a	1386^{ab}	1359	37	2453^b	2468^b	2461
STB (T_4)	1448^a	1530^a	1489	50	2557^a	2613^a	2585
CV (%)	4.99	6.17	-	-	2.88	3.74	-
$LSD_{0.05}$	111	178	-	-	245	269	-
	T. aman						
Control (T_1)	3352^c	3188^c	3270	-	3463^c	3293^c	3378
F. practice (T_2)	3651^b	3700^b	3675	12	3769^b	3823^b	3796
AEZ (T_3)	3887^b	3988^{ab}	3937	20	4027^b	4135^{ab}	4081

Treatment	Grain yield (kg ha^{-1})				Straw/stover yield (kg ha^{-1})		
	1st year	2nd year	mean	% of increase over control	1st year	2nd year	mean
STB (T_4)	4452^a	4591^a	4521	38	4633^a	4768^a	4700
CV (%)	3.35	5.31	-	-	3.43	5.22	-
$LSD_{0.05}$	371	740	-	-	386	747	-

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

Nutrients management practices significantly influenced on grain and straw/stover yields of mustard, mungbean and T. aman rice in both the years (Table 2). The grain yields (mean of two years) due to different fertlizer treatments ranged from 798 to 1543 kg ha^{-1} in mustard, 995 to 1489 kg ha^{-1} in mungbean and 3270 to 4521 kg ha^{-1} in T. aman rice. The control (T_1) treatment gave the lowest grain yield of 798, 995 and 3270 kg ha^{-1} (mean of two years) in mustard, mungbean and T. aman rice, respectively. The farmers practice of fertilizer application (T_2) increased grain yield to 1132 kg ha^{-1} in mustard, 1206 kg ha^{-1} in mungbean and 3675 kg ha^{-1} in T. aman rice. Fertilizer dose on AEZ basis (T_3) resulted in further yield increased of 1315 kg ha^{-1} in mustard, 1359 kg ha^{-1} in mungbean and 3937 kg ha^{-1} in T. aman rice. The T_4 treatment (soil test basis fertilizer application) gave the highest crop yields for all the test crops (Table 2). In case of straw/stover yield due to different treatments varied from 2060 to 4191, 2174 to 2585 and 3378 to 4700 kg ha^{-1} (mean of two years) in mustard, mungbean and T. aman rice, respectively. The treatments normally statistically differed with one another and significantly highest value found in T_4 treatment and lowest in T_1 treatment for all the test crops in both the years. The percent grain yields of mustard, mungbean and T. aman rice increased over control due to different nutrient management practices were 42 to 93%, 21 to 50% and 12 to 38%, respectively (Table 2). Most of the yield contributing characters of mustard, mungbean and T. aman rice highly responded to soil test basis fertilization (T_4) followed by AEZ basis fertilization (T_3) (data not showed).

3.2. Nutrient Concentration and Defficiency Determination in Grain

Grain nutrient concentration (mean of two years) of test crops- mustard, mungbean and T. aman and critical values are presented in Tables 3. The nutrients concentration of mustard due to different fertilizer management practices ranged from 3.23 to 3.44% N, 0.42 to 0.46% P, 0.60 to 0.64% K, 0.89 to 0.92% S, 34.3 to 37.6 ppm Zn and 28.2 to 32.8 ppm B. In case of mungbean, nutrient concentration varied in different treatment from 3.04 to 3.22% N, 0.21 to 0.24% P, 1.33 to 1.39% K, 0.095 to 0.115% S, 26.8 to 31.0 ppm Zn and 15.2 to 21.5 ppm B. Further in T. aman rice, concentration also ranged due to fertilizer treatments from 1.45 to 1.49% N, 0.20 to 0.23% P, 0.19 to 0.22% K, 0.050 to 0.075% S, 50.9 to 52.9 ppm Zn and 21.6 to 24.1 ppm B. Test crops nutrients values and critical values were compared due to different treatments (Table 3). Different nutrient management practices exhibited the deficiency of N in mustard, mungbean and T. aman rice. The highest N deficiency showed 0.37% in mustard, 0.59% in mungbean, respectively for T_1 treatment and 1.57% in T. aman rice for T_2 treatment. The lowest N deficiency found in all the test crops for T_4 treatment. There was no P deficiency in mustard but mungbean and rice crop was showed minor deficency due to different treatment. Severe deficiency of K in mustard 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 sufficiency of S in mustard, deficiency of S in mungbean and T. aman rice. There was affected of Zn in mustard and less affected of Zn in mungbean and T. aman rice due to different treatments. There was no deficiency of B in mustard for T_3 and T_4 treatment. 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 3rd crop T. aman rice crops showed B sufficiency in all the treatments (Table 3).

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

Treatment	N	P	K	S	Zn	B
Mustard	**(%)**				**ppm**	
Control (T_1)	3.23	0.42	0.60	0.89	34.3	28.2
F. practice (T_2)	3.34	0.43	0.63	0.90	34.4	28.3
AEZ (T_3)	3.37	0.45	0.64	0.91	37.0	32.6
STB (T_4)	3.44	0.46	0.64	0.92	37.6	32.8
Critical value	3.60	0.25	1.60	0.13	50.0	30.0
Mungbean						
Control (T_1)	3.04	0.21	1.33	0.095	26.8	15.2
F. practice (T_2)	3.16	0.22	1.36	0.105	26.9	15.9
AEZ (T_3)	3.18	0.23	1.37	0.115	30.5	20.5
STB (T_4)	3.22	0.24	1.39	0.115	31.0	21.5
Critical value	3.63	0.26	1.75	0.20	35.0	27.0
T. aman rice						
Control (T_1)	1.45	0.20	0.19	0.050	50.9	21.6
F. practice (T_2)	1.43	0.21	0.20	0.055	51.2	22.3
AEZ (T_3)	1.45	0.22	0.21	0.065	52.6	23.2
STB (T_4)	1.49	0.23	0.22	0.075	52.9	24.1
Critical value	3.00	0.23	1.20	0.15	60.0	15.0

Nutrient critical values source: [19, 20].

3.3. Nutrient Uptake

Nutrient management practices had significant effect on the uptake of N, P, K, S, Zn and B by the crops in mustard-mungbean-T. aman rice cropping system in both the years (Table 4). Fertilizer application on soil test basis (T_4) showed significantly higher nutrient uptake by mustard, mungbean and T. aman rice in both the years. The nutrient uptake followed the order: N>K>S>P>Zn>B. The lower nutrient uptake was observed in control (T_1) treatment by all test crops. The total uptake of nutrients by crops (mustard+mungbean+T. aman) ranged from 167-278 kg N ha^{-1}, 16.7-30.7 kg P ha^{-1}, 129-199 kg K ha^{-1}, 17.6-35.5 kg S ha^{-1}, 0.49-0.81 kg Zn ha^{-1} and 0.28-0.48 kg B ha^{-1} (Figures 1 & 2).

Maximum N uptake was found in STB (278 kg ha^{-1}yr^{-1}) followed by AEZ (T_3). Minimum uptake was estimated in control (T_1). The treatment STB showed highest phosphorus uptake (30.7 kg ha^{-1} yr^{-1}) followed by AEZ (25.1 kg ha^{-1}yr^{-1}). The lowest uptake was found in control (16.7 kg ha^{-1} yr^{-1}). Due to different treatments the highest total potassium uptake was found in STB (199 kg ha^{-1} yr^{-1}) followed by AEZ (174 kg ha^{-1} yr^{-1} for all test crops. The lowest K uptake was observed in control (129 kg ha^{-1} yr^{-1}). Among the treatments, maximum S uptake was observed in STB (35.5 kg ha^{-1} yr^{-1}) followed by AEZ (30.1 kg ha^{-1} yr^{-1}) and the minimum was in control treatment (17.6 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 (Figures 1 & 2).

Table 4. *Effect of nutrient management practices on nutrient uptake (kg ha^{-1}) by mustard-mungbean-T. aman (grain+straw/stover) cropping system.*

Treatment	N		P		K		S		Zn		B	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
	Mustard											
Control (T_1)	47.0^{d}	44.3^{d}	4.15^{d}	3.60^{d}	29.4^{d}	27.8^{d}	12.4^{d}	11.5^{d}	0.09^{c}	0.08^{c}	0.07^{c}	0.06^{c}
F. practice (T_2)	67.2^{c}	67.5^{c}	6.12^{c}	5.72^{c}	41.4^{c}	41.8^{c}	17.5^{c}	17.3^{c}	0.12^{bc}	0.12^{bc}	0.10^{b}	0.10^{bc}
AEZ (T_3)	82.2^{b}	82.7^{b}	7.81^{b}	7.33^{b}	51.3^{b}	52.2^{b}	21.4^{b}	21.1^{b}	0.15^{b}	0.16^{b}	0.13^{ab}	0.14^{b}
STB (T_4)	99.6^{a}	100^{a}	9.73^{a}	9.14^{a}	60.0^{a}	60.7^{a}	24.9^{a}	24.2^{a}	0.18^{a}	0.19^{a}	0.16^{a}	0.17^{a}
CV (%)	2.64	2.45	4.69	4.85	3.92	3.54	4.32	3.46	7.55	8.12	8.56	6.88
$LSD_{0.05}$	3.88	3.39	1.10	1.23	4.89	4.34	1.08	1.12	0.019	0.02	0.02	0.019
	Mungbean											
Control (T_1)	59.1^{d}	55.1^{d}	4.50^{c}	3.72^{d}	47.6^{d}	44.9^{d}	2.13^{c}	1.74^{c}	0.07^{c}	0.06^{c}	0.06^{b}	0.05^{c}
F. practice (T_2)	65.6^{c}	65.7^{c}	5.12^{bc}	4.51^{c}	51.8^{c}	51.4^{c}	2.61^{bc}	2.33^{bc}	0.08^{bc}	0.07^{bc}	0.07^{b}	0.08^{bc}
AEZ (T_3)	72.4^{b}	74.2^{b}	5.77^{b}	5.44^{b}	55.6^{b}	56.8^{b}	3.23^{ab}	2.95^{b}	0.09^{b}	0.11^{b}	0.09^{a}	0.10^{a}
STB (T_4)	82.0^{a}	85.6^{a}	6.71^{a}	6.23^{a}	61.4^{a}	63.0^{a}	3.81^{a}	3.44^{a}	0.10^{a}	0.12^{a}	0.10^{a}	0.11^{a}
CV (%)	2.94	2.19	6.34	2.41	2.86	2.54	6.77	4.82	7.34	8.22	8.87	7.73
$LSD_{0.05}$	3.88	3.25	1.26	0.96	3.14	2.98	0.41	0.33	0.019	0.04	0.019	0.02
	T. aman											
Control (T_1)	67.0^{d}	62.3^{d}	9.51^{d}	8.02^{c}	55.5^{d}	51.6^{c}	4.44^{d}	2.92^{d}	0.35^{c}	0.32^{d}	0.15^{b}	0.14^{c}
F. practice (T_2)	74.1^{c}	74.3^{c}	11.0^{c}	10.4^{bc}	2^{c}	60.6^{bc}	5.21^{c}	4.14^{c}	0.39^{bc}	0.38^{c}	0.17^{b}	0.18^{bc}
AEZ (T_3)	80.2^{b}	81.1^{b}	12.6^{b}	11.3^{b}	65.7^{b}	66.3^{b}	6.35^{b}	5.29^{b}	0.43^{b}	0.44^{a}	0.19^{ab}	0.19^{b}
STB (T_4)	94.3^{a}	95.2^{a}	15.3^{a}	14.4^{a}	76.5^{a}	76.9^{a}	7.73^{a}	6.92^{a}	0.51^{a}	0.52^{a}	0.22^{a}	0.23^{a}
CV (%)	3.24	2.55	4.77	5.22	5.14	6.54	5.86	6.21	7.33	4.25	9.74	8.41
$LSD_{0.05}$	4.31	3.84	1.08	1.12	5.21	5.24	1.04	0.92	0.02	0.019	0.02	0.019

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

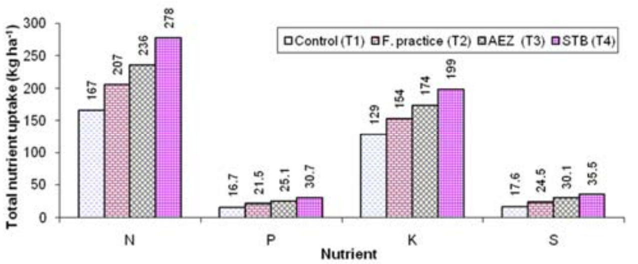

Figure 1. *Effect of fertilizer management practices on total uptake of nutrients by crops under mustard-mungbean-T. aman cropping system.*

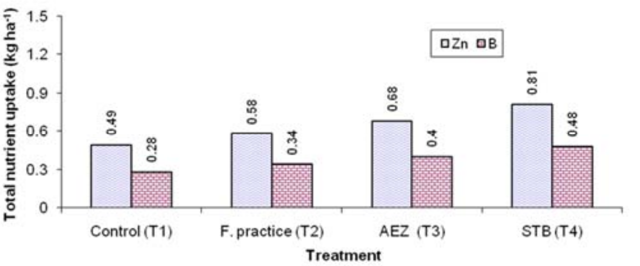

Figure 2. *Effect of fertilizer management practices on total uptake of zinc and boron by crops under mustard-mungbean-T. aman cropping system.*

3.4. Physiological Efficiency of Nutrient

Physiological efficiency (PE) of nutrient was calculated from the ratio of economic yield (yield of fertilized plot minus yield of unfertilized plot) and nutrient uptake by the above ground biomass of crop (nutrient uptake of fertilized plot minus nutrient uptake of unfertilized plot). Physiological efficiency of N in mustard, mungbean and T. aman were 13.6 to 15.2, 17.4 to 21.3 and 40.3 to 42.1 kg kg^{-1}, respectively, in the first year and 13.9 to 15.6, 19.3 to 28.5 and 42.5 to 42.7 kg kg^{-1}, respectively in the second year (Table 5). Physiological efficiency of N for all test crops had a higher value in second year compared to the first year. Among the treatments, physiological efficiency of N showed comperatively higher value in T_2 treatment over the others treatment in both the years. Mustard, mungbean and T. aman rice showed physiological efficiency of P due to different treatment varied from 128 to 155, 181 to 223 and 173 to 201 kg kg^{-1}, respectively in first year and 140 to 170, 235 to 382 and 215 to 244 kg kg^{-1}, respectively in the second year. Physiological efficiency of P for all the crops had a higher value in second year compared to the first year. In case of physiological efficiency of K and S in mustard, mungbean and

T. aman showed the similar trend as physiological efficiency of N and P in both the years (Table 5). Mustard due to different nutrient management practices had physiological efficiency of Zn and B ranged from 7.96 to 10.2 & 7.96 to 10.2 kg g^{-1}, respectively in first year and similar trend also had in second year. Physiological efficiency of Zn and B in mungbean varied from 12.1 to 14.2 and 9.43 to 12.1 kg g^{-1}, respectively in first year and 8.92 to 30.2 and 8.92 to 10.1 kg g^{-1}, respectively in second year. Physiological efficiency of Zn and B in T. aman rice found 6.69 to 7.48 and 13.4 to 15.7 kg g^{-1}, respectively in first year and 6.67 to 8.53 and 12.8 to 16.0 kg g^{-1}, respectively in second year. Among the different treatment, physiological efficiency of Zn and B observed higher in T_1 treatment in mustard and mungbean at both the years except PE of Zn in mungbean at 1st year but it was higher (14.2 kg g^{-1}) in T_3 treatment (Table 5).

Table 5. *Effect of fertilizer management practices on physiological efficiency of nutrient in crops of mustard-mungbean-T. aman rice cropping system.*

Treatment	Physiological efficiency											
	kg kg^{-1}								kg g^{-1}			
	N		P		K		S		Zn		B	
	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr	1st yr	2nd yr
	Mustard											
Control (T_1)	-	-	-	-	-	-	-	-	-	-	-	-
F. practice (T_2)	15.2	15.6	155	170	25.5	25.8	60.0	62.2	10.2	9.03	10.2	9.03
AEZ (T_3)	13.7	14.4	132	148	22.0	22.6	53.6	57.4	8.03	6.89	8.03	6.89
STB (T_4)	13.6	13.9	128	140	23.4	23.5	57.3	60.9	7.96	7.03	7.96	7.03
	Mungbean											
Control (T_1)	-	-	-	-	-	-	-	-	-	-	-	-
F. practice (T_2)	18.6	28.5	195	382	28.81	46.5	252	512	12.1	30.2	12.1	10.1
AEZ (T_3)	21.3	23.4	223	259	35.38	37.5	257	369	14.2	8.92	9.43	8.92
STB (T_4)	17.4	19.3	181	235	28.91	32.6	238	347	13.3	9.83	9.98	9.83
	T. aman											
Control (T_1)	-	-	-	-	-	-	-	-	-	-	-	-
F. practice (T_2)	42.1	42.7	201	215	52.5	56.9	388	420	7.48	8.53	14.9	12.8
AEZ (T_3)	40.5	42.6	173	244	52.4	54.4	280	338	6.69	6.67	13.4	16.0
STB (T_4)	40.3	42.5	190	220	52.4	55.5	334	351	6.88	7.02	15.7	15.6

3.5. Leaching of Nutrients

Leaching loss was estimated only to T. aman rice. Due to dry land condition, leaching loss was not considered during mustard and mungbean cultivation. 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 favoured the loss of P, K, S, Zn and B element through leaching. The loss of nutrients (average of two years) through leaching ranged from 0.18 to 0.41 kg P ha^{-1}, 2.33 to 8.04 kg K ha^{-1}, 1.13 to 2.83 kg S ha^{-1}, 0.03 to 0.09 kg Zn ha^{-1} and 0.05 to 0.28 kg B ha^{-1}. The highest and lowest values of nutrients loss were always found in T_4 and T_1 treatments (Table 6).

Table 6. *Leaching of nutrients due to different fertilizer management practices under mustard-mungbean-T. aman cropping system (average of two years).*

Treatment	P	K	S	Zn	B
	kg ha^{-1}				
Control (T_1)	0.18	2.33	1.13	0.03	0.05
F. practice (T_2)	0.36	5.94	1.81	0.03	0.05
AEZ (T_3)	0.40	7.64	2.28	0.08	0.21
STB (T_4)	0.41	8.04	2.83	0.09	0.28

3.6. Total Input of Nutrients

The nutrient input was mainly from fertilizer but in this estimate, the nutrients supply from fertilizer, rainfall and irrigation under mustard-mungbean-T. aman rice cropping system. BNF was not considerd. Total input of nitrogen was 166 to 190 kg N ha^{-1} of which the major part was added through fertilizer application, except in control treatment. Phosphorus input ranged from 0.48 to 56.5 kg ha^{-1} yr^{-1} and K from 9.04 to 119 kg ha^{-1} yr^{-1}. The S input varied from 5.49 to 41.5 kg ha^{-1} yr^{-1}. Input of Zn ranged from 0.14 to 4.14 kg ha^{-1} yr^{-1}. Boron input was estimated 0.34 to 4.35 kg ha^{-1} yr^{-1} (Table 7).

Table 7. *Total input of N, P, K, S, Zn and B from fertilizer, rainfall and irrigation under mustard-mungbean-T. aman rice cropping system.*

Treatment	N	P	K	S	Zn	B
	kg ha^{-1}					
Control (T_1)	0.00	0.48	9.04	5.49	0.14	0.34
F. practice (T_2)	166	26.5	53.0	5.49	0.14	0.34
AEZ (T_3)	157	34.5	97.0	28.4	1.14	1.35
STB (T_4)	190	56.5	119	41.5	4.14	4.35

3.7. Total Output of Nutrients

The output of nutrients (mean of two years) ranged from 167 to 278 kg N ha^{-1}, 17.0 to 31.0 kg P ha^{-1}, 131 to 207 kg K ha^{-1}, 19.0 to 38.0 kg S ha^{-1}, 0.52 to 0.90 kg Zn ha^{-1} and 0.35 to 0.76 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).

Table 8. *Effect of fertilizer management practices on total output (crop uptake and leaching loss) of nutrients by mustard-mungbean-T. aman rice cropping system (mean of two years).*

Treatment	N	P	K	S	Zn	B
	kg ha^{-1}					
Control (T_1)	167	17	131	19	0.52	0.35

Treatment	N	P	K	S	Zn	B
	kg ha^{-1}					
F. practice (T_2)	207	22	160	26	0.61	0.39
AEZ (T_3)	236	25	182	32	0.77	0.63
STB (T_4)	278	31	207	38	0.90	0.76

3.8. Apparent Nutrients Balance

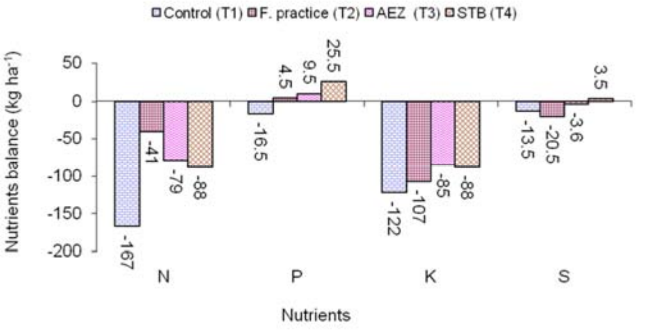

Figure 3. *Effect of nutrient management practices on apparent nutrient balance of N, P, K and S in soil under mustard-mungbean-T. aman cropping system.*

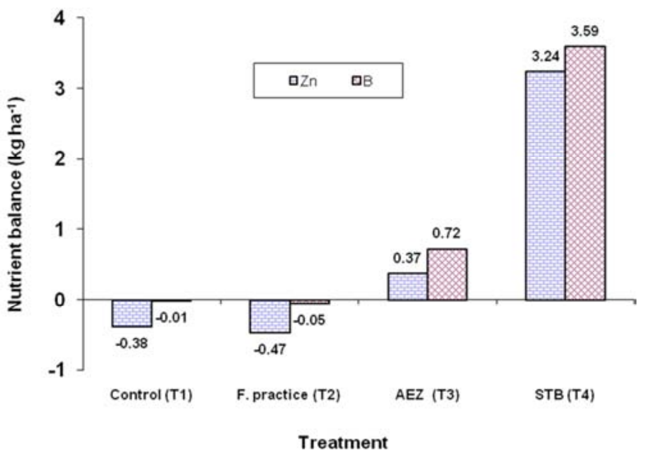

Figure 4. *Effect of nutrient management practices on apparent balance of zinc and boron in soil under mustard-mungbean-T. aman cropping system.*

An apparent nutrient balance was calculated considering the amount of added nutrient through fertilizer, rain, irrigation water 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 or BNF. Apparent balance of N, P, K, S, Zn and B are shown in Figures 3 & 4. Apparent balance was mainly affected by different nutrient management practices. The apparent balance of N was negative in all the treatment and the depletion ranged from −41.0 to −167 kg N ha^{-1} yr^{-1}. In case of P balance which was negative (-16.5 kg ha^{-1} yr^{-1}) in control treatment (T_1) and the P balance was positive (4.50 to 25.5 kg ha^{-1} yr^{-1}) in all other treatment where P containing fertilizer was utilized. The balance of K was negative in all the treatments where the K mining ranged from −85.0 to −122 kg K ha^{-1} yr^{-1}. The highest K mining was recorded from control treatment followed by farmer practice (T_2) and the lowest K mining was found in AEZ basis fertilizer treatment (T_3).

The balance for S was showed negative value in control, farmers practice and AEZ basis fertilizer treatments ranged from –3.60 to –20.5 kg ha^{-1} yr^{-1} while STB treatment observed positive (3.50 kg ha^{-1} yr^{-1}). The negative Zn and B balance was observed in control and farmers practice treatments ranged from –.38 to –0.47 and –0.01 to –0.05 kg ha^{-1} yr^{-1}, respectively. Remaining treatments showed positive balance ranged from 0.37 to 3.24 and 0.72 to 3.59 kg ha^{-1} yr^{-1}, respectively. The highest positive balance of Zn (3.24 kg ha^{-1} yr^{-1}) and B (3.59 kg ha^{-1} yr^{-1}) was recorded from STB (T_4) treatment.

3.9. 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 mustard-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 6.3, 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. Potasium (K) slightly decreased in all plots over the initial status. The available 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 post soil fertility status after two cycles of mustard-mungbean-T. aman rice cropping system due to different fertilizer management practices.*

Treatment	pH	OM (%)	Total N (%)	K	P	S	Zn	B
				Meq. 100 g^{-1}	µg g^{-1}			
Initial	6.3	1.39	0.061	0.15	15.0	17.1	1.38	0.19
Control (T_1)	6.4	1.39	0.059	0.13	15.0	16.3	1.35	0.17
F. practice (T_2)	6.2	1.41	0.060	0.13	16.0	16.7	1.36	0.17
AEZ (T_3)	6.3	1.43	0.061	0.14	16.1	17.3	1.39	0.20
STB (T_4)	6.3	1.46	0.063	0.14	16.7	18.0	1.41	0.21

3.10. Economic Analysis

The gross margin due to treatment T_4 increased over farmers practice (T_2) and AEZ (T_3) for higher crop yield. Gross returns varied in different treatments mustard-mungbean-T. aman rice cropping system which were directly related to the price that received from the product. The gross returns were highest (Tk. 232160 ha^{-1} yr^{-1}) in the treatment T_4 followed by T_3 and T_2 and the lowest was in control treatment. The highest marginal benefit cost ratio (3.46) was recorded in T_3 followed by T_4. In this study T_3 was economically viable due to the cost of production of T_3 (Tk. 70313 ha^{-1} yr^{-1}) was lower than T_4 (Tk. 81222 ha^{-1} yr^{-1}) (Table 10).

Table 10. *Economic analysis of mustard-mungbean-T. aman rice cropping system affected by different nutrient management 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)	56110	151673	-	-	-	
F. practice (T_2)	65050	179472	8940	27799	18859	3.11
AEZ (T_3)	70313	200783	14203	49110	34907	3.46
STB (T_4)	81222	232160	25112	80487	55375	3.21

Note: 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}, Provex fungicide = Tk.3200 kg^{-1}, Ripcord insecticide = Tk.105 100^{-g}, Karate insecticide= Tk.450 500^{-ml}, Plowing= Tk.1400 ha^{-1} (one pass), Labour wage= Tk.125 day^{-1}, Mustard seed= Tk.45 kg^{-1}, Mungbean seed= Tk.60 kg^{-1}, T. aman rice seed= Tk.35 kg^{-1}.
Output prices: Mustard grain= Tk. 35 kg^{-1}, Mungbean grain= Tk.55 kg^{-1}, T. aman rice grain= Tk.19 kg^{-1}, Mustard straw rate = Tk.1 kg^{-1}, Rice straw= Tk.1.25 kg^{-1}.

4. Discussion

The yields of all test crops were highly responded to soil test basis fertilization (T_4) followed by AEZ basis fertilization (T_3). The nutrient management practices have positive effect on the yields of mustard, mungbean and T. aman rice. Initially the soil fertility status under study was very low to low. Application of fertilizer in this soil following different management practices brought about significant yield increase over control with the highest values in soil test basis fertilization (T_4). This indicated that the treatment T_4 was more balanced than that of T_2 and T_3. Balanced fertilization through soil test based treatment produce higher yields of crops as well as sustains soil fertilty [21]. These results are also supported by Ram and Pathak [22]; Rundala *et al.* [23]; Tandon and Roy [24]; Rahman *et al.* [18]. Mustard, mungbean and T. aman rice yields of second year were relatively higher than that of first year. 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 biomasses left back in the field contain nutrient including nitrogen rich residues [25]. Nawab *et al.* [26] and Aggarwal *et al.* [27] also found that incorporation of green manure into soil enhanced the fertility and yield of crop. The increased soil fertility due to incorporation of crop residues in addition to fertilization was probably the reasons for the obtained higher yield of test crops in second year over first year.

The soil test basis fertilization contributed the highest mean yield increase in test crops of 93%, 50% and 38% over control. This higher yield increase might be possible for more balanced fertilization than that of other treatments. Islam *et al.* [28] is in agreement with the findings. From the gross return and gross margin the treatment T_4 is preferable and viable. Similar report was made by Malika *et al.* [29]. Comparision between test crops nutrient and critical values among different treatments N and K deficiency showed more pronounced. These findings are in agreement with the findings of Timsina *et al.* [30]; Panaullah *et al.* [31]. The results are also confirmed by the observation of Bell and Kovar [20] and Kalra [19].

Nutrient management practices significantly affected the uptake of N, P, K, S, Zn and B by the crops in this system at both the years. Maximum N uptake was found in STB (278 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.* [30] who reported that N uptake was consistently and significantly greater due to STB fertilizer management. The treatment STB showed highest phosphorus uptake (30.7 kg ha^{-1} yr^{-1}) followed by AEZ (25.1 kg $ha^{-1}yr^{-1}$). The lowest uptake was found in control (16.7 kg ha^{-1} yr^{-1}). Tarafder *et al.* [32] observed that an uptake of P ranged from 160 to 202 kg ha^{-1} yr^{-1} in potato-boro-T. aman rice cropping pattern. Maximum potassium uptake was obtained from STB (199 kg ha^{-1} yr^{-1}) followed by AEZ (174 kg ha^{-1} yr^{-1}. Shrestha and Ladha [33] found different amount of K uptake by sweet pepper–fallow–rice (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 (35.5 kg ha^{-1} yr^{-1}) followed by AEZ (30.1 kg ha^{-1} yr^{-1}) and the minimum was in control treatment (17.6 kg ha^{-1} yr^{-1}). Sulphur uptake in wheat-T. aus-T. aman cropping system varied from 20 to 47 kg ha^{-1} yr^{-1} [34]. The uptake of other nutrients (Zn and B) due to different nutrients management practices followed almost the same trend of N uptake.

The balance of N, P, K, S, Zn and B was influenced significantly by different fertilizer treatment under mustard-mungbean-T. aman cropping system. Higher N mining was occurred in control plot as no fertilizers were used and less mining was observed in soil test basis fertilizer treated plot. More N was added in soil through fertilizer as well as added mungbean biomass and other crop residues. Hence, the soil test basis fertilizer treatment (T_4) showed lesser mining of N. Kumar and Goh [35] also found minimum N mining from balanced fertilization. On the other hand, apparent balance of N was negative in all the treatment and the depletion ranged from −41.0 to −167 kg N ha^{-1} yr^{-1}. Some researchers supported the results: in rice-maize system in Bangladesh, the apparent nutrient balance showed highly negative for N (–120 to –134 kg ha^{-1} yr^{-1}) [36]. Phosphorus balance was positive in all P treated plots except control treatment (T_1) with the highest value in soil test basis fertilizer treatment (T_4) than the other treatments. This result is supported to the findings of Jahan *et al.* [37]. In rice-maize system in Bangladesh, the apparent P balance was found positive (15 to 33 kg ha^{-1}) [38]. The balance of K was negative in all the treatments where the highest mining was in control treatment. 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 [39]. Biswas *et al.* [40] 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. Zinc and B balance was positive under all treatments except for control and farmers practice treatments. Other studies have also showed positive balance of Zn and B in maize-mungbean-rice system when it was added [21]. Similar results corroborated by Jahan *et al.* [41] 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. The above discussion seems that N and K balance were strongly negative in soils and seasons.

5. Conclusion

Yields/productivity of tested system showed higher through soil test basis fertilization. The nutrient uptake by mustard, 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 margin and soil fertility the soil test basis fertilizer management practice (STB) is economically profitable and viable for achieving sustainable crop yield. Results of the present study indicate clearly an opportunity for the re-adjustment of the N, P, K, S and miconutrients (Zn & B) fertilizer doses for the different rice-based cropping systems in Bangladesh.

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