Bulgarian Journal of Agricultural Science, 24 (No 6) 2018, 992–1003

Soil test based with additional nutrients increased the fertility and productivity of wheat-mungbean-T. *Aman* rice cropping pattern in the High Ganges River Floodplain soils of Bangladesh

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Abstract

Das, S., Ali, M. M., Rahman, M. H., Khan, M. R., Hossain, A., EL Sabagh, A., Barutcular, C., & Akdeniz, H. (2018). Soil test based with additional nutrients increased the fertility and productivity of wheat-mungbean-T. *Aman* rice cropping pattern in the High Ganges River Floodplain soils of Bangladesh. *Bulgarian Journal of Agricultural Science*, *24*(6), 992–1003

Wheat-mungbean-T. *Aman* rice (W-M-R) is one of the most dominant cropping patterns in the High Ganges River Floodplain Soils (HGR; AEZ-11) of Bangladesh. However, the average yield of wheat, mungbean and T. *Aman* rice in the HGR is low compared to the other parts of the country, due to the majority of farmers grow wheat in the same land after harvest of T. *Aman* rice. One of the major causes of poor yield may be application of fertilizers considering single crop rather than whole cropping pattern. By considering this important issue, an experiment was conducted to find out an optimum and economic fertilizer dose for wheat-mungbean-T. *Aman* rice cropping pattern at Atgharia, Pabna (AEZ-11) of Bangladesh during 2011-2012 and 2012-2013. The initial soil of the experimental field was chemically analyzed and fertilizer doses for each crop were calculated on yield goal basis as per fertilizer recommendation for the location specific soils. There were eight treatments combination: T_1 = 100% NPK (STB – soil test-based nutrients management); $T_2 = T_1$+25% N; $T_3 = T_1$+25% NP; $T_4 = T_1$+25% NK; $T_5 = T_1$+25% PK; $T_6 = T_1$+25% NPK; T_7 = 75% of T_1 and T_8 = control (without fertilizers), where STB applied fertilizers for wheat ('BARI Gom 26') were 120-18-75-10-2-1 kg N-P-K-S-Zn-B ha^{-1}; for mungbean ('Binamoog-5') were 18-18-30-10-0.5 kg N-P-K-S-B ha^{-}1 and for T. *Aman* rice ('Binadhan-7') were 64-8-24-6 kg N-P-K-S ha^{-1}. After two years of research, the maximum yield of wheat was obtained in T_6 (T_1+25% NPK) treatment which was statistically higher than other treatments except T_3. While, both mungbean and T. *Aman* rice gave the maximum yield in treatment T_3 (T_1+25% NP) and the lowest was observed in control plot (T_8). Considering the economic point of view, the maximum net benefit was obtained from T_6 treatment (T_1+25% NPK) followed by T_3 (T_1+25% NP) and the maximum MBCR was also obtained from T_3 treatment. So, the fertilizer dose 150-23-94-10-2-1 kg N-P-K-S-Zn-B ha^{-1} for wheat, 23-23-30-10-0.5 kg N-P-K-S-B ha^{-1} for mungbean and 80-10-24-6 kg N-P-K-S ha^{-1} for T. *Aman* rice were recommended for higher yield and economic return for the W-M-R cropping pattern in HGR (AEZ-11) soil of Bangladesh.

Keywords: nutrient management**;** wheat; mungbean; T. *Aman* rice; cropping pattern

*List of the abbreviations:*AEZ-11 – Agro-ecological zone 11; BARC – Bangladesh Agricultural Research Council; BARI – Bangladesh Agricultural Research Institute; BBS – Bangladesh Bureau of Statistics; CRI – crown root initiation; FP – farmers' practice; FYM – farmyard manure; GM – green manure; GY – grain yield; HGR – High Ganges River Floodplain; IGP – Indo-Gangetic Plains; IPNS – integrated plant nutrition system; K – potassium; MoP – muriate of potash; MBCR – marginal benefit cost ratio; N – nitrogen; OC – organic carbon; OM – organic manure; P – phosphorous; PM – poultry manure; R-W – rice-wheat system; W-M-R – wheat-mungbean-rice cropping pattern; S – sulphur; SOM – soil organic matter; T. *Aman* – Transplanted *Aman* rice; STB – soil test basis; STVI – soil test value interpretation; TSP – triple super phosphate; UN – United Nations; WEY – wheat equivalent yield; Zn – zinc.

Introduction

Among the production system in agriculture, the highest agricultural production obtained from rice-wheat system. It occupies about 26 million ha and mostly spread over Indo-Gangetic Plains (IGP) in the South Asia (12.37 million ha) and China (Balasubramanian et al., 2012). It covers highest in India (9.2 million ha), where 2.2 million ha in Pakistan, 0.55 million ha in Nepal and 0.4 million ha in Bangladesh which is extended upto the Himalayan foothills (Timsina et al., 2010). Rice is the staple food for Bangladesh and demand of wheat is increasing and thus rice-wheat system grain production covers 97% of grain (BBS, 2012; Mainuddin and Kirby, 2015) and national calorie intake from this production system is 94% (Timsina and Connor, 2001; Hossain and Teixeira da Silva, 2013). Research argued that food demand will be 75-100% additional production to feed the world population in next 2050 (Tilman et al., 2011; Tilman et al., 2017) where Sub-continent area will demand higher. According to the medium variant UN projection (UN, 2015), Bangladesh' population will further increase to 186 and 202 million by the years 2030 and 2050, respectively (Timsina et al., 2018). As the demand of grain is increasing along with the increase in population, it is very much necessary to investigate for present constrain of increasing production of rice as well as wheat and cropping pattern based production that are presently practiced (BBS, 2012).

Although the scope of expanding agricultural land is very much limited in south Asia but intensification could open a new window to increase production of cereal crops. Therefore, crop intensification along with increasing resource-use efficiency and reducing the environmental footprint or 'ecological intensification' (Hochman et al., 2013).The soil organic matter content is low soil's in the IGP and are being consistently depleted of their finite reserve of nutrients by crops, although the R-W production system generates a large amount of crop residues annually in the IGP, but soils contain low organic matter content and are being consistently depleted of their finite reserve of nutrients by crops (Singh et al., 2004). The straw (rice & wheat) is being removed from the field traditional by the farmer for use as cattle feed and several other purposes such as livestock bedding, thatching material for houses and bio-fuel (Samra et al., 2003).

In contrast, use of only chemical fertilizers for nutrient management in R-W systems has lot of information (Hossain et al., 2016) but indiscriminate use of this fertilizers without nutrient recycling has led to an immense loss of soil fertility and productivity (Ram, 2000). As a result, R-W system has been mining the major nutrients (nitrogen, phosphorus, potassium and sulphur) thus creating a nutrient imbalance which leading to soil deterioration through declining SOM (Alam et al., 2013). Therefore, the productivity of the R-W system is decreasing with deficiencies in N, P, and K being the most extensive (Hossain et al., 2016; Jahan et al., 2016). Crop intensification with modern varieties and nutrient leaching with monsoon rains caused a marked depletion of nutrients from the soil of R-W system. To maintain and improve soil fertility, it is high time to take a serious view of this potential danger to the productivity of our soils.

It is well documented that the addition of legume crops as GM or grain legumes in the R-W cropping system is more beneficial rather than a simple R-W sequence (Singh et al., 2011). Legume crop is very important not only for biological nitrogen fixation, but it can also improve nutrient availability, soil structure, reduce the incidence of disease and promote mycorrhizal colonization (Hossain et al., 2016; Jahan et al., 2016). Mungbean crop can establish a symbiotic association with specific bacteria setting up the biological N fixation in root nodules that supply plants needs for N as result improves the fertility status of soil through atmospheric N fixation (Zahran, 1999).

Although, fertilizers are essential part of present farming and about 50% of the world's crop production depend on fertilizer use (Pradhan, 1992), nevertheless, one of the alternatives to economize their use is to apply balanced fertilizers for crop production. The sustainable and higher crop production might be possible through the taking proper cropping pattern and management of fertilizer. Soil test and judicious application of fertilizers target yield of crops is one of the approaches to overcome the problem of nutrient mining from soils. Whereas, in the HGR soil (HGR; AEZ-11), T. *Aman* rice is the main crop grown in rainfed condition during the *kharif* season. Wheat-mungbean-T. *Aman* rice (W-M-R) is one of the most dominant cropping pattern in this area. This cropping system has great potentialities to fulfill the gap between food production and food requirement. The average yield of wheat and T. *Aman* rice in the HGR is low compared to the other parts of the country. The majority of farmers grow wheat in the same land after harvest of T. *Aman* rice and apply fertilizer on single crop basis rather than whole cropping pattern. But some of the nutrients have considerable residual effect on the succeeding crops. Considering the above points of view, the present study was, therefore, undertaken to determine fertilizer requirement for W-M-R cropping pattern in AEZ-11.

Materials and Methods

Experimental site

An experiment based on a two-year W-M-R cropping sequence was established at Atgharia, Pabna (28°22′N; 88°39′E; 20 m.a.s.l.) during 2011-12 to 2012-13. The experimental site belongs to the agro-ecological zone of the High Ganges River Floodplain (AEZ-11) (FRG, 2012). Physical, morphological and chemical properties of AEZ-11's soils are available in Table 1 and 2 (FRG, 2012; Hossain et al., 2016). Monthly record of rainfall, mean daily minimum and maximum temperature, and relative humidity (%) for the period of experiment are presented in Fig. 1.

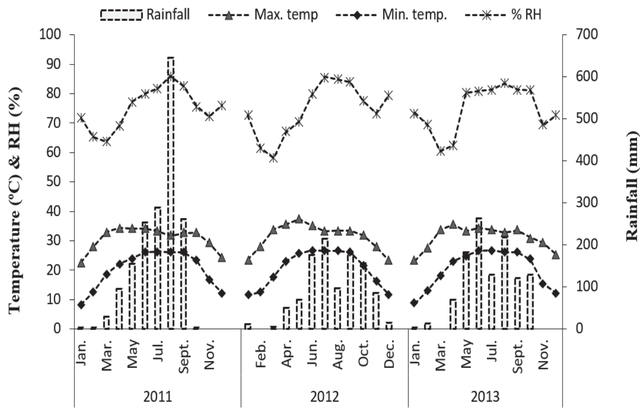

Fig. 1. Agro-climatic condition during two W-M-R cropping cycles (2011-12 & 2012-13) at Atgharia, Pabna (AEZ-11)

Experimental design and treatments

The experiment was laid out in a randomized complete block design (RCBD). There were eight treat-

Table 1. Soil physical and chemical characteristics of the experimental sites in the AEZ-11 and adjoining regions

Profile	Sand (%)	Silt (%)	Clay (%)	Stone	pH	CEC (meq/100g)	EC (ds/m)	OC (%)	Total N (%)	Moisture (%)	NO_3 (mg/kg)	NH_4 (mg/kg)
20	30	40	30	0	7.5	17.5	0.2	1.5	0.12	0.22	10	5
40	25	43	32	0	7.2	15.3	0.17	1.2	0.09	0.24	9	6
80	20	45	35	0	6.8	11.2	0.11	0.9	0.07	0.26	7	7
150	18	50	32	0	6.2	8.00	0.06	0.3	0.02	0.28	5	5

CEC – cation exchange capacity; EC – electric conductivity; OC – organic carbon
Source: (Hossain et al., 2016)

Table 2. Physical and morphological characteristics of the types of soil in experimental fields

AEZ-11	Extent (km²)	Land type (%)	Organic matter	Fertility status	Physiological ccharacteristics of the soil
High Ganges River Flood Plain	13205	High – 43%, Medium high – 32% Medium low – 12% Others – 13%	Low	Low	General soil type – calcareous dark grey Topography – medium high land Drainage – well drained Flood level – above flood level Colour – dark grey

Source: (FRG, 2012)

ments, i.e. T_1=100% STB; T_2=T_1+25% N; T_3=T_1+25% NP; T_4=T_1+25% NK; T_5=T_1+25% PK; T_6=T_1+25% NPK; T_7=75% of T_1 and T_8 = control, each treatment replicated three times, where STB applied fertilizers for wheat ('BARI Gom 26') were 120-18-75-10-2-1 kg N-P-K-S-Zn-B ha^{-1}, for mungbean ('Binamoog-5') were 18-18-30-10-0.5 kg N-P-K-S-B ha^{-1} and for T. *Aman* rice ('Binadhan-7') were 64-8-24-6 kg N-P-K-S ha^{-1} (Table 3).

Table 3. Soil test-based nutrients management for two years W-M-R cropping pattern

Crops	Variety	N	P	K	S	Zn	B
		kg ha^{-1}					
Wheat	BARI Gom 26	120	18	75	10	2	1
Mungbean	Binamoog-5	18	18	30	10	0	0.5
T.*Aman* Rice	Binadhan-7	64	8	24	6	0	0

Treatments details: T_1 = 100% STB (soil test based), T_2 = T_1 + 25% N, T_3 = T_1 + 25% NP, T_4 = T_1 + 25% NK, T_5 = T_1 + 25% PK, T_6 = T_1 + 25% NPK, T_7 = 75% of T_1, T_8 = control (without fertilizers)

Crop and soil management

Before transplantation the land was well prepared by ploughing, cross ploughing and uniformly leveled by laddering. In that cropping system, only rice was transplanted by hand into well-puddled soil, and all other crops were sown by hand. Wheat (cv. 'BARI Gom 26'), mungbean (cv. 'Binamoog-5'), T. *Aman* rice (cv. 'Binadhan-7') were planted with 20 cm row spacing for wheat, 30 cm × 10 cm for mungbean, and 20 cm×15 cm for rice. Wheat was sown in late November, mungbean in early April, and rice was transplanted in early to mid-July in each year. Fertilizer was applied to each plot as per treatment. Fertilizers TSP (triple super phosphate), MoP (muriate of potash), gypsum and Zn (zinc sulphate) were applied as basal to each individual plots during final land preparation. For rice, all fertilizers except N was broadcast and incorporated at the time of final land preparation. Nitrogen was broadcast in three equal splits at 15, 30 and 45 days after transplanting. For wheat, full dose of all fertilizers and two-thirds of N were applied at sowing time. The remaining N was top-dressed at crown-root initiation stage (CRI), 17-21 days after sowing (DAS), i.e. immediately after first irrigation. At each year wheat received three irrigations of approximately 75 mm each at CRI (17-21 DAS), booting stage (50-55 DAS), and grain filling (70-75 DAS) stages. Necessary intercultural operations were done as and when necessary. The crop was harvested at maturity. The harvested crop from each plot was bundled separately and brought to the threshing floor. The crops were threshed, cleaned and processed. Then, grain and straw were sundried and stored for chemical analysis. The yield component information was noted on randomly selected 10 plants of each plot. The moisture content of grain was 10-12% during storage.

Yield measurement

According to treatments, all crops in W-M-R cropping pattern were harvested at full maturity. However, to avoid border effects sample plants for each crop were harvested separately in the center of each plot from an area of 6 m^2. The harvested sample crop of each plot was bundled separately, tagged and placed on a threshing floor. Then, the bundles were dried in bright sunshine, then weighed and threshed. Moisture content of the grain was measured by a moisture meter. Grain yield (GY) for wheat and grain legumes (mungbean) was measured at 12% moisture and rice grain at 14% moisture from the sample grain of harvested area and expressed as t ha^{-1}.

Economic of wheat equivalent yield

The productivity of wheat, mungbean and rice in W-M-R cropping sequences was calculated as wheat equivalent yield (WEY), since wheat was considered the main crop of the pattern (Singh et al., 2011). WEY was calculated by using the following formula (Ahlawat and Sharma, 1993):

$$\text{WEY} = \frac{\text{Yield of each crop (tha}^{-1}\text{)} \times \text{Economic value of perspective crop (amount of money t}^{-1}\text{)}}{\text{Price of wheat grain (amount of money t}^{-1}\text{)}},$$

where, prices of wheat grain was considered 0.26 US$ kg^{-1}; rice grain, 0.19 US$ kg^{-1}; seed of mungbean, 0.78 US$ kg^{-1}; wheat straw, mungbean stover, rice straw, 0.01 US$ kg^{-1}.

Chemical analyses of soil and plant sample

The initial soil (i.e., before land preparation) and post-harvest soil (i.e., after the harvest of each crop) were collected at a depth of 0-15 cm from different randomly selected spots of the experimental fields and prepared a composite sample. Then the composite soil sample was air dried, ground with mottle pestle and passed through a 2 mm sieve. However, some initial soil was kept in a deep freezer (-5°C) for ensuing analysis after end of the two-year crop cycles. Soil physical and chemical properties were determined in the laboratory of Soil Science Division at Bangladesh Institute of Nuclear Agriculture, Mymensingh. Soil chemical properties such as pH, organic matter (OM) (%), total available N (%), P, K and S were measured (Table 4).

The soil pH was determined with the help of a glass electrode pH meter, the soil-water ratio being 1:2.5, as stated by Jackson (1962). Organic carbon content of soil was determined following wet digestion method (Walkley and Black, 1935). Organic matter was calculated by multiplying the percent organic carbon with the van Bemmelen factor, 1.724. Total N content of soil was assessed by the Micro-Kjeldahl method (Bremner and Mulvaney, 1982) being digestion with conc. H_2SO_4 and distillation using 40% NaOH. The ammonia which evolved was taken in a boric acid indicator and was titrated against 0.02 N H_2SO_4 (Black et al., 1965). Available P content was extracted from soil with 0.5M $NaHCO_3$ solution at a pH 8.5 (Watanabe and Olsen, 1965). A digital Spectronic 21D spectrophotometer (model EW-02650-24D, Milton Roy, Houston, TX, USA) was used to determine the color developed by the ascorbic acid method as described by John (1970). Exchangeable K content of soil was determined by extraction with 1M NH4OAc, as stated by Jackson (1973) and followed by a measurement of K using a model 55B atomic absorption spectrophotometer. And, available S content of soil was determined by extracting soil sample with 0.01 M Ca $(H_2PO_4)_2$. The S content in the extract was assessed turbidimeterically and the turbid was measured by the model EW-02650-24D spectrophotometer at 420 nm (Page et al., 1982).

The plant samples (grain and straw) were analyzed for the determination of N, P, K and S contents. Both samples were dried in an oven at 65°C for about 48 hours and then ground by mottle pestle passed through a 20 mesh sieve. The ground samples were stored in small paper bags and placed in desiccators for the analysis of different elements. Plant sample was analysis according to Jahan et al. (2016) and Hossain et al. (2016).

Statistical analysis

The collected data of experiment measured in crops for each year were done using statistical programe MSTAT and mean differences were compared by Duncan's Multiple Range Test (Gomez and Gomez, 1984). Mean comparisons of the treatments were determined by the Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results

Soil test-based with additional nutrients influenced the productivity of W-M-R cropping sequence

Wheat

The yield of wheat at Atgharia, Pabna (AEZ#11) during *Rabi* 2011-12 and 2012-2013 are shown in Table 5. During 2011-12, the highest grain yield (4.2 t ha^{-1}) was obtained from T_6 treatment (100% STB management with additional 25% NPK applied plots) which was statistically different than other treatments except T_3 (3.9 t ha^{-1}). Regarding straw, the highest yield was obtained from treatment T_3 (T_1+25% NP) which differed statistically with all other treatments. During 2012-13, the highest grain yield (4.01 t ha^{-1}) was obtained from treatment T_6 (T_1+25% NPK) which was significant over all other treatments except T_4 (3.94 t ha^{-1}). It was noted that treatment T_6 showed highest straw yield which was statistically similar to T_5 treatment. The treatment T_8 produced lowest yield in both years.

Mungbean

In case of mungbean, year specific remarkable difference in yield was obtained among the treatments (Table 5). The highest yield (2.31 t ha^{-1}) was recorded from STB nutrients management with additional 25% NPK applied plots (T_6) and it was statistically identical with other treatments except T_7 and T_8 and the lowest in control, T_8 (1.68 t ha^{-1}) during 2011-12. While in the year 2012-13, the maximum yield of mungbean (1.89 t ha^{-1}) was recorded in treatment T_3 which was similar with treatments $T_{1,}$ $T_{2,}$ T_5 and T_6 and the lowest yield was recorded from T_8 treatment. Whereas, the highest stover yield was recorded in T_5 (6.15 t ha^{-1}) which was significantly higher than other treatments except T_2 (Table 5).

T. Aman rice

In T. *Aman* rice, result showed that application of N, P, K on the basis of STB with extra addition of their according proportion statistically is influenced by the grain and straw yield of T. *Aman* rice in W-M-R cropping pattern in both the years (Table 5). In the first year (2011-12), the highest grain yield was obtained from STB with ad-

Table 4. Initial soil physical and chemical properties of experimental fields

Items	Soil texture (loamy)			pH	OM (%)	N (%)	P (mg kg^{-1})	K (cmol kg^{-1})	S (mg kg^{-1})
Initial soil	Sand (49.6%)	Silt (32.0%)	Clay (18.4%)	7.0	1.76	0.088	11.88	0.15	18.40
Critical level	–	–	–	–	–	0.12	10.00	0.12	10.00

Table 5. Grain and straw yield (t ha^{-1}) of wheat, mungbean and T. *Aman* rice as influenced by combination of different fertilizers management in W-M-R cropping pattern at Atgharia, Pabna (AEZ-11)

Treatments	2011-12					2012-13					
	Wheat		Mungbean	T. *Aman* rice		Wheat		Mungbean		T. *Aman* rice	
	Grain	Straw	Seed	Grain	Straw	Grain	Straw	Seed	Stover	Grain	Straw
T_1=100% (STB)	2.8d	5.0e	2.1ab	4.0bc	5.18cd	3.55d	5.32d	1.84ab	5.28cd	4.18d	5.13d
T_2= T_1+ 25% N	3.4bcd	6.5bc	2.2ab	4.7ab	6.42a	3.71c	5.62c	1.88a	5.91ab	4.32cd	5.70b
T_3= T_1+25% NP	3.9ab	7.9a	2.2a	4.7a	6.50a	3.70c	5.70c	1.89a	5.52bc	4.66b	5.49c
T_4= T_1+25% NK	3.5bc	6.9b	2.2ab	4.2abc	5.48bc	3.94ab	5.87b	1.77b	5.58bc	4.90a	5.91a
T_5= T_1+25% PK	3.4bcd	5.8cd	2.2ab	4.7ab	5.83abc	3.88b	6.29a	1.83ab	6.15a	4.41c	5.78b
T_6=T_1+25% NPK	4.2a	6.8b	2.3a	4.6ab	6.25ab	4.01a	6.37a	1.85ab	5.45bc	4.43c	5.50c
T_7= 75% of T_1	2.9cd	5.7de	1.9bc	3.7c	4.50d	2.64e	4.23e	1.76b	4.91d	3.28e	4.87e
T_8= Control	1.7e	3.3f	1.7c	2.2d	2.58e	0.90f	1.78f	1.53c	2.67e	2.13f	2.59f
CV (%)	9.9	6.9	9.1	9.8	8.6	1.3	1.2	3.0	4.7	4.8	4.0

In a column figures with same letters or without letters do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT

ditional 25% NP nutrients management plots (T_3), which was statistically similar with T_2, T_4, T_5 and T_6. Similarly, the maximum straw yield was also observed in treatment T_3 (T_1+25% NP), followed by T_2, T_5 and T_6 treatments. In the second year (2012-13), the maximum grain yield of T. *Aman* rice in W-M-R cropping pattern was found from (STB with additional 25% NK nutrients management plots (T_4), which varied significantly with other treatments and the lowest was found in control plot. Similarly, the highest straw yield was also recorded from T_4 (T_1+25% NK) treatment, that was also differed statistically with other treatments (Table 5).

System productivity of W-M-R cropping pattern

Cropping pattern with legume which included three crops produced higher WEY than only two-crop sequence without legume. However, in most of the treatment, maximum WEY was observed in first year than second year (Table 6). In first year, the highest WEY was recorded in STB with additional 25% NPK applied plots (14.58 t ha^{-1}), while in second year the maximum WEY was found in STB with additional 25% NK applied plot. Although, WEY in both the years was statistically similar in the treatments T3 and T6. The lowest WEY was found in control treatment in both the years. However, with little exception, other treatment showed statistically similar WEY yield in both the years in W-M-R cropping pattern (Table 6).

Soil test-based with additional nutrients influenced the soil fertility status of W-M-R cropping sequence

The changes in soil pH, organic matter and different nutrients (N, P, K and S) due to the use of soil test based as well as with additional extra nutrients in two years W-M-R

Table 6. System productivity of W-M-R cropping pattern as influenced by combination of different fertilizers management in W-M-R cropping pattern at Atgharia, Pabna (AEZ-11)

Treatments	Economic yield of wheat (t ha^{-1})		Economic yield of mungbean (t ha^{-1})		Economic yield of rice (t ha^{-1})		System *WEY (t ha^{-1})	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
T_1=100% STB	2.84d	3.55d	2.10ab	1.84ab	4.00bc	4.18d	12.14	12.21
T_2= T_1+ 25% N	3.38bcd	3.71c	2.20ab	1.88a	4.67ab	4.32cd	13.48	12.59
T_3= T_1+25% NP	3.94ab	3.70c	2.24a	1.89a	4.71a	4.66b	14.19	12.87
T_4= T_1+25% NK	3.50bc	3.94ab	2.21ab	1.77b	4.22abc	4.90a	13.30	12.93
T_5= T_1+25% PK	3.42bcd	3.88b	2.16ab	1.83ab	4.67ab	4.41c	13.40	12.68
T_6= T_1+25% NPK	4.18a	4.01a	2.31a	1.85ab	4.63ab	4.43c	14.58	12.88
T_7= 75% of T_1	2.92cd	2.64e	1.85bc	1.76b	3.72c	3.28e	11.26	10.38
T_8= Control	1.67e	0.90f	1.68c	1.53c	2.20d	2.13f	8.36	7.09
CV (%)	9.90	1.27	9.11	3.01	9.82	4.78	–	–

* Wheat equivalent yield. In a column figures with same letters or without letters do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT

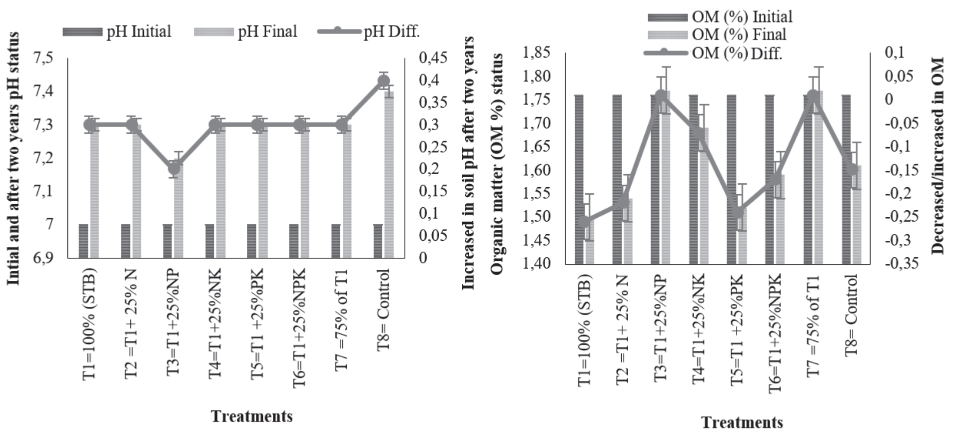

Fig. 2. Change in soil pH value and organic matter in two years W-M-R cropping pattern at Atgharia, Pabna (AEZ-11) as compared with initial value (bars indicate ±SE)

cropping pattern (Fig. 2 to 6).While, most of the treatments appeared an increasing tendency in soil pH and N, P, K and S contents except a minor decrease in organic matter content. In general, without any nutrient management (control treatment) had decreasing tendency of nutrient status compare with initial value (Fig. 2 to 6). Soil pH was not varied by STB based nutrients management in combination with extra nutrients management (Fig. 2). After two cycles, a very small decrease (but not significant) in soil pH was observed in W-M-R cropping sequences compared to the initial value. As compared with initial value, SOM had decreasing tendency in all treatments except T_3 and T_7 (1.77 and 1.77) (Fig. 2). While, total N content (%) in the soil of W-M-R cropping pattern showed an increasing trend. As compared with initial total N (%), the maximum N was deposit in T_6 (0.116) and T_4 (0.115). However, in control plot total N content was unchanged after two years crop cycle (Fig. 3). Similarly, P, K and S content in the soil of W-M-R cropping pattern were deposited after two years crop cycle, except K and S in control plot (Fig. 3, 4). The maximum P was deposited in the soil of T_1 treatment, followed by T_6. In case of K and S, the maximum deposited was found in T_4, followed by T_2, whereas negative value was recorded in control plot in both the years.

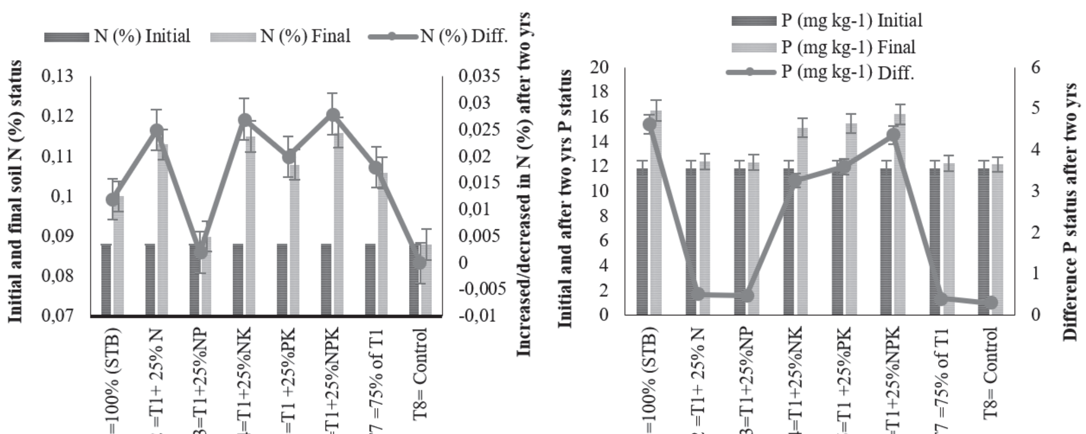

Fig. 3. Change in soil (N %) and P status in two years W-M-R cropping pattern at Atgharia, Pabna (AEZ-11) as compared with initial value (bars indicate ±SE)

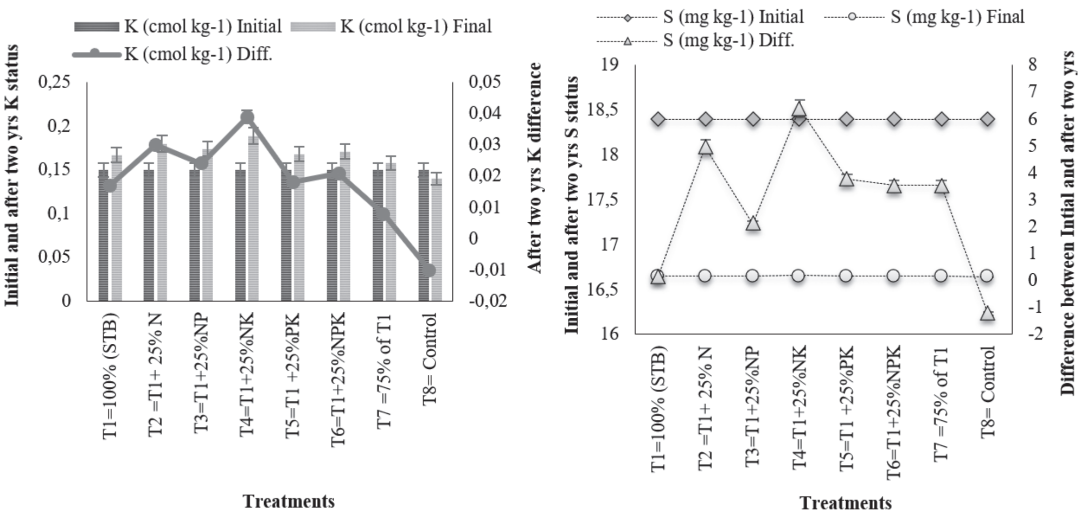

Fig. 4. Change in soil K and S status in two years W-M-R cropping pattern at Atgharia, Pabna (AEZ-11) as compared with initial value (bars indicate ±SE)

Soil test-based with additional nutrients influenced the nutrients uptake of W-M-R cropping sequence

The nutrients (N, P, K and S) uptake by the crops of W-M-R cropping pattern were calculated for different nutrients management treatments (two-year mean data) and discussed in detail next (Fig. 5, 6). Two years of present study indicated that nutrient uptake in different nutrients management treatments varied significantly as compared with control treatment. Considering on N uptake, maximum uptake was recorded in the treatment where STB nutrients with extra 25% N, P, K was applied (T_6), followed by STB nutrients with extra 25% N, P treatment (T_3). Indicated that extra 25% NP help to increase the uptake of N to plants in W-M-R cropping pattern. Similarly, both P and K uptake was higher in T_6 treatment, followed T_5 and T_4 in both the years. Whereas, STB nutrients management with extra addition 25% NK (T_4) help to increase the uptake S by plants in W-M-R cropping pattern, by T_5 and T_6 treatments (Fig. 5, 6).

Overall economic performance in the W-M-R cropping pattern

From the average yields (Table 7), the results of partial budget analysis of W-M-R cropping pattern showed the highest net benefit of 3419 US$ ha^{-1} was obtained in T_6 (T_1+25% NPK) followed by 3413US$ ha^{-1} in T_3 treatment. The highest MBCR (3.59) was also obtained from T_3 followed by T_2 (3.44) and T_6 (3.42). Based on the most profitable STB nutrients management, 150-23-94-10-2-1 kg N-P-K-S-Zn-B ha^{-1} for wheat, 23-23-30-10-0.5 kg N-P-K-S-B ha^{-1} for mungbean and 80-10-24-6 kg N-P-K-S ha^{-1} for T. *Aman* rice were recommended for maximizing the productivity and economically profitable and viable nutrient management for the W-M-R cropping pattern in HGR (AEZ-11) soils of Bangladesh (Table 7).

Discussion

Two years' weather condition during the time of experiment at AEZ#11

During the time of experiment maximum rainfall was recorded from April to September in both the growing seasons of W-M-R cropping pattern and the minimum rainfall was observed at November to February. Similarly, relative humidity was also recorded as maximum at April to September and was minimum at November to March. Whereas, maximum temperature was recorded from March to September and minimum was December to February in both the growing season. Indicated that weather condition in both the growing season were favourable for wheat, mungbean and rice (Fig. 1).

Initial soil chemical properties

Texturally the soil was loamy with sand 49.6%, silt 32.0%, clay 18.4%, pH 7.0, organic matter 1.76%, total N – 0.088%, available P – 11.8 mg kg^{-1}, available S – 18.4 mg kg^{-1} and exchangeable K – 0.15 cmol kg^{-1} contents (Table 4).

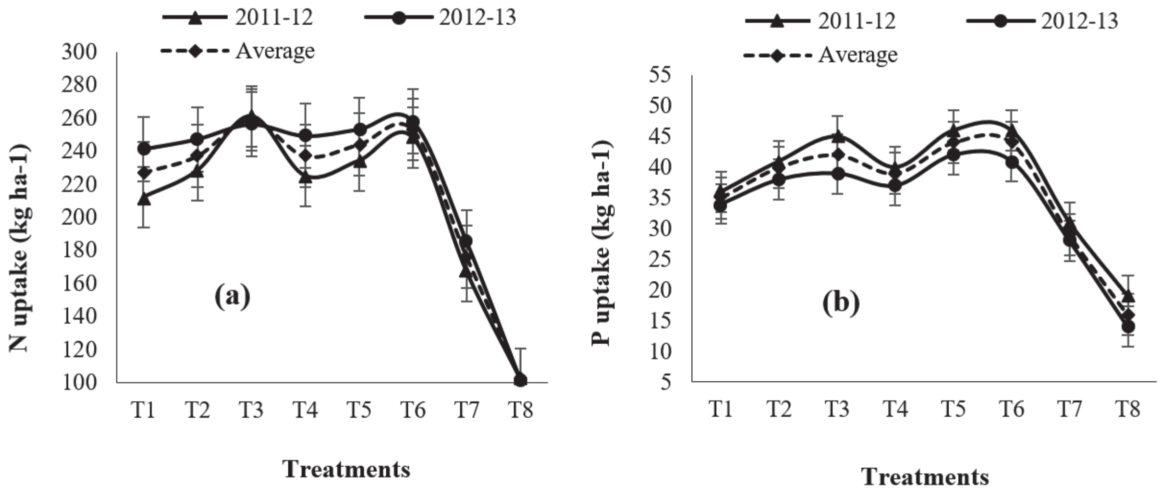

Fig. 5. N (a) and P (b) uptake in two years wheat-mungbean-rice (W-M-R) cropping pattern at Atgharia, Pabna (AEZ-11) as compared with initial value (bars indicate ±SE)

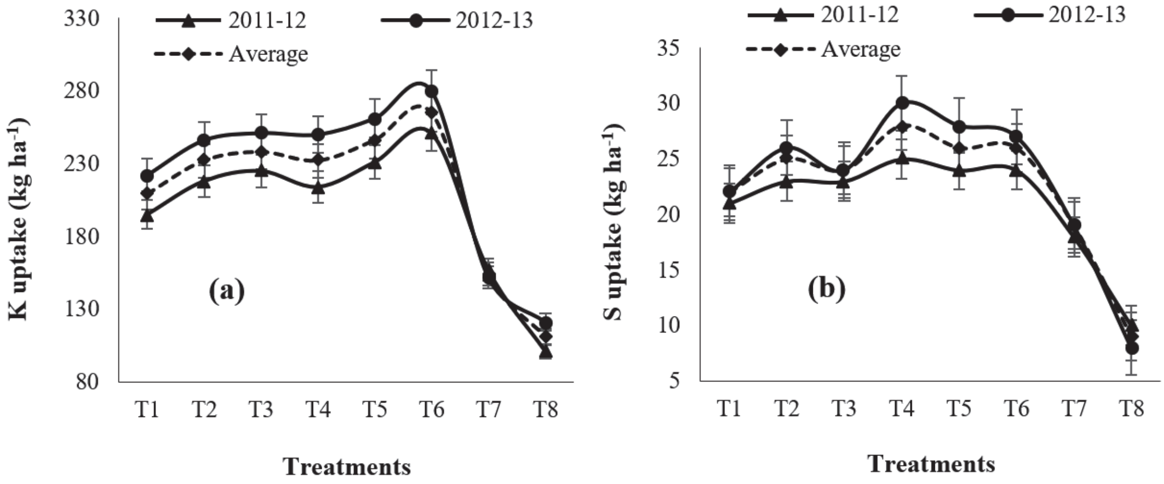

Fig. 6. K (a) and S (b) uptake in two years W-M-R cropping pattern at Atgharia, Pabna (AEZ-11) as compared with initial value (bars indicate ±SE)

Soil test-based with additional nutrients increased the productivity of W-M-R cropping pattern

In the HGR soils (AEZ-11), W-M-R cropping patter is one of the most dominant cropping pattern in this area, where T. *Aman* rice is grown in rainfed condition during the *kharif* season (Hossain et al., 2016).Therefore, this cropping system has great potentialities to produce higher crop for increasing population as rice is the main food crop then wheat (Timsina et al., 2018). However, the average yield of wheat and T. *Aman* rice in the HGR is low as compared to the yield of other district. Although, some of the nutrients have residual effect on the succeeding crops, but most of the farmers cultivate wheat in the same land after harvest of T. *Aman* rice and apply fertilizers on single crop basis rather than whole cropping pattern. As a result, soil fertility and productivity are declining day by day and also increasing farmers' production cost. In the present study, significant variation of grain and straw yield of wheat, mungbean and rice, and their system yield were observed in W-M-R cropping pattern under STB with additional extra nutrients management treatments (Table 5, 6). It might be due to plot/treat-

Table 7. Economic performance of W-M-R cropping pattern over two years after soil test-based applying different nutrient management at Atgharia, Pabna (AEZ-11)

Treatments	Average (2011-12 & 2012-13)						Gross return	Fertilizers' cost	Net return	Marginal return	MBCR
	Wheat		Mungbean		T. *Aman* rice		(US$ ha^{-1})				
	Grain	Straw	Seed	Stover	Grain	Straw					
T_1=100% (STB)	3.2	5.18	1.97	5.28	4.09	5.16	3366	310	3056	942	3.04
T_2=T_1+ 25% N	3.55	6.06	2.04	5.91	4.50	6.06	3622	340	3283	1169	3.44
T_3=T_1+25% NP	3.82	6.79	2.1	5.52	4.69	5.60	3775	362	3413	1299	3.59
T_4=T_1+25% NK	3.72	6.38	1.99	5.58	4.56	5.70	3635	359	3276	1162	3.24
T_5=T_1 +25% PK	3.65	6.06	1.99	6.15	4.54	5.81	3617	352	3265	1151	3.27
T_6=T_1+25% NPK	4.1	6.56	2.08	5.45	4.53	5.88	3801	381	3419	1305	3.42
T_7=75% of T_1	2.78	4.97	1.81	4.91	3.50	4.69	3004	239	2765	651	2.73
T_8= Control	1.29	2.56	1.61	2.67	2.17	2.59	2114	-	2114	-	-

All US$ values refer to US$ amounts. Prices: wheat grain – 0.26 US$ kg^{-1}; rice grain – 0.19 US$ kg^{-1}; seed of mungbean – 0.78 US$ kg^{-1}; wheat straw, mungbean stover, rice straw – 0.01 US$ kg^{-1}. Fertilizers nutrients: N – 0.58 US$ kg^{-1}; P – 1.95 US$ kg^{-1}; K – 0.65 US$ kg^{-1}; S – 0.71 US$ kg^{-1}; Zn – 1.32 US$ kg^{-1}; B – 11.45 US$ kg^{-1}, MBCR – marginal benefit cost ratio

ment/site specific additional nutrients help to increase the biomass production of specific crop that ultimately lead the final grain production. The assumption of the present study is also confirmed by earlier study as reported by Timsina et al. (2006); Panaullah et al. (2006); Saleque et al. (2006); Rafique et al. (2012) and Dobermann et al. (2013). They reported that site-specific plant nutrient management (SSNM, equivalent to STB in our study) can improve yield as well as nutrient use efficiency of crop rotation and reduce yield gap. They also reported that in some areas, SSNM may be farm-specific, but in many areas it is likely to simply be specific to a region or a crop season. Similarly, Hossain et al. (2016) and Jahan et al. (2016) noticed that in agro-ecologically specific area, soil nutrient status should be considered during nutrient management along with good management practices for increase crop yield. Fertilizer recommendation guide, 2012 (FRG, 2012) was developed by BARC in collaboration with different crop research institutes and was prepared for specific crops on the basis of site-specific soil test values as well as agro-ecological conditions in Bangladesh which is widely used by the farmers. Despite this, these recommendations sometimes do not produce higher crops in specific areas. In this study, we found that STB based management in combination with other nutrient management practices were better for sustainable crop production as well as increased the fertility status of W-M-R cropping pattern than STB recommendation alone (Tables 5, 6; Fig. 2-6).

Conclusions

An appropriate combination of fertilizer is critical and important for crop production system. From the results of this investigation, it may be concluded that nutrients combination 150-23-94-10-2-1 kg N-P-K-S-Zn-B ha^{-1} for wheat, 23-23-30-10-0.5 kg N-P-K-S-Zn-B ha^{-1} for mungbean and 80-10-24-6 kg N-P-K-S ha^{-1} for T. *Aman* rice could be recommended for higher yield and economically profitable for the W-M-R cropping pattern in HGR (AEZ-11) soil of Bangladesh.

Acknowledgements

The authors are most grateful to the staffs of Soil Science Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh-2202, Bangladesh, for maintaining the experimental plants as well as supporting during the analysis of soil and plant samples. We gratefully acknowledge the project staffs of coordinated project on 'Soil Fertility and Fertilizer Management for Crops and Cropping Patterns-BINA component' supporting this research work.

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Received: December 26, 2017; *Accepted*: March 23, 2018; *Published*: December 31, 2018