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Cropping pattern based micronutrient application for wheat-mungbean-T. *aman* crop sequence under Tista Meander Floodplain soil at Rangpur

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Abstract

Intensification of agricultural land use coupled with cultivation of modern varieties has remarkably increased in Bangladesh. This in turn has resulted in deterioration of soil fertility, with emergence of macro- and micro-nutrient deficiency of crops. With this point in view, a study was undertaken to evaluate the effect of different micronutrients on crop yield, and to determine the requirement of selected micronutrients for crops and cropping patterns in the Tista Meander Floodplain (AEZ 3). Experiments were conducted at BINA substation and farmers' fields of Rangpur district within AEZ 3. In experiment 1, the field trials were done with six micronutrients (B, Zn, Cu, Mn, Fe & Mo) designed in an additive manner. These elements were imposed to the first crop and their residual effects were monitored on the next two crops over the patterns: wheat-mungbean-T. *aman*. The rates of micronutrient application were 3 kg Zn, 2 kg B, 2 kg Cu, 3 kg Mn, 5 kg Fe and 1 kg Mo per hectare, added as fertilizers such as $ZnSO_4.7H_2O$, H_3BO_3, $CuSO_4.5H_2O$, $MnCl_2$, $FeSO_4.7H_2O$ and Na_2MoO_4, respectively. Other nutrients viz. N, P, K & S were applied at recommended rates to all plots; rationale was followed for the second and third crops. Intercultural operations were done whenever required. The results revealed that across the experimental sites, the crops were quite responsive to the added Zn and B. Positive effect of Cu was also noted in some cases. In the following year (expt. 2), two micronutrients, Zn and B were taken into the same cropping pattern and designed in a way to determine whether 1stcrop, 2ndcrop or 3rdcrop application is necessary to achieve satisfactory crop yield. The rates of Zn application were 0, 2, 4 & 6 kg ha^{-1}, and the rates for B were 0, 1.5 and 3 kg ha^{-1}. The results show that Zn application at 4 kg ha^{-1} coupled with B application at 1.5 kg ha^{-1} to the first crop can meet their requirement for the subsequent two crops in a pattern. The present study suggests that cropping pattern based field trials with Zn, B and Cu need to be done at farm level in the high cropping intensity areas of this country in order to determine micronutrient requirement of crops.

Introduction

The fertility status of soils is variable and in most of the areas in Bangladesh it has declined. The soil in Tista Meander Floodplain (AEZ 3) is moderately acidic throughout, low in organic matter content on the high land, but moderate in the low lands. Fertility level, in general, is low to medium (Banglapedia, 2015). Texturally the soils are loam and sandy loam. Intensification of agricultural land use has increased remarkably and the cropping intensity has increased from 143% in 1971–72 to about 191% in 2014–2015 (Krishi Diary, 2016). Cultivation of high yielding varieties for all crops has increased remarkably. Consequently, this has resulted in deterioration of soil fertility with emergence of micronutrient deficiency. In this country, chronologically N, P, K, S, Zn and B deficiencies have appeared in soils and crops of Bangladesh. Among the micronutrients, next to zinc, boron deficiency is prominent in soils of Dinajpur, Rangpur, Bogra, Sirajganj, Mymensingh, Comilla and Sylhet district (SRDI, 2010). In early 1980s, S and Zn deficiency in rice was observed in Bangladesh (Jahiruddin *et al*., 1981). Boron deficiency of some crops was reported (Jahiruddin *et al*., 1995) in early 1990's. There is sporadic information of Cu, Mo and Mn deficiencies in crops (Bhuiyan *et al*., 1998). Micronutrients are required for supporting normal growth and development of plants. Micronutrients that are essential for crops include Fe, Mn, Zn, Cu, Mo, Cl and B. Micronutrient trials have been made principally on rice (Jahiruddin *et al*., 1994), wheat (Hossain, 2005) and maize (Hossain *et al*., 2008). However, cropping pattern based micronutrient research is limited. The importance of Zn in crop nutrition has received considerable attention during eighties in Bangladesh. Zinc deficiency is particularly evident in calcareous and wetland rice soils (SRDI, 2008). Zinc deficiency in crops reduces not only the crop yield, but also hampers nutritional quality (Cakmak, 2008). Although taken up in small quantities, boron deficiency may lead to serious consequences regarding economic yield of various crops like wheat, mustard (Islam, 2008). Light textured soils of the country are deficient in plant available boron where significant leaching loss of borate ions occurs. Gupta (1979) states that because of non-ionic nature, boron is once released from soils it can be leached out from soils fairly rapidly. In Bangladesh, boron deficiency is more common in *rabi* crops (dry season), as observed in wheat (Jahiruddin, 2011), mustard (Hossain, 2007), chickpea (Johnson *et al*., 2005) and lentil (Srivastava *et* *al.*, 2000). Cooke (1982) suggested that when the hot water soluble B in soil is less than 0.5 μg g^{-1}, deficiency is likely to occur and all crops are to be treated with B. Rashid *et al*. (2009) have shown 15–25% increase in grain yield of rice over N, P and Zn coupled with appreciable improvement in grain and cooking quality with application of B. Research is needed to determine all the deficient elements, whether macronutrients or micronutrients. Fertilizer management is needed on sustainable basis. Fertility management system that is profitable in short-term and sustainable in long-term should be formulated and it needs to be confirmed by on-farm research trials. Keeping the above points in view, the present study was carried out to evaluate the effect of micronutrients application on the yield of wheat, mungbean and T. *aman* rice crops and to find out the optimum rate of micronutrients for the wheat-mungbean-T. *aman* cropping pattern in AEZ 3.

Materials and Methods

Experiments on a dominant cropping pattern of wheat-mungbean-T. *aman* were set up at BINA substation and farmers' fields at Rangpur Sadar in 2011-2012 (experiment 1 in two locations) and in 2012-13 (experiment 2) at Kaunia upazila under Rangpur district. The objectives were to evaluate the effects of different micronutrients on the crop yield and to see the direct and residual effects of Zn and B as to determine the requirement of Zn and B for the wheat-mungbean-T. *aman* cropping sequence. Experiment 1 with seven treatments was set up in November 2011 in two locations with wheat the first crop of the cropping pattern followed by mungbean as a legume (2^{nd} crop) and T. *aman* rice (3^{rd} crop). It continued up to October 2012 by T. *aman* rice harvest. Experiment 2 was started at Kaunia upazila under Rangpur district in November 2012 with wheat and completed by T. *aman* rice harvest. The details of experiments are given below:

Experiment 1:

Parameters	Wheat	Mungbean	T. *aman*
Variety	BARI Gom-25	Binamung-8	Binadhan-7
Sowing/Planting date	20 November 2011	02 April 2012	23 July 2012
Plant spacing	20 cm × continuous	40 cm × 25 cm	20 cm × 15 cm
Seed rate/Seedling rate	120 kg ha^{-1}	25 kg ha^{-1}	2 seedlings $hill^{-1}$
Harvesting date	22 March 2012	27 June 2012	19 October 2012

Experiment 2:

Parameters	Wheat	Mungbean	T. *aman*
Variety	BARI Gom-25	Binamung-8	Binadhan-7
Sowing/Planting date	16 November 2012	19 March 2013	15 July 2013
Plant spacing	20 cm × continuous	40 cm × 25 cm	20 cm × 15 cm
Seed rate/Seedling rate	120 kg ha^{-1}	25 kg ha^{-1}	2 seedlings $hill^{-1}$
Harvesting date	18 March 2013	10 June 2013	12 October 2013

Treatments for experiment 1 and experiment 2: For the first year (expt. 1), the treatments were designed taking all micronutrients except Cl following additive element trial technique. The experiments (1 & 2) were laid out in a Randomized Complete Block Design (RCBD), with three replications. There were seven treatments (expt. 1) with six micronutrients, as follows:

T_1: Control (No use of micronutrients)
T_2: Zn
T_3: Zn + B
T_4: Zn + B + Cu
T_5: Zn + B + Cu + Mn
T_6: Zn + B + Cu + Mn + Fe
T_7: Zn + B + Cu + Mn + Fe + Mo

These micronutrient treatments were imposed on the first crop only (Expt. 1). Their residual effects were observed on the next two crops over the year. The rates of micronutrients were 3 kg Zn, 2 kg B, 2 kg Cu, 3 kg Mn, 5 kg Fe and 1 kg Mo per hectare. The elements were added as $ZnSO_4.7H_2O$ (23% Zn), H_3BO_3 (17% B), $CuSO_4.5H_2O$ (25% Cu), $MnCl_2$ (17% Mn), $FeSO_4.7H_2O$ (19% Fe) and Na_2MoO_4 (39% Mo), respectively. Other nutrients viz. N, P, K & S were used at recommended rates for all plots (for wheat 100-20-60-10, mungbean 20-15-25-8 and T. *aman* 90-15-40-10 kg ha^{-1} N-P-K-S, respectively from Urea, TSP, MoP and Gypsum); rationale was followed for the second and third crop within a year. For the wheat, one-third urea was applied at final land preparation and the rest was applied at an equal rate during tillering and booting stages. For the rice, the one-third urea was applied after seven days of transplanting and the rest at an equal rate during the maximum tillering and panicle initiation stages. For mungbean, the one-third urea was added before sowing, another one-third after 25 days of sowing and the rest urea after 50 days of sowing. The experiment 1 was conducted at BINA substation farm and in a farmers' field both at Rangpur. The experiment 2 was conducted at Kaunia, Rangpur in a farmers' plot. Before conducting field experiments soil samples were collected and analyzed. The soil properties are presented in Table 1. Data on grain and straw/stover yield of crops were recorded and analyzed statistically following Duncan's New Multiple Range Test (DMRT).

Results from expt. 1 (Table 2) revealed that the effect of Zn addition was distinct in wheat. Next to Zn, the B effect was positive. With this end in view, Zn and B treatments were designed for next year experiment (expt. 2) to ascertain whether 1st-crop, 2nd-crop and 3rd-crop application is required in 1 year- crop cycle as follows:

Wheat		**Mungbean**		**T. *aman***	
Treatment code	Treatment combination	Treatment code	Treatment combination	Treatment code	Treatment combination
T_1	Zn_0B_0	$T_{1.1}$	Zn_0B_0	$T_{1.1.1}$	Zn_0B_0
T_2	$Zn_2B_{1.5}$	$T_{2.1}$	Zn_0B_0	$T_{2.1.1}$	Zn_0B_0
				$T_{2.1.2}$	Zn_2B_0
		$T_{2.2}$	Zn_2B_0	$T_{2.2.1}$	Zn_0B_0
				$T_{2.2.2}$	Zn_2B_0
		$T_{2.3}$	$Zn_2B_{1.5}$	$T_{2.3.1}$	Zn_0B_0
				$T_{2.3.2}$	Zn_2B_0
T_3	$Zn_4B_{1.5}$	$T_{3.1}$	Zn_0B_0	$T_{3.1.1}$	Zn_0B_0
				$T_{3.1.2}$	Zn_2B_0
T_4	Zn_6B_3	$T_{4.1}$	Zn_0B_0	$T_{4.1.1}$	Zn_0B_0

Subscripts of Zn and B represent kg ha^{-1}.

Economic analysis was done following the principle of partial budget analysis (Kay, 1981). Marginal benefit-cost ratio (MBCR), the ratio of marginal or added benefits and costs, is the indicative of the superior treatments. Only variable costs i.e. chemical fertilizer was taken into account as added cost for each cropping system. The benefit was calculated based on yield (main product and by-product).

To compare different treatments with control treatment the following equation was used.

$$\text{MBCR (over control)} = \frac{\text{Gross return } (T_i) - \text{Gross return } (T_1)}{\text{VC } (T_i) - \text{VC } (T_1)} = \frac{\text{Added benefit (over control)}}{\text{Added cost (over control)}}$$

Where, T_i = various treatments
T_1 = control treatment
VC = Variable cost (Zn & B fertilizers costs)
Gross return = Yield × Price

Results and Discussion

Regarding effects of different micronutrients on crops (expt. I), it appeared that there was a significant positive effect of micronutrient application on the grain yield of wheat (Table 2). At both locations, the effects of Zn were pronounced and next to Zn, the effect of B was remarkable. Residual effect of Zn and B was also noticed in following mungbean (Binamung-8) and T. *aman* rice (Binadhan-7) crops. In farmers' field, though soil available status of Cu and Mn were high (3.04 µg g^{-1} and 57 µg g^{-1}, respectively), positive effect of Cu and Mn was found in wheat (grain yield enhancement in farmers' field was mainly due to increase in effective tiller m^{-2} for Cu and Mn application even the soil was not deficient) and their residual effect on the following mungbean crop.

From expt. I, it is apparent that across the locations and crops, the effect of Zn is quite clear. Next to Zn, the B effect was quite positively responsive. Thus, further field trials were designed to determine an optimum rate of Zn and B application and to ascertain whether 1st-crop, 2nd-crop and 3rd-crop application is required in 1 year- crop cycle towards that end.

Table 1. Soil morphological, physical and chemical properties of the experimental sites (Expt. 1 & 2)

Soil properties	BINA substation	Farmers' field	Farmers' field at Kaunia
	Experiment 1		Experiment 2
A. Morphological properties			
AEZ (UNDP/FAO, 1988)	Tista Meander Floodplain	Tista Meander Floodplain	Tista Meander Floodplain
General soil type	Non-calcareous Brown Floodplain soil	Non-calcareous Brown Floodplain soil	Non-calcareous Brown Floodplain soil
Soil series	Gangachhara	Gangachhara	Kaunia
Topography	Medium high land	Medium high land	Medium high land
Drainage	Well drained	Well drained	Well drained
Flood level	Above flood level	Above flood level	Above flood level
B. Physical properties			
Sand (%) (2-0.05 mm)	57.9	58.2	49.5
Silt (%) (0.05-0.002mm)	21.3	25.2	35.3
Clay (%) (<0.002 mm)	20.8	16.6	15.2
Soil texture	Sandy loam	Sandy loam	Sandy loam
C. Chemical properties			
pH	5.28	4.85	6.10
OM (%)	0.83	1.03	1.77
Total N (%)	0.04	0.054	0.091
Ex. K (cmol kg^{-1})	0.13	0.14	0.07
P (µg g^{-1})	30.40	30.5	7.92
S (µg g^{-1})	23.05	35.6	4.20
Zn (µg g^{-1})	0.80	1.21	0.78
B (µg g^{-1})	0.17	0.17	0.25
Cu (µg g^{-1})	2.47	3.04	-
Mn (µg g^{-1})	27.10	57.0	-
Fe (µg g^{-1})	47.60	114.7	-

Table 2. Effects of micronutrients on the grain and straw yields of wheat, mungbean and T. *aman* in the wheat-mungbean-T. *aman* crop sequence

Treatments	Wheat				Mungbean				T. *aman*			
	BINA Sub-station farm		Farmers' field		BINA Sub-station farm		Farmers' field		BINA Sub-station farm		Farmers' field	
	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	4.11c	5.66c	3.61c	4.94c	1.48c	1.36c	1.18c	1.09c	4.09d	4.72d	2.61c	3.00c
T_2	4.65ab	6.43ab	4.03b	5.52b	1.64bc	1.50bc	1.38ab	1.27ab	4.31cd	4.99cd	3.05bc	3.52ab
T_3	4.81a	6.66a	4.32a	5.93ab	1.99a	1.83a	1.33ab	1.22abc	4.73bc	5.46bc	3.48a	4.01a
T_4	4.63ab	6.40ab	4.39a	6.03a	2.00a	1.83a	1.33ab	1.22abc	5.05a	5.83b	2.98bc	3.45bc
T_5	4.50b	6.23b	4.46a	6.13a	1.82ab	1.66ab	1.42a	1.30a	4.80a	6.69a	2.96bc	3.40bc
T_6	4.57ab	6.33ab	4.60a	6.32a	1.67bc	1.53bc	1.29abc	1.19abc	4.58bcd	5.30bcd	3.02bc	3.48bc
T_7	4.45b	6.15b	4.61a	6.32a	1.61bc	1.47bc	1.25bc	1.15bc	4.82a	5.58bc	3.20ab	3.69ab
CV (%)	3.53	2.98	3.70	3.94	8.57	8.63	5.36	5.58	6.79	6.84	7.08	7.59
Level of significance	**	**	**	**	**	**	*	*	**	**	*	*
SE (±)	0.060	0.070	0.060	0.087	0.056	0.052	0.026	0.025	0.056	0.052	0.026	0.025

Means followed by same letter in a column are not significantly different at 5 % level by DMRT, SE (±) = Standard error of means, CV= Coefficient of variation, *= Significant at 5 % level, **= Significant at 1% level

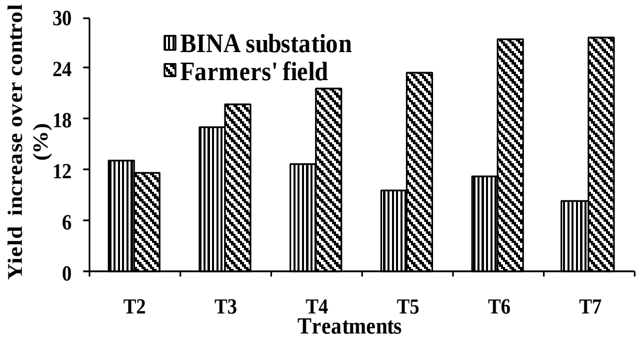

Fig. 1. Percent grain yield increase of wheat due to micronutrients application over control

Effects of Zn and B on the yield of crops in wheat-mungbean-T. *aman* cropping sequence

Grain yield of wheat: There was a significant positive effect of Zn and B application on grain yield of wheat (BRRI gom25) (Table 3). The grain yield ranged from 3.65-4.86 t ha^{-1} over the treatments. The Zn-B fertilization resulted in 8-18% increase in grain yield over control treatment. Treatment T_3 (Zn at 4 kg ha^{-1} and B at 1.5 kg ha^{-1}) recorded the highest yield (4.86 t ha^{-1}) and was identical to T_4 (Zn at 6 kg ha^{-1} and B at 3 kg ha^{-1}, 4.42 t ha^{-1}). In terms of grain yield, the treatments can be ranked in the order: $T_3 > T_4 > T_2 > T_1$. The result clearly indicated yield advantage for Zn & B application along with the recommended rates of NPKS application in wheat. Application of N, P, K and S at a recommended rate with no micronutrients (i.e. control) had the minimum grain yield (3.65 t ha^{-1}). Chaudhary *et al.* (2010) recorded the highest and 11.8% increased grain yield of wheat by application of 5 kg Zn ha^{-1} and over control in rice-wheat cropping pattern. Keram *et. al*. (2014) observed the application of 20 kg Zn ha^{-1} along with recommended basal dose of NPK on wheat crop enhanced both grain and straw yields. Boron deficiency is now a world-wide problem for field crop since it affects the flowering and plant reproductive process and therefore directly affects harvested yield (Bolanos *et al*., 2004). Ahmad *et al*. (2012) in an extensive review observed an increase in yield of 14% in wheat with B fertilization by using appropriate rates, methods and sources on B-deficient soils. Nadim *et al*. (2011) found that use of B at 2 kg ha^{-1} produced higher leaf area index, enhanced crop growth rate, number of grains $plant^{-1}$ and grain yield of wheat (cv. Gomal-8). Khanom (2013) observed B application at 1.5 kg ha^{-1} to the 1st crop can meet up their requirement for the subsequent crops in a pattern.

Straw yield of wheat: Like grain yield, the straw yield of wheat was also significantly influenced by Zn-B treatments and the yield ranged from 4.77-6.29 t ha^{-1} (Table 3). Treatment T_3 (Zn at 4 kg ha^{-1} and B at 1.5 kg ha^{-1}) with NPKS gave the maximum straw yield (6.29 t ha^{-1}) which corresponded to the maximum grain yield over the control yield (4.77 t ha^{-1}). The treatment T_3 was found identical to the treatment T_2 (Zn at 2 kg ha^{-1} and B at 1.5 kg ha^{-1}, 5.62 t ha^{-1}) and T_4 (Zn at 6 kg ha^{-1} and B at 1.5 kg ha^{-1}, 6.13 t ha^{-1}) treatments. Application of recommended rate of macronutrients without any micronutrient (control treatment) showed the minimum straw yield. Treatments based grain yields followed the order as $T_3 > T_4 > T_2 > T_1$.

Seed yield of mungbean: There was a significant residual effect of the Zn-B treatments on the second crop, mungbean (Binamung-8) in the wheat-mungbean-T. *aman* sequence of 1-year crop cycle. The seed yield ranged from 1.63-2.14 t ha^{-1} over the treatments (Table 3). Treatment $T_{2.1}$ (Zn 2 kg ha^{-1} and B 1.5 kg ha^{-1} applied to wheat) produced the maximum seed yield (2.14 t ha^{-1}) which was statistically identical with $T_{2.2}$ (Zn 2 kg ha^{-1} and B 1.5 kg ha^{-1} addition to the first crop and Zn 2 kg ha^{-1} at the second crop, mungbean, 1.98 t ha^{-1}), $T_{2.3}$ (Zn 2 kg ha^{-1} and B 1.5 kg ha^{-1} addition to wheat and again to mungbean- 2nd crop, 2.05 t ha^{-1}), $T_{3.1}$ (Zn 4 kg ha^{-1} and B 1.5 kg ha^{-1} addition to the wheat, 2.02 t ha^{-1}) and $T_{4.1}$ (Zn 6 kg ha^{-1} and B 3 kg ha^{-1} addition to wheat, 1.94 t ha^{-1}) treatments. Seed yield of mungbean responded significantly to the application of Zn-B showing that the treatment T_2 (Zn at 2 kg ha^{-1} and B at 1.5 kg ha^{-1} to wheat), T_3 (Zn at 4 kg ha^{-1} and B at 1.5 kg ha^{-1} to wheat) and T_4 (Zn at 6 kg ha^{-1} and B at 3 kg ha^{-1} to wheat) added to the wheat was enough to support the mungbean yield which was identical to the yield obtained with renewed application of only Zn (Zn_2B_o) or Zn-B ($Zn_2B_{1.5}$). These results showed that the seed yield did not respond to further only Zn or Zn-B combined application. It appeared that application of 2, 4 or 6 kg Zn ha^{-1} and 1.5 kg B ha^{-1} to the 1st crop (wheat) was optimum to obtain satisfactory yield of both the 1st and 2nd crops. The lowest seed yield (1.63 t ha^{-1}) was recorded in Zn-B control treatment. The Zn-B supply resulted in 16-23% seed yield increase of mungbean over control. Application of 2 kg Zn and 1.5 kg B ha^{-1} in the previous wheat crop resulted in 23% seed yield increase of mungbean over Zn-B control. The present study clearly indicated that residual effect of Zn-B was enough to get satisfactory yield of mungbean seed yield without further application of Zn or Zn-B to the 2nd crop (mungbean) (Table 2). Gentry (2011) stated that mungbean was very responsive to Zn where soil test level was below 0.4 µg g^{-1} on acid soils. Hossain *et al.* (2008) found optimum rate of Zn for the maize-mungbean-rice cropping system to be 4-0-2 kg ha^{-1} for the 1st year and 2-0-2 kg ha^{-1} for subsequent years particularly when mungbean residue was removed, and such rates for mungbean residue incorporation being 4-0-1 and 2-0-1 kg ha^{-1}, respectively. Rahman *et al.* (2015) stated that seed and stover yields of mungbean increased with increasing levels of P and Zn up to certain level. Shekhaw *et al.* (2012) in a sunflower-mungbean cropping system, 1.5 kg boron ha^{-1} applied to the sunflower crop and found optimum in the succeeding mungbean crop in terms of yield, yield attributing characters, B concentrations and uptake, productivity and residual nutrient status for the system. Hossain *et al*. (2013) recorded the highest mungbean yield from recommended fertilizer dose (N-P-K-S-Zn @ 20-20-30-10-4 kg ha^{-1} plus B (@1 kg ha^{-1}) treated plot of wheat crop in the research field of Wheat Research Centre, Dinajpur, Bangladesh.

Stover yield of mungbean: Significant residual effect of Zn-B application on the stover yield of mungbean was also observed (Table 3). The stover yield ranged from 2.33-3.16 t ha^{-1} over the treatments. The stover yield obtained with treatment $T_{2.2}$ (Zn 2 kg ha^{-1} and B 1.5 kg ha^{-1} to the first wheat crop and only Zn 2 kg ha^{-1} to the second mungbean crop) showed the maximum stover yield (3.16 t ha^{-1}) which was statistically identical with treatments $T_{2.1}$, $T_{2.3}$, $T_{3.1}$ and $T_{4.1}$. The addition of Zn and B or residual effect yielded always higher stover yield over control (without Zn-B). The Zn-B addition increased 16–26% stover yield over Zn-B control.

Grain yield of T. *aman* rice: There was a significant and positive effect of Zn-B application on the grain yield of T. *aman* rice (3rd crop in the pattern). All the Zn-B treatments ($T_{2.1.1}$-$T_{4.1.1}$) gave significantly higher (7–28%) grain yield over the control treatment ($T_{1.1.1}$, only NPKS). The rice grain yield varied from 3.41 t ha^{-1} as recorded minimum with the absolute Zn-B control to 4.79 t ha^{-1} obtained with $T_{2.2.2}$ (Zn addition at 2 kg ha^{-1} and B at 1.5 kg ha^{-1} to first crop, wheat and only Zn at 2 kg ha^{-1} to the second and third crops, T. *aman* rice). Statistically identical grain yield was found between $T_{2.3.1}$ (Zn at 2 kg ha^{-1} and B at 1.5 kg ha^{-1} to first crop-wheat and second crop-mungbean, 4.47 t ha^{-1}) and $T_{2.3.2}$ (Zn at 2 kg ha^{-1} and B at 1.5 kg ha^{-1} to the first crop and the second crop, again only Zn at 2 kg ha^{-1} to the third crop, T. *aman* rice, 4.40 t ha^{-1}) treatment (Table 3). Maharana *et al.* (1993) observed a significant response of rice yield to $ZnSO_4$ application in both kharif and rabi seasons. Rashid *et al*. (2009) quantified rice yield increase by 15%–25% over control with the application of 1 kg B ha^{-1}, coupled with appreciable improvement in grain/cooking quality with application of B in Pakistan.

Straw yield of T. *aman* rice: As in grain yield, the straw yield of T. *aman* rice was markedly influenced due to Zn-B treatments (Table 3). The straw yield ranged from 3.81-5.33 t ha^{-1} noted in the different treatments. The lowest straw yield was recorded with absolute Zn-B control and the highest yield with treatment $T_{2.3.2}$ (Zn at 2 kg ha^{-1} and B at 1.5 kg ha^{-1} to 1st crop- wheat and 2nd crop- mungbean, again Zn 2 kg ha^{-1} to the third crop, T. *aman* rice).

Table 3. Effects of micronutrients on the grain and straw yields of wheat, mungbean and T. *aman* in the wheat-mungbean-T. *aman* crop sequence and partial economic analysis for different treatments

Wheat	Mung bean	T. *aman*	Wheat		Mungbean		T. *aman*		Added cost (Tk ha^{-1})	Gross return (Tk ha^{-1})	Added benefit over control (Tk ha^{-1})	MBCR (over control)
Treatment code			Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})				
T_1	$T_{1.1}$	$T_{1.1.1}$	3.65b	4.77b	1.63b	2.33b	3.41e	3.81f	-	200420	0	0
T_2	$T_{2.1}$	$T_{2.1.1}$	3.98b	5.62a	2.14a	2.89a	3.67de	4.10ef	2895	232860	32440	11.2
		$T_{2.1.2}$					3.95cd	4.35de	4026	237320	36900	9.2
	$T_{2.2}$	$T_{2.2.1}$			1.98a	3.16a	3.84cd	4.11ef	4026	229280	28860	7.2
		$T_{2.2.2}$					4.79a	4.95ab	5156	244370	43950	8.5
	$T_{2.3}$	$T_{2.3.1}$			2.05a	3.01a	4.47ab	4.38cde	5790	241660	41240	7.1
		$T_{2.3.2}$					4.40ab	5.33a	6921	241560	41140	5.9
T_3	$T_{3.1}$	$T_{3.1.1}$	4.86a	6.29a	2.02a	2.78a	3.72de	5.02ab	4026	247690	47270	11.7
		$T_{3.1.2}$					4.42ab	4.51cd	5156	257680	57260	11.1
T_4	$T_{4.1}$	$T_{4.1.1}$	4.42a	6.14a	1.94a	2.88a	4.23bc	4.77bc	6921	243020	42600	6.2
CV %			5.91	7.80	6.77	7.41	5.41	5.21	**Price (Rate/kg):** Zinc sulphate heptahydrate Tk. 130; Boric acid Tk. 200; Wheat grain Tk. 20, Straw Tk. 1.00; Mungbean seed Tk. 40, Stover 1.00; Rice grain 15, straw 1.00			
Level of significance			**	*	*	*	**	**				
SE (±)			0.125	0.222	0.541	0.086	0.070	0.074				

Means followed by same letter in a column are not significantly different at 5 % level by DMRT, SE (±) = Standard error of means, CV= Coefficient of variation, **= Significant at 1% level, *= Significant at 5% level

Summary: There was a significant positive effect of Zn & B application on the grain yield of wheat. Apparently the treatment that had received Zn at 4 kg ha^{-1} and B at 1.5 kg ha^{-1} recorded superior yield. Similar yield was also obtained with Zn_6B_3 treatment. Residual effect of Zn and B was also noticed in mungbean and T. *aman* rice yield. The field experiments showed a clear response of crops to Zn and B application. Crop response to Zn supplement was higher than that to B supplement indicating that Zn was more deficient than B in soils. Both Zn and B application had positive residual effect on the second and third crops in a cycle. The economic analysis shows that the wheat-mungbean-T. *aman* cropping pattern, the $Zn_4B_{1.5}$-Zn_0B_0-Zn_0B_0 treatments combination had the highest MBCR (11.7) followed by the $Zn_2B_{1.5}$-Zn_0B_0-Zn_0B_0 combination (11.2 MBCR) and the $Zn_4B_{1.5}$-Zn_0B_0-Zn_2B_0 combination (11.1 MBCR); then all others had MBCR in the range of 5.9–9.2.

Conclusion: Zn application at 4 kg ha^{-1} coupled with B application at 1.5 kg ha^{-1} to the first crop can meet their requirement for the subsequent two crops in a cropping pattern.

Future Research Need: Cropping pattern based field trials with Zn, B, Cu and Mn need to be initiated at farm level in the high cropping intensity areas of this country.

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References

Ahmad, W., Zia, M.H., Malhi, S.S., Niaz. A. and Saifullah. 2012. Boron Deficiency in Soils and Crops: a review. INTECH Open Access Publisher.

Banglapedia. 2015. Soil fertility. Viewed on 19 February 2016 at: http://en.banglapedia.org/index.php?title=Soil_Fertility

Bhuiyan, M.A.H., Khanam, D., Khatun, M.R. and Hassan, M.S. 1998. Effect of molybdenum, boron and Rhizobium on nodulation, growth and yield of chickpea. Bulletin of the Institute of Tropical Agriculture, Kyushu University 21: 1–7.

Bolaños, L., Lukaszewski, K., Bonilla, I. and Blevins, D. 2004. Why boron? Plant Physiology and Biochemistry 42(11): 907–912.

Cakmak, I. 2008. Enrichment of cereals grains with zinc: Agronomic and genetic biofortification? Plant and Soil 302(1-2): 1–17

Chaudhary, E.H., Chaudhary, M.A., Timmer, V., Khalid, R. and Raheem, M. 2010. Contribution of micronutrient fertilization in wheat production and its economic repercussions. Pakistan Journal of Scientific and Industrial Research 53(2): 92–97.

Cooke, G.W. 1982. Fertilizing for maximum yield. 3rd edn., Granada Publishing Ltd, UK pp. 465. Available at: www.cabdirect.org/ abstracts/ 19821972127.html

Gentry, J. 2011. Mungbean management guide- a compilation, 2nd edn., Department of Employment, Economic Development and Innovation, Queensland, Australia.

Gupta, U.C. 1979. Boron nutrition of crops. Advances in Agronomy 31: 273–307.

Hossain, A., Sarker, M.A.Z., Hakim, M.A., Islam, M.T. and Ali, M.E. 2013. Effect of lime, magnesium and boron on wheat (Triticum aestivum L) and their residual effects on mungbean (Vigna radiatea L.) International Journal of Agricultural Research, Innovation and Technology 1(1–2): 9–15.

Hossain, M.A. 2007. Requirement of boron for mustard-mungbean-rice pattern and zinc for maize-mungbean-rice pattern in calcareous soil. PhD Dissertation, Department of Soil Science, Bangladesh Agriculture University, Mymensingh.

Hossain, M.A., Jahiruddin, M., Islam, M.R. and Mian, M.H. 2008. The requirement of zinc for improvement of crop yield and mineral nutrition in the maize–mungbean–rice system, Plant and Soil 306(1): 13–22.

Hossain, M.S. 2005. Effects of different methods of zinc application on grain yield and grain zinc concentration of wheat genotypes. MS Thesis, Department of Soil Science, Bangladesh Agricultural University, Mymensingh.

Islam, M.S. 2008. Soil fertility history, present status and future scenario in Bangladesh. Bangladesh Journal of Agriculture and Environment 4: 129–151.

Jahiruddin, M. 2011. Screening, selection and molecular characterization of boron efficient wheat genotypes. Project Report, Department of Soil Science, BAU, Mymensingh.

Jahiruddin, M., Ali, M.S., Hossain, M.A., Ahmed, M.U. and Hoque, M.M. 1995. Effect of boron on grain set, yield and some other parameters of wheat cultivars. Bangladesh Journal of Agricultural Science 22(1): 179–184.

Jahiruddin, M., Bhuiya, Z.H., Hoque, M.S. and Rahman, L. 1981. Effect of rates and methods of zinc application on rice. Madras Agricultural Journal 68: 211–216.

Jahiruddin, M., Islam, M.N., Hashem, M.A. and Islam, M.R. 1994. Influence of sulphur, zinc, and boron on yield and nutrient uptake of BR-2. Progressive Agriculture 5(1): 61–67.

Johnson, S.E., Lauren, J.G., Welch, R.M. and Duxbury, J.M. 2005. A comparison of the effects of micronutrient seed priming and soil fertilization on the mineral nutrition of chickpea (*Cicer arietinum*), lentil (*Lens culinaris*), rice (*Oryza sativa*) and wheat (*Triticum aestivum*) in Nepal. Experimental Agriculture 41(04): 427–448.

Kay, R.D. 1981. Farm Management Planning Control and Implementation. McGraw-Hill Book company, New York, USA. p. 60.

Keram, K.S., Sharma, B.L., Kewat, M.L., and Sharma, G.D. 2014. Effect of zinc fertilization on growth, yield and quality of wheat grown under agro-climatic condition of kymore plateau of madhyapradesh, India. The BioScan 9(4): 1479–1483.

Khanom, R. 2013. Requirement of zinc and boron for composite and hybrid maize and their residual effects on rice. PhD Dissertation, Department of Soil Science, BAU, Mymensingh.

Krishi Diary 2016. Agriculture Information Service. Khamarbari, Farmgate, Dhaka.

Maharana, D.P., Sarengi, S.K., Singh, R.N.B. and Ali, M.H. 1993. Response of rice to application of zinc sulphate in different broad soil groups of Orissa. In Proc.: Micronutrients. 22-23 January 1992, IBFEP, HFC, Bhubaneswar, Orissa, India pp. 228–262.

Nadim, M.A., Awan, I.U., Baloch, M.S., Khan, E.A., Naveed, K., Khan, M.A., Zubair, M. and Hussain, N. 2011. Effect of micronutrients on growth and yield of wheat. Pakistan Journal of Agricultural Science 48(3): 191–196.

Rahman, M.M., Adan, M.J., Chowdhury, M.S.N., Ali, M.S. and Mahabub, T.S. 2015. Effects of phosphorus and zinc on the growth and yield of mungbean (BARI mug 6). International Journal of Scientific and Research Publications 5(2).

Rashid, A., Yasin, M., Ali, M.A., Ahmad, Z. and Ullah, R. 2009. Boron deficiency in rice in Pakistan: A serious constraint to productivity and grain quality. In: Salinity and water stress: Improving crop efficiency, Ashraf, M., Ozturk, M. and Athar, H. R. (Editors), Springer-Verlag, Berlin-Heidelberg, Germany pp. 213–219.

Shekhawat, K. and Shivay, Y.S. 2012. Residual effects of nitrogen sources, sulfur and boron levels on mungbean (Vigna radiata) in a sunflower (Helianthus annuus)–mungbean system. Archives of Agronomy and Soil Science 58(7): 765–776.

SRDI 2008. GIS map, Zinc status of Bangladesh soils. SRDI, Farmgate, Dhaka.

SRDI 2010. GIS map, Boron status of Bangladesh soils, SRDI, Farmgate, Dhaka.

Srivastava, S.P. Bhandari, T.M.S., Yadav, C.R., Joshi, M. and Erskine, W. 2000. Boron deficiency in lentil: yield loss and geographic distribution in a germplasm collection. Plant and Soil 219(1-2): 147–151.

UNDP/FAO 1988. Agroecological regions of Bangladesh. Technical Report 2. Project BDG/81/035; FAO, Rome.