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NUTRIENT BALANCE UNDER WHEAT-MUNGBEAN-T. AMAN CROPPING PATTERN IN CALCAREOUS SOILS OF BANGLADESH

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Abstract

Field experiments on Wheat-Mungbean-T. *aman* cropping pattern were conducted at Regional Pulses Research Station (RPRS), Madaripur in calcareous soils under Low Ganges River Floodplain (AEZ-12) during 2009 to 2010 to prepare nutrient balance sheet for the cropping pattern and fertilizer recommendation for study area. The treatments were T_1= Control; T_2 = Farmer's practice; T_3 = AEZ based recommended fertilizer dose and T_4 = Soil test based fertilizer dose. The experiment was laid out in RCBD with three replications. Results revealed that the average yields of wheat, mungbean and T. aman ranged from 1517 to 3124 kg ha^{-1}, 1320 to 1863 kg ha^{-1} and 2974 to 4859 kg ha^{-1}, respectively. Grain yield of all crops increased significantly higher in soil test based (STB) fertilizer treatment (T_4) over the other treatments. Among the major nutrients, the magnitude of negative balance was greater with N and K followed by Mg and Ca. The negative balance of N (-56.0 to -183 kg ha^{-1}), K (-71.0 to -167 kg ha^{-1}), Ca (-7.50 to -27.1 kg ha^{-1}), and Mg (-16.7 to -35.7 kg ha^{-1}) was observed in all the managements might be due to added lower amount of nutrients in soil and higher removal by the crops from the soil. Positive balance of P indicated that the added amount of P is larger than the removal; P fertilization was enough to make apparent balances positive. Across various treatments, there was some amount of positive apparent S balance except absolute control plots and farmer's practice. On the other hand, Zn and B balance in the system was neutral to slightly positive. Results revealed that, N, K, Ca, and Mg balance after two years of cropping was negative regardless of soil type and management strategies adopted. There was an improvement in organic matter in all treatments where biomasses of mungbean were incorporated. Organic matter, N, P, S, Zn and B status in soil was improved due to soil test based fertilization over the initial status. Considering the gross margin and soil fertility the soil test based (STB) fertilizer management practice is economically profitable and sustainable.

Keywords: Cropping pattern, management, nutrient balance, calcareous soils.

Introduction

Cropping pattern means yearly sequence of crop production followed in an area. The pattern in an area depends largely on agro-climatic, technical and

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institutional factors. Among food grain crops, rice occupies the first position both in terms of areas and production, next to wheat (Ghosh, 2011). These cereal based patterns cause considerable depletion of soil fertility and threat to long-term crop productivity. Besides that, farmers of Bangladesh use imbalanced of fertilizers for crop production leading to degraded in soil health and fertility (Ali *et al.,* 2010). High yielding varieties of crops uptake higher amount of nutrient from soils resulting dwindling soil organic matter and deterioration of native soil fertility, poses a serious threat to long-term sustainability of crop production. Moreover, continuous cropping without adequate replacement of removed nutrients in harvested materials, nutrient loss through erosion, leaching and gaseous emission deplete soil fertility and causes soil organic matter level to decline (Yu *et al*., 2014). The bulk of the literature indicates that, apart from residue management, cropping system productivity may become sustainable through integrated use of organic and inorganic nutrients.

Hence, it is important to develop a cropping system based fertilizer dose for specific agro-ecological zones. Low levels of plant nutrients (macro and micro) in many soils especially calcareous soil accompanied with improper nutrient management are major constraints for food security and malnutrition. Quantification of the loss or gain of nutrients under different cropping patterns has not been done properly. Nutrient balance is an important tool for assessing the fate of native and added nutrients in soils. Plant fertilization and yield increase is the main objectives of nutrient balance calculations (FRG, 2012).

Therefore, the existing situations are appeared to be threatening to the whole agricultural system. In this situation, introducing legume crop and proper fertility management practices in the existing cropping patterns is the only means of rejuvenation of soil as well as increase in total national product. Considering the above circumstances, the study was under taken to prepare nutrient balance sheet for Wheat-Mungbean-T. aman cropping pattern and fertilizer recommendation for the study area.

Materials and method

The field experiments were conducted for consecutive two years from *rabi* 2008-09 to October 2010 at Regional Pulses Research Station (RPRS), BARI, Madaripur (23° 10′ 53″ N latitude and 90° 11′ 28″ E longitude) at an elevation of 7.0 m above the sea level. The land belongs to the agro ecological zone, Low Ganges River Floodplain (AEZ-12) and Gopalpur soil series (Soil taxonomy: Aquic Eutrochrepts). The soil had neutral pH (7.3) and loamy in texture. The other soil properties were 1.32% organic matter, total N was 0.063%, exchangeable K, Ca and Mg were 0.14 meq. 100 g^{-1}, 10.3 meq. 100 g^{-1} and 3.10 meq. 100 g^{-1}, respectively. The available P, S, Zn and B were 13.5 µg g^{-1}, 18 µg g^{-1}, 1.20 µg g^{-1} and 0.14 µg g^{-1}, respectively. Cropping system Wheat-Mungbean-

T. *aman* was considered for the study. The experiments were carried out over the three crop seasons such as Rabi, *Kharif-I* and *Kharif-II*. Wheat, mungbean and T. aman were grown in *rabi*, *Kharif-I* and *Kharif-II* season, respectively. There were four treatments along with control for each crop. The treatments were T_1= Control; T_2 = Farmer's practice; T_3 = AEZ based recommended fertilizer dose and T_4 = Soil test based fertilizer dose. The descriptions of treatments are given in Table 1.

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

Treatments	Wheat	Mungbean	T. *aman*
T_1	Control	Control	Control
T_2	$N_{85}P_{24}K_{24}$	$N_{23}P_{15}K_{8}$	$N_{70}P_{10}K_{15}$
T_3	$N_{90}P_{16}K_{25}S_{8}Zn_{1}B_{0.5}$	$N_{15}P_{18}K_{9}S_{8}$	$N_{66}P_{6}K_{12}S_{7}Zn_{1}$
T_4	$N_{120}P_{22}K_{62}S_{25}Zn_{2}B_{1}$	$N_{21}P_{23}K_{30}S_{18}Zn_{2}B_{1.5}$	$N_{100}P_{14}K_{66}S_{6}Zn_{1.5}B_{1}$

T_1= Control, T_2= Farmers' practice, T_3= AEZ based recommended fertilizer dose, T_4= Soil test based fertilizer dose.

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 4 m × 3 m for all crops having the spacing of 30 cm × 10 cm for wheat, 40 cm × 10 cm for mungbean and 20 cm × 15 cm for T. *aman* rice. The layout was kept undisturbed for the cropping system over two years. The amount of all fertilizers, except urea in rice crop of each treatment was applied to respective plot at the time of final land preparation. Fertilizers were mixed with soil by spading. Urea was applied in three equal splits for T. *aman* rice (first split was applied immediately after seedling establishment, the second split during maximum tillering stage and before panicle initiation stage last split was applied). 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. Wheat (var. BARI Gam-24) seeds were sown on 22 November 2008 and 23 November 2009. Mungbean (BARI Mung-6) seeds were sown on 18 March 2009 and on 27 March 2010. T. *aman* rice (var. BRRI dhan33) seedlings (30 days old) were transplanted on 23 July 2009 and on 9 July 2010. The crop wise seed rate was-wheat: 120 kg ha^{-1}, mungbean: 30 kg ha^{-1} and T. *aman* rice: 25 kg ha^{-1}. 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 and yield contributing characters of all crops from all plots were recorded. The yields data were expressed as kg ha^{-1} which was adjusted to 14% moisture content for T. *aman* rice and 12% moisture for wheat and mungbean. Analysis of variance (ANOVA) for 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) using MSTAT-C software.

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 N, P, K, S, Ca, Mg, Zn and B. Rain and irrigation water were collected and analyzed for determining the nutrients (N, P, K, S, Ca, Mg, Zn and B) added to the soil. In calculating percolation water ($L\ m^{-2}$) the formula $Q = -K_wAT.\Delta\Psi_h/\Delta z$ 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.

An apparent nutrient balance was made by considering the nutrient input and output. The inputs were N, P, K, S, Ca, Mg, Zn and B which were supplied from (i) fertilizer (ii) rainfall and (iii) irrigation water. On the other hand, the outputs were calculated from the (i) crop uptake and (ii) leaching loss by percolation in a cycle.

A partial budget (average of two years) was calculated by a standard procedure. Benefit cost ratio (BCR) was used as a tool of partial budget analysis. It is the ratio of gross return and total cost. Gross returns were calculated by multiplying yield with the price of output. Total costs were calculated by variable cost. Variable cost consisting market price of fertilizer, pesticides and labor wages for land preparation, ploughing, weeding, seed sowing and fertilizers application. Land used cost or rental value of land was not considered here. Cost and return were estimated of crops due to different treatment.

Results and Discussion

Crops yields

The grain and straw/stover yields of wheat and mungbean exhibited significant variation due to different nutrient management practices in the consecutive two years (Table 2). Grain yield of wheat and mungbean increased significantly being higher under soil test based (STB) fertilizer treatment (T_4) over the other treatments. 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 (Hossain *et al.*, 2008). Biswas *et al.* (2009) found that balanced fertilizer management practice ($N_{20}P_{20}K_{20}S_{10}Zn_2$) showed higher seed yield (1214 kg ha^{-1}). The average grain yields of wheat and mungbean ranged from 1517 to 3124 kg ha^{-1} and 1320 to 1863 kg ha^{-1}, respectively. In case of straw/stover yield, the effects of treatments were statistically differed with some exception and significantly highest value found in T_4 treatment. The highest seed and stover yields of mungbean due to soil test based balanced fertilization was also found by other researchers (Kumar and Singh 2009). The lowest grain and straw/stover yields of wheat and mungbean were found in control T_1 treatment in both the years. The percent grain yield of wheat and mungbean increased over control due to different nutrient management practices were 43 to 106% and 15 to 41% for calcareous soils (Madaripur), respectively. Most of the yield contributing characters of wheat and mungbean were highly responded to soil test based fertilization (T_4) followed by AEZ based fertilization (T_3). Aggarwal *et al.* (1997) also found that incorporation of green manure and chemicl fertilizer into soil which enhanced the yield contributing characters of wheat. Ved Ram *et al.* (2008) also observed that the application of N, P, K, S and Zn nutrients favoured the seeds per pod and 1000 seed weight.

The grain and straw yields of T. *aman* (3rd crop) responded significantly to different nutrient management practices in both the years at calcareous soils (Table 2). The grain yield recorded from the treatment soil test based fertilizer dose and BARC recommended fertilizer dose (T_3) was statistically identical during 2009 and higher than farmer's practice (T_2) and control treatment. In case of straw yield, the treatments soil test based fertilizer dose (T_4) and BARC recommended fertilizer dose (T_3) differed significantly in 2010 but in 2009 they were statistically alike although soil test based fertilizer dose dominated over T_3. Rahman *et al.* (2011) observed that the grain and straw yields of T. aman were favoured by balanced nutrient application. Similar results were also observed by Biswas *et al.* (2009). The yield of T. aman was comparatively higher in first year than in second year in all treatments except control. The windy weather along with heavy shower at the flowering and ripening stage hampered pollination as a consequence the yield declined in second year. The lowest grain and straw yields were found in the control treatment. The grain yield (2 years' average) of T. *aman* varied from 2974 to 4859 kg ha^{-1}. The different nutrient management practices produced 32 to 63% yield increased over the control. Islam *et al.* (1996) also reported 42% yield increase of rice over control due to balanced fertilization.

Table 2. Effect of nutrient management practices on grain and straw/stover yields of Wheat-Mungbean-T.*aman* cropping sequence

Treatment	Grain yield (kg ha^{-1})				Straw/stover yield (kg ha^{-1})		
	2009	2010	mean	% of increase over control	2009	2010	mean
				Wheat			
Control (T_1)	1555d	1478d	1517	-	2302d	2189d	2245
F. practice(T_2)	2061c	2168c	2168	43	2499c	2712c	2605
AEZ (T_3)	2804b	2933b	2868	89	3471b	3546b	3508
STB (T_4)	3019a	3229a	3124	106	3599a	3767a	3683
CV (%)	2.52	2.88	-	-	3.16	3.46	-
$LSD_{0.05}$	161.85	172.5	-	-	246.3	259.1	-
				Mungbean			
Control (T_1)	1360d	1280d	1320	-	2613c	2590d	2602
F. practice (T_2)	1566c	1467c	1517	15	2912b	2844c	2878
AEZ (T_3)	1701b	1620b	1661	26	3056b	3004b	2950
STB (T_4)	1926a	1800a	1863	41	3110a	3075a	3093
CV (%)	2.32	3.20	-	-	3.31	4.33	-
$LSD_{0.05}$	162	240	-	-	175	296	-
				T. *aman*			
Control (T_1)	3211c	2736d	2974	-	3376c	2870d	3123
F. practice (T_2)	3973bc	3859c	3916	32	4128bc	3958c	4043
AEZ (T_3)	4518ab	4500b	4509	52	4614ab	4590b	4602
STB (T_4)	4938a	4779a	4859	63	5036a	4909a	4972
CV (%)	5.21	3.80	-	-	4.94	3.74	-
$LSD_{0.05}$	502.5	318.8	-	-	446.7	321.7	-

Values within the same column with a common letter do not differ significantly (p=0.05). F= Farmers.

Nutrient uptake

Nutrient management practices have made significant effect to uptake of N, P, K, S, Ca, Mg, Zn and B by wheat, mungbean and T. aman under Wheat-Mungbean-T. *aman* cropping pattern during 2009 & 2010 (Tables 3 & 4). The soil test based fertilizer treatment (T_4) showed the significantly higher nutrients uptake by wheat in both the years. Similar results were found by Jahan *et al.* (2015a). The second highest uptake was observed in T_3 which was followed by T_2. The nutrient uptake followed the order: N>K>Ca>Mg>P>S>Zn>B. Almost all nutrient found higher uptakes by mungbean in soil test based fertilizer treatment (T_4) followed by T_3 and then T_2 treatments.The soil test based fertilizer treatment (T_4) influenced to uptake highest amount of all nutrients by T. *aman* rice followed by T_3 and than T_2 treatment. The lower nutrient uptake was found in control (T_1) treatment by all crops (Tables 3 & 4). The total uptake of nutrients by crops (wheat+mungbean+T. *aman*) ranged from 183-305 kg N ha^{-1}, 21.1-38.5 kg P ha^{-1}, 148-223 kg K ha^{-1}, 9.45-18.6 kg S ha^{-1}, 37.8-60.5 kg Ca ha^{-1}, 28.4-46.6 kg Mg ha^{-1}, 0.47-0.82 kg Zn ha^{-1} and 0.25-0.43 kg B ha^{-1}. These observations are in agreement with Tarafder *et al.* (2008) in potato-boro-T. *aman* rice cropping pattern. The uptake of all nutrients due to different nutrients management practices followed almost same trend (Fig. 1 & 2).

Table 3. Effect of nutrient management practices on nutrient uptake (kg ha^{-1}) by Wheat-Mungbean-T. aman (grain+straw/stover) cropping pattern

Treatment	N		P		K		S	
	2009	2010	2009	2010	2009	2010	2009	2010
	Wheat							
Control (T_1)	42.2d	39.3d	6.00c	5.63c	35.7d	33.4d	3.17d	2.64b
F. practice (T_2)	54.0c	56.7c	8.16b	8.35b	40.2c	42.6c	4.06c	3.85b
AEZ (T_3)	74.7b	76.7b	11.2a	11.7a	56.2b	57.1b	5.86b	5.42a
STB (T_4)	81.6a	85.8a	12.5a	13.2a	59.8a	61.8a	6.56a	6.24a
CV (%)	2.24	3.57	8.63	10.25	2.72	3.62	6.10	8.18
$LSD_{0.05}$	3.12	4.61	1.63	1.99	2.65	3.52	1.19	1.29
	Mungbean							
Control (T_1)	79.2d	75.3d	8.66d	7.98d	74.7d	70.1d	3.19c	2.71b
F.practice (T_2)	91.1c	86.2c	9.96c	9.10c	84.6c	80.9c	3.60b	3.03b
AEZ (T_3)	98.6b	94.6b	10.9b	10.3b	89.8b	87.1b	4.32b	3.72ab
STB (T_4)	108a	103a	12.3a	11.5a	95.0a	91.9a	5.11a	4.44a
CV (%)	2.45	1.85	4.57	5.16	1.21	1.29	8.01	9.25
$LSD_{0.05}$	3.10	1.53	1.14	1.03	1.95	1.63	1.23	1.00
	T. aman							
Control (T_1)	72.2d	57.8d	7.85d	6.13d	44.8d	37.3d	4.31c	2.82c
F.practice (T_2)	91.8c	87.6c	10.5c	8.95c	55.8c	53.2c	5.69b	4.70b
AEZ (T_3)	106b	104b	12.3b	11.3b	62.5b	62.2b	6.86a	6.36ab
STB (T_4)	118a	113a	14.4a	13.0a	69.3a	67.5a	7.99a	6.79a
CV (%)	1.39	2.25	4.46	4.86	2.05	2.47	5.29	4.46
$LSD_{0.05}$	2.70	3.68	1.01	1.45	2.38	2.49	1.00	0.87

Values within the same column with a common letter do not differ significantly (p=0.05). F= Farmers.

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

Treatment	Ca		Mg		Zn		B	
	2009	2010	2009	2010	2009	2010	2009	2010
	Wheat							
Control T$_1$)	8.55b	7.55d	6.94c	6.08b	0.17d	0.16d	0.10c	0.09d
F. practice (T$_2$)	10.2b	10.1c	8.34b	7.97b	0.20c	0.21c	0.11c	0.12c
AEZ (T$_3$)	14.6a	14.1b	11.8a	11.2b	0.29b	0.31b	0.16b	0.17b
STB (T$_4$)	15.7a	15.9a	13.1a	13.1a	0.32a	0.35a	0.18a	0.19a
CV (%)	7.11	6.87	6.47	7.97	8.41	8.01	4.64	6.08
LSD$_{0.05}$	1.73	1.64	1.29	1.81	0.02	0.02	0.04	0.019
	Mungbean							
Contro l (T$_1$)	18.0d	17.2d	14.0d	12.9d	0.09b	0.08b	0.07b	0.06b
F.practice (T$_2$)	20.2c	19.1c	15.8c	14.6c	0.10ab	0.09ab	0.07ab	0.07ab
AEZ (T$_3$)	21.9b	20.9b	17.2b	16.1b	0.11ab	0.10ab	0.09ab	0.08ab
STB (T$_4$)	23.6a	22.4a	18.6a	17.4a	0.12a	0.11a	0.10a	0.09a
CV (%)	4.05	3.81	4.53	3.77	6.23	5.26	7.02	6.76
LSD$_{0.05}$	1.32	1.52	1.36	1.15	0.03	0.02	0.04	0.019
	T. aman							
Control (T$_1$)	13.6d	10.7c	9.59d	7.31d	0.24d	0.20d	0.10d	0.09d
F.practice (T$_2$)	17.1c	15.7b	12.2c	9.80c	0.29c	0.28c	0.12c	0.11c
AEZ (T$_3$)	19.7b	18.7ab	14.2b	12.8b	0.35b	0.34b	0.14b	0.15b
STB (T$_4$)	22.5a	20.9a	16.5a	14.6a	0.37a	0.36a	0.17a	0.16a
CV (%)	4.60	5.12	4.94	5.51	5.02	4.52	4.69	3.79
LSD$_{0.05}$	1.57	1.87	1.29	1.47	0.019	0.05	0.019	0.02

Values within the same column with a common letter do not differ significantly (p=0.05). F= Farmers.

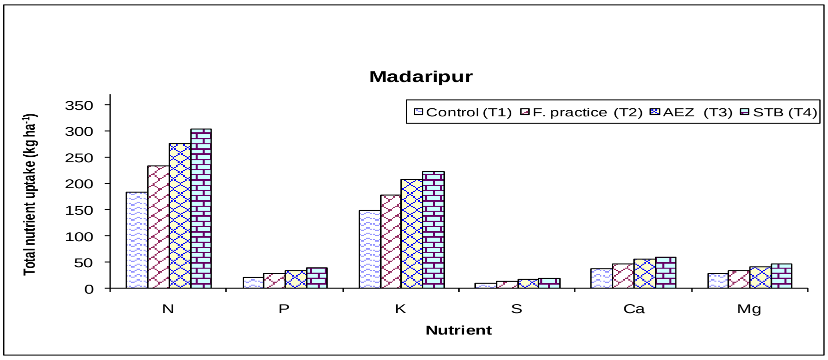

Fig. 1. Effect of fertilizer management practices on total uptake of nutrients by crops (wheat+mungbean+T. aman) under Wheat-Mungbean-T. aman cropping pattern at Madaripur.

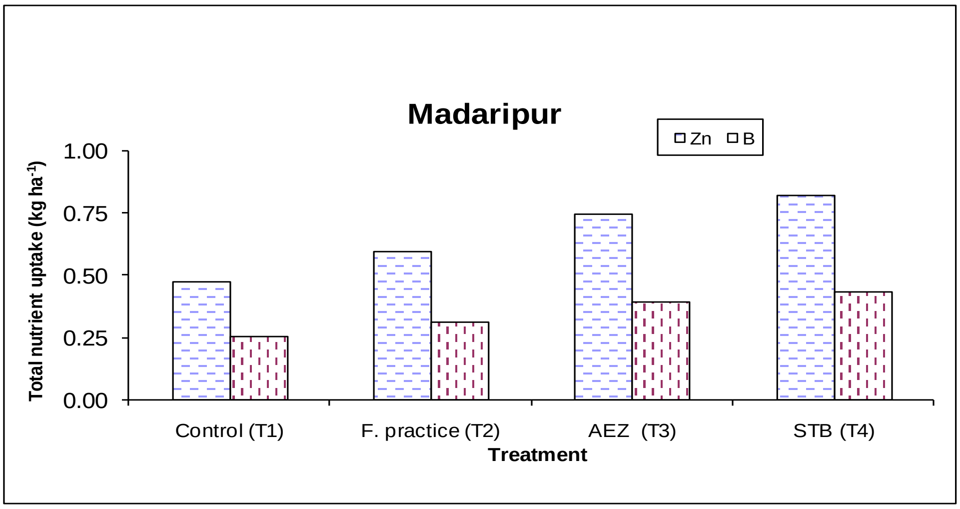

Fig. 2. Effect of fertilizer management practices on total uptake of zinc & boron by crops (wheat+mungbean+T. aman) under Wheat-Mungbean-T. aman cropping pattern.

Leaching of nutrients

Loss through leaching was taken into account only to T. *aman* rice. We assumed that there would be no loss of nutrients through leaching from the soil during wheat 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, Ca, Mg, Zn and B element through leaching. The loss of nutrients (average of two years) through leaching ranged from 0.30 to 0.71 kg P ha^{-1}, 3.29 to 11.9 kg K ha^{-1}, 1.57 to 4.35 kg S ha^{-1}, 15.3 to 20.5 kg Ca ha^{-1}, 9.66 to 10.6 kg Mg ha^{-1}, 0.05 to 0.12 kg Zn ha^{-1} and 0.10 to 0.37 kg B ha^{-1}. Katoh *et al.* (2003) reported that the amounts of nutrients leached by percolation ranged from 25-130 kg ha^{-1} Ca, 8-24 kg ha^{-1} Mg, from -1 to 9 kg ha^{-1} K, respectively were lost each year from the soil layer during rice cultivation. The highest and lowest values of nutrients were always found in T_4 and T_1 treatments, respectively (Table 5).

Table 5. Effect of nutrient management practices on nutrient loss through leaching under Wheat-Mungbean-T. *aman* cropping pattern (average of two years)

Treatment	P	K	S	Ca	Mg	Zn	B
	kg ha^{-1}						
Control (T_1)	0.30	3.29	1.57	15.3	9.66	0.05	0.10
F. practice (T_2)	0.60	8.60	2.49	18.1	10.4	0.06	0.10
AEZ (T_3)	0.66	11.1	3.93	18.9	10.5	0.11	0.35
STB (T_4)	0.71	11.9	4.35	20.5	10.6	0.12	0.37

Total input of nutrients

The nutrient input mainly from fertilizer but in this estimate, the nutrients supply from fertilizer, rainfall and irrigation under Wheat-Mungbean-T. *aman* cropping pattern. BNF was not considerd. Total input of nitrogen was 178-241 kg N ha^{-1} of which the major part was added through fertilizer application, except in control treatment. Phosphorus input ranged from 0.55 to 59.5 kg ha^{-1} yr^{-1} and K from 5.75 to 164 kg ha^{-1} yr^{-1} (Table 6). The S input varied from 3.26 to 52.6 kg ha^{-1} yr^{-1}, Ca and Mg input from 45.7 to 53.9 kg ha^{-1} yr^{-1} and 21.3 to 21.3 kg ha^{-1} yr^{-1}, respectively. Input of Zn ranged from 0.076 to 5.58 kg ha^{-1} yr^{-1}. Zinc and B input was estimated 0.076 to 5.58 kg ha^{-1} yr^{-1} and 0.34 to 3.84 kg ha^{-1} yr^{-1}, respectively (Table 6).

Table 6. Total input of N, P, K, S, Ca, Mg, Zn and B from fertilizer, rainfall and irrigation under Wheat-Mungbean-T. *aman* cropping pattern

Treatment	N	P	K	S	Ca	Mg	Zn	B
	2009-10	2009-10	2009-10	2009-10	2009-10	2009-10	2009-10	2009-10
	kg ha^{-1}							
Control(T_1)	0.00	0.55	5.75	3.26	45.7	21.3	0.076	0.34
F. practice(T_2)	178	49.5	52.8	3.41	51.7	21.3	0.076	0.34
AEZ (T_3)	171	40.5	51.8	26.5	51.3	21.3	2.076	0.84
STB (T_4)	241	59.5	164	52.6	53.9	21.3	5.58	3.84

Total output of nutrients

Output of nitrogen with the harvested product was about double time larger than the sum of inputs. We could not include N from leaching. The output of phosphorus is also moderate (21.4 to 39.2 kg P ha^{-1} yr^{-1}). The removal of potassium is 2 to 4 folds greater than the sum of inputs. The removal of calcium with the yield and leaching is greater than the sum of inputs. For magnesium, the nutrient removal with the yield and leaching is about two times larger than the sum of inputs. The output of nutrients (mean of two years) ranged from 183 to 305 kg N ha^{-1}, 21.4 to 39.2 kg P ha^{-1}, 151 to 235 kg K ha^{-1}, 11.0 to 22.9 kg S ha^{-1}, 53.2 to 81.0 kg Ca ha^{-1}, 38.0 to 57.0 kg Mg ha^{-1}, 0.52 to 0.94 kg Zn ha^{-1} and 0.36 to 0.83 kg B ha^{-1} (Table 7).

Table 7. Effect of nutrient management practices on total output (crop uptake and leaching loss) of nutrients by Wheat-Mungbean-T. *aman* cropping pattern (average of two years)

Treatment	N	P	K	S	Ca	Mg	Zn	B
	kg ha^{-1}							
Control (T_1)	183	21.4	151	11.0	53.2	38.0	0.52	0.36
F. practice (T_2)	234	28.1	188	15.0	64.0	45.0	0.65	0.40
AEZ (T_3)	277	35.0	219	20.2	74.0	52.0	0.85	0.75
STB (T_4)	305	39.2	235	22.9	81.0	57.0	0.94	0.83

Apparent nutrients balance

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 losses occurred through crop harvest and leaching. However, the nutrient balance did not account for the addition of N from rainfall, irrigation water, or gaseous losses of N or BNF. Apparent balance of N, P, K, S, Ca, Mg, Zn and B are shown in Figs. 03 & 04. The balance was mainly affected by different nutrient management practices. The apparent balance of N was negative in all the treatment and the soil depletion ranged from −56.0 to −183 kg N ha^{-1} yr^{-1}. Some researchers supported the results: in rice-maize system in Bangladesh, the apparent nutrient balances have been highly negative for N (–120 to –134 kg ha^{-1} yr^{-1}) (Timsina *et al*., 2010). 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. This evident indicated that P depletion was fewer amounts as compared added fertilizer. Saleque *et al.* (2006) expressed the same agreement.The balance of K was negative in all the treatments where the K mining ranged from −71.0 to −167 kg K ha^{-1} yr^{-1}. The maximum K depletion was observed in control plot and application of K gradually decreased the depletion with increasing rate. Bijay and Yadvinder (2002) observed that the depletion of K decreased with increasing rate of K application in soil. The negative S, Zn and B balance was observed in control and farmers practice treatments ranged from –7.74 to –11.6, -0.44 to -0.57 and –0.02 to –0.06 kg ha^{-1} yr^{-1}, respectively. Remaining treatments showed positive balance ranged from 6.30 to 29.7, 1.23 to 3.66 and 0.10 to 3.01 kg ha^{-1} yr^{-1}, respectively. Among the treatments, the maximum positive balance was observed in STB followed by AEZ treatment. Alam *et al.* (2000) observed that S balance was positive in soil due to integrated application of fertilizer and manure. The apparent balance for Zn and B was negative in the treatment of T_1 and T_2 and positive in T_3 and T_4 treatments due to their application. Similar results were also obtained by Hossain *et al.* (2008). Apparent balance for Ca and Mg was negative in all treatment. Calcium and Mg uptake was comparatively higher than that of supplied which got from soil, irrigation and rain water. The calcareous soil having more $CaCO_3$, but the Ca balance was negative; it might be due to less soluble form in high pH. Jensen and Thomas (2010) reported that soil pH greater than 7.2-7.5, phosphate ions tend to react quickly with Ca and Mg to form less soluble compounds. A long term study by Srinivasarao *et al*. (2014) on groundnut-fingermillet crop rotation, a negative balance to positive balance (–315 to 12.37 kg Ca ha^{-1} yr^{-1}) was found for Ca. On the other hand, Mg balance was found to be negative which ranged from –64 to –207 Kg Mg ha^{-1} yr^{-1}.

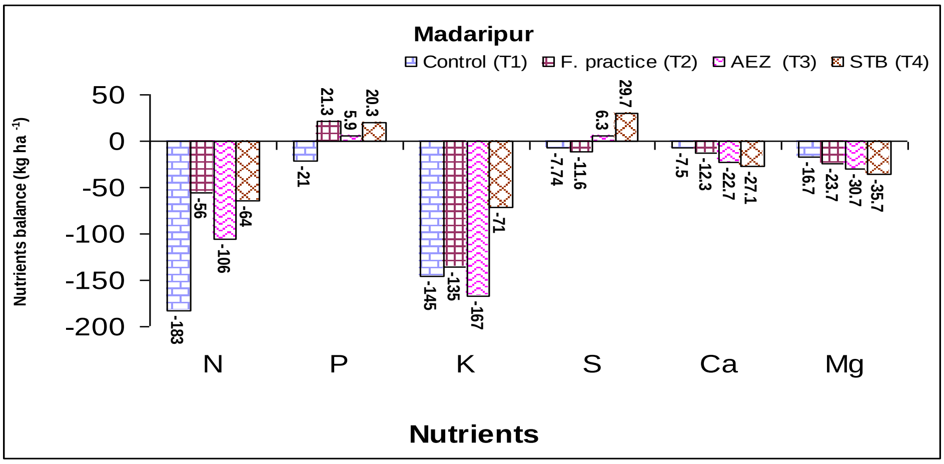

Fig.3. Apparent nutrient balance of N, P, K, S, Ca and Mg under Wheat-Mungbean -T. aman cropping pattern at Madaripur.

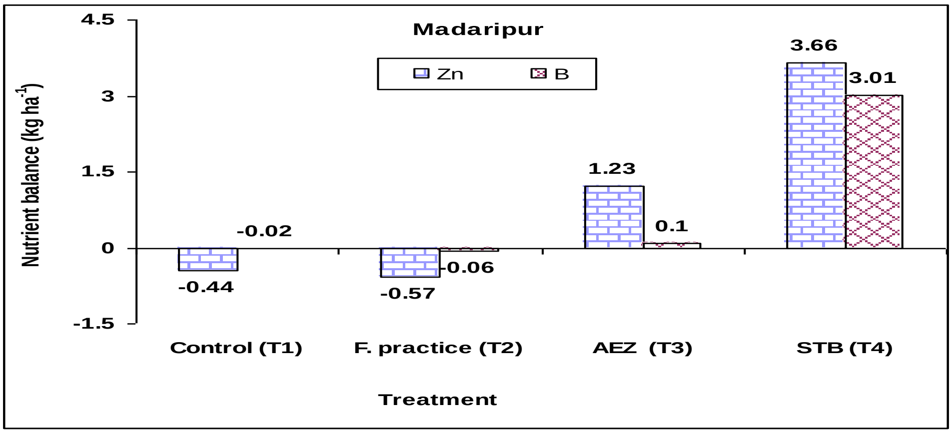

Fig. 4. Apparent nutrient balance of zinc and boron under Wheat-Mungbean -T. aman cropping pattern at Madaripur.

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 Wheat-Mungbean-T. aman cropping pattern for analyzing different soil properties viz. soil pH, organic matter, total N and available P, K, S, Ca, Mg, Zn and B. The initial and post harvest soil results are presented in Table 8. Initially the soil pH was 7.3, 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 based fertilizer application (T_4) tended to maintain the initial fertility or increased slightly (Table 8). Aggarwal *et al.* (1997) observed that the fertility of soil was improved due to incorporation of green manure into soil. The treatment T_4 showed an encouraging effect on organic matter, N, P, S, Ca, Zn and B only. Potasium (K) and Mg 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, but remained almost static or increase when applied (Table 8).

Table 8. Initial and post soil fertility status after two cycles of Wheat-Mungbean-T. aman cropping pattern due to different fertilizer management practices

Treatment	pH	OM (%)	Total N (%)	Ca	Mg	K	P	S	Zn	B
				Meq. 100 g^{-1}			µg g^{-1}			
Initial	7.3	1.32	0.063	10.3	3.10	0.14	13.5	18.0	1.20	**0.14**
Control(T_1)	7.3	1.31	0.062	10.0	2.99	0.11	13.8	17.6	1.17	**0.12**
F. practice(T_2)	7.3	1.35	0.064	10.3	3.00	0.12	14.3	18.0	1.17	0.12
AEZ (T_3)	7.2	1.38	0.065	10.3	3.02	0.12	14.3	18.3	1.26	0.14
STB (T_4)	7.2	1.40	0.068	10.4	3.02	0.13	14.5	19.0	1.34	0.16

Economic analysis

Gross returns varied in different treatments Wheat-Mungbean-T. *aman* cropping system which were directly related to the price that received from the product. The gross returns were highest (Tk. 263260 ha^{-1} yr^{-1}) in the treatment T_4 followed by T_3 and T_2 and the lowest was in control treatment (Table 8). Cost of cultivation was involved with wage rate, pesticides, irrigation and fertilizers cost. Data on cost and return analysis showed that the maximum gross margin (Tk. 173663 ha^{-1} yr^{-1}) was calculated from T_4 and minimum from T_1. The gross margin by T_4 was increased two fold over control (T_1) treatment due to get higher crop yield. Similar observation was showed by Malika *et al.* (2015). The highest benefit cost ratio (3.29) was obtained from T_3 followed by T_4 (2.94) and T_2 (2.88). Considering the benefit cost ratio (BCR) T_3 treatment showed ranked first followed by T_4. However, the cost of production of T_3 (Tk. 72881 ha^{-1} yr^{-1}) was lower than T_4 (Tk. 89595 ha^{-1} yr^{-1}).

Table 9. Economic analysis of Wheat-Mungbean-T.*aman* cropping pattern affected by different nutrient managements (after completing two years cycle)

Treatment	Variable cost	Gross return	Gross margin	BCR
	Tk. $ha^{-1}yr.^{-1}$			
Control(T_1)	59875	163699	103824	2.73
F. practice(T_2)	71549	206148	134599	2.88
AEZ (T_3)	72881	240062	167181	3.29
STB (T_4)	89595	263260	173663	2.94

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}, Wheat seed= Tk.25 kg^{-1}, Mungbean seed= Tk.60 kg^{-1}, T. aman rice seed= Tk.35 kg^{-1}.

Output prices: Wheat= Tk.18.75 kg^{-1}, Mungbean= Tk.55 kg^{-1}, T. aman rice= Tk.19 kg^{-1}, Wheat straw rate = Tk.1 kg^{-1}, Rice straw= Tk.1.25 kg^{-1}.

The BCR and gross margin was the highest in T_3 and T_4, respectively and economically viable. The fertilizer doses under T_3 were very low, hence its nutrients balance was highly negative after control. On the other hand, the fertility of soil remains almost static or increased slightly due to T_4 treatment. Therefore, considering the gross margin and soil fertlity the treatment T_4 is preferable to T_3.

Conclusion

The magnitude of negative balance was greater with N and K followed by Mg and Ca. 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 based fertilizer management practice (STB) is economically profitable and sustainable. Therefore, Wheat-Mungbean-T. *aman* cropping pattern is good in sustaining soil fertility and found economically sound and viable for Madaripur region in Bangladesh.

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