ENRICHMENT OF ZINC AND BORON IN CROPS THROUGH FERTILIZER MANAGEMENT

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Abstract

Micronutrient deficiency is considered as one of the emerging challenges to food and nutrition security particularly in developing countries. Bio-fortification with micronutrients in edible parts of crop can be achieved by utilizing crop and soil management. To identify the best fertilizer management practices for enriching micronutrient contents of locally produced food, a field study was conducted during July 2020 to July 2021 at Atbarpur Union of Chandina, Cumilla. Treatments were T_1= Farmer's practice, T_2 =recommended fertilizer dose (RFD) with Zn as basal; T_3= RFD with Zn as foliar spray; T_4= RFD with Zn & B as foliar spray; T_5 = 50% RFD + 50% Organic manure (vermicompost), T_6 = 50% RFD + 50% organic manure with Zn & B as foliar spray taking five replications. Findings revealed that treatment T_6 provided the significantly highest amount of Zn and B in the edible parts of rice grain, cauliflower curd and mungbean seed. The highest Zn concentration 30.25, 74.06 and 57.77 mg kg^{-1} were found in rice grain, cauliflower and mungbean, respectively and rice grain, cauliflower curd and mungbean seed Zn level were increased 4.39, 7.60 and 12.11 mg kg^{-1}, respectively than RFD of NPKS along with soil application of Zn and B fertilizer. On the other hand, the highest B content in rice grain, cauliflower and mungbean was found 31.72, 32.62 and 7.33 mg kg^{-1}, respectively and rice grain, cauliflower curd and mungbean seed B level were increased 5.06, 10.30 and 0.98 mg kg^{-1}, respectively than RFD of NPKS along with soil application of Zn and B fertilizer. Protein content was increased significantly in mungbean seed but it was insignificant in rice grain and cauliflower curd. It is concluded that 50% organic manure + 50% inorganic RFD along with foliar spray of Zn & B might be a good option to fortified micronutrient in locally produced food.

Keywords: Biofortification, Boric acid, Foliar spray, Micronutrients, Zinc chelate

1. Introduction

Micronutrient deficiency is considered as one of the emerging challenges to food and nutrition security particularly in developing countries. There is a growing realization of food-based approach for addressing this issue. Soil health is directly related to human health

(Rahman, 2024). The wide diversity of plant genetic resources provides opportunity for identifying micronutrient-rich genotypes for direct use or for genetic enrichment of staple crops using breeding strategies (Sowjanya *et al.,* 2020). Micronutrients are indispensable for most living organisms, including human who need a supply of 16 mineral microelements, which can be obtained through a balanced diet. Current estimate suggested that almost half of the world population suffers from mineral deficiencies, primarily of iron and zinc.

The Copenhagen Consensus (2008) ranks the alleviation of iron and zinc deficiencies as a top priority. Bio-fortification with micronutrients in edible parts of crop can be achieved by utilizing crop and soil management (Zuo and Zhang, 2011). Rice feeds almost 50-58% of the world's population, hence can be considered as a global grain but it is considerably deficient in micronutrient. Therefore, even a small increase in the nutritive value of rice can be highly significant for human nutrition (Zhang et al., 2012). Sustainable agricultural production, maintain its production quality and protecting the deterioration of soil health are the major challenges in the changing global climate (Rahman, 2014). Bangladesh agriculture has made an outstanding achievement in food sufficiency. Even in the midst of Covid-19 pandemic, Bangladesh agriculture had made a significant contribution to the country's food security. Her agriculture has been passing through a transition from subsistence farming to commercial agriculture. Crop production and cropping intensity increased several times during the last three decades. It is easily understandable that there has been a tremendous pressure on its arable land, the most important natural resource of the country (Abdullah et al., 2019). There creates a chance of nutrient depletion in terms of nutrient mining. Farmers are mostly using macronutrient fertilizers like urea, TSP, DAP, MoP and Gypsum in rice cultivation (Sarkar et al., 2016). On the other hand, there is very little or no use of micronutrient fertilizers like zinc (Zn) and boron (B) especially in rice cultivation. Farmer's common perception is that crops are not responding like earlier in use of urea, TSP, DAP and MoP.

A long-term study finding of Soil Resource Development Institute (SRDI) showed that low to very low soil Zn status in soils were increased 28.71% to 78.84% in arable land since 2010-2020 in Bangladesh and in case of boron (B) it was increased 25.99% to 30.78% in arable land area in the same period (Hasan et al., 2020). It indicates that there prevails a deficiency of micronutrient like Zn and B and the deficiency is increased with the advance of time. Boron is a limiting factor in crop productivity in rice-based cropping system. Such a deficiency of boron has emerged as an important micronutrient problem in Indian soils and crops, next to zinc. Soil sample analytical reports indicate that a deficiency of boron has been found in up to 84% with a mean of 33% and upland calcareous areas in India are prone to B deficiency (Singh, 2006). Various soil factors including pH, organic matter, clay minerals, sesquioxide's (Fe and Al oxides), carbonates, and tillage significantly influence the plant availability to B, the content of soil extractable B, and different B fractions transformations in soil. Retention of B in soil constituents is favored by an increase in pH. Calcareous soils with a light (sandy) texture and low organic matter content suffer from boron deficiency. An increase in the calcium carbonate content raises soil pH, limiting the availability of B by serving as a sink for B in soil, where it is involved in the surface adsorption of a large portion of the soluble B, thus decreasing its availability for plant uptake. So, sustainable soil management is urgent required for safe and quality food production.

The Government of Bangladesh, FAO and the Global Soil Partnership (GSP) launched a German Government-funded project on nutrition-sensitive agriculture. In Bangladesh, the project was implemented by the Bangladesh Agricultural Research Council (BARC) and the Soil Resource Development Institute (SRDI). This project aims to promote and support the application of sustainable soil management (SSM) for nutrition-sensitive agriculture with the aim of improving the nutritional quality of local produced food. It would develop advice for SSM, based on existing knowledge related to the transfer of micronutrients from the soil to the edible part of agricultural produce, and using a multidisciplinary approach, to illustrate the role of soil in human health. Considering the perspective, a field study was conducted to identify best practices for SSM to address micronutrient deficiency issues taking objectives to quantify the increase of Zn and B content in Rice, Cauliflower and mungbean by fertilizer management, and identify the best management practices and their effects to increase Zn and B content in Rice, Cauliflower and mungbean.

2. Materials and Methods

The experiment was conducted at Atbarpur Union of Chandina Upazila of Cumilla districts, Bangladesh to identify the best SSM practices and their effects to increase nutrient status of soil, yield and quality of rice, cauliflower and mungbean. The T. aman (BINA dhan 20), cauliflower and mungbean were grown as first, 2^{nd} and 3^{rd} crops, respectively in the same plots. The study area, crops and treatments were considered through consultation meeting with the renowned soil scientists working/worked at NARS institutes and academicians of different universities considering soil nutrient status and land use of that locality. The field experiment was laid out in randomized complete block design (RCBD) comprise of six fertilizer management treatments. For fertilizer management treatments were (T_1= Farmer's practice; T_2 = Recommended Fertilizer Dose of NPKS (RFD) with Zn as basal; T_3= RFD with Zn as foliar spray; T_4= RFD with Zn & B as foliar spray; T_5 = 50% RFD + 50% Organic manure (Vermicompost), T_6 = 50% RFD + 50% Organic manure (Vermicompost) + Zn & B as foliar spray. Five farmer's field from Modhusair Block (under Atbarpur Union, Chandina of Cumilla district) was selected as replications for the study with the help of Department of Agriculture Extension (DAE). GPS location of the farmer's field was farmer-1 (R_1)-N: $23^0$27'21.6'' E: $91^0$0'14.4''; farmer-2 (R_2)-N: $23^0$27'21.6'' E: 91^0 0'14.4''; Farmer-3 (R_3)-N:$23^0$27'21.6'' E: $91^0$0'21.6''; Farmer- 4 (R_4)-N:$23^0$27'18'' E: $91^0$0'21.6'' and Farmer-5 (R_5)-N:$23^0$27'18'' E: $91^0$0'21.6''. The experiment was conducted during July, 2020 to July, 2021. BINA dhan-20, a Zinc sensitive rice variety was selected for cultivation in T. aman season. Seeds of T. aman were sown on 31^{st} July, 2020 in the seed bed and seedling was transplanted on 27^{th} August 2020 in all plots. The individual plot size was 20 m^2 (5m× 4m) and the number of plots was 6 in each farmer's field by maintaining plot to plot 1 meter distance and the total number of plots was 30 (6×5). Pre-Cropping composite soil sample were collected from each farmer's field for initial soil nutrient status as well as fertilizer recommendation.

After final land preparation for T. aman rice fertilizers were applied as per treatments (T_1: Urea- 102 kg ha^{-1} applied at 7, 17, 27 DAT T_2: Urea- 196 kg ha^{-1} at 7, 17, 27 DAT, TSP- 50 kg ha^{-1}, MoP- 70 kg ha^{-1}, Gypsum- 55 kg ha^{-1} , Zinc sulfate monohydrate- 6.5 kg ha^{-1} applied as basal; T_3: Urea- 195 kg ha^{-1} applied at 7, 17, 27 DAT, TSP- 50 kg ha^{-1} , MoP- 70 kg ha^{-1}, Gypsum- 55 kg ha^{-1} applied as basal; T_4: Urea- 195 kg ha^{-1} applied at 7, 17, 27 DAT, TSP- 50 kg ha^{-1}, MoP- 70 kg ha^{-1}, Gypsum- 55 kg ha^{-1} applied as basal and Zn chelate and Boric acid applied with 0.2 % solution as foliar spray at anthesis; T_5: Urea- 97.5 kg ha^{-1} at 7, 17, 27 at DAT, TSP- 25 kg ha^{-1}, MoP-35 kg ha^{-1}, Gypsum- 27.5 kg ha^{-1} , compost- 2.5 t ha^{-1} applied as basal, T_6: Urea- 97.5 kg ha^{-1} at 7, 17, 27 DAT, TSP- 25 kg ha^{-1} , MoP- 35 kg ha^{-1}, Gypsum- 27.5 kg ha^{-1} , Compost- 2.5 t ha^{-1} applied as basal and Zn chelate and Boric acid applied with 0.2 % solution as foliar spray at anthesis). Afterwards, the intercultural operations were done in several intervals as per field conditions. Parching and light trap were set up to protect the field from stem borer and green leaf hopper (GLH). Pesticides and other intercultural operations like water manage management were maintained when and where required. Harvesting of T. aman rice was done on 29th November 2020 where grain yield (t/ha), 1000 seed weight, straw yield (t/ha) were recorded. Post rice and pre-cauliflower soil samples were collected for chemical analysis that was required fertilizer recommendation for cauliflower. Accordingly, the 2nd crop (cauliflower) was cultivated in the same plots with the treatments of fertilizer dose for cauliflower. Cauliflower; Snow-white (F_1), a hybrid named CLX 321 was selected for Rabi season. Cauliflower seeds were sown on 6th November 2020 in the seed bed after overnight water soaking and seedling were transplanted on 9th December 2020 maintaining the spacing of 55 cm × 45 cm.

Treatment wise fertilizers were applied as basal and on growing crops (T_1: Urea 450 kg ha^{-1} basal as well as split at 20, 40, 60 DAT; TSP- 660 kg ha^{-1} basal as well as split at 20, 40 DAT, MoP- 411.5 kg ha^{-1}, Gypsum- 206 kg ha^{-1}, Zinc sulfate- 10.5 kg ha^{-1} as basal; T_2: Urea- 330 kg ha^{-1} basal as well as split at 20, 40, 60 DAT, TSP- 250 kg ha^{-1}, MoP- 200 kg ha^{-1} basal as well as split at 20, 40, 60 DAT, Gypsum 144 kg ha^{-1}, Zinc sulfate monohydrate- 5 kg ha^{-1}, Boric acid- 5 kg ha^{-1} as basal; T_3: Urea- 330 kg ha^{-1} basal as well as split at 20, 40, 60 DAT, TSP- 250 kg ha^{-1}, MoP- 200 kg ha^{-1} basal as well as split at 20, 40, 60 DAT, Gypsum 144 kg ha^{-1} as basal and 0.2% Zinc chelate applied as foliar spray at 40, 60 DAT; T_4: Urea- 330 kg ha^{-1} basal as well as split at 20, 40, 60 DAT, TSP- 250 kg ha^{-1}, MoP- 200 kg ha^{-1} basal as well as split at 20, 40, 60 DAT, Gypsum 144 kg ha^{-1} as basal and 0.2% Zinc chelate and Boric acid applied as foliar spray at 40, 60 DAT; T_5: Urea- 165 kg ha^{-1} basal as well as split at 20, 40, 60 DAT, TSP- 125 kg ha^{-1}, MoP- 100 kg ha^{-1} basal as well as split at 20, 40, 60 DAT, Gypsum 72 kg ha^{-1}, compost-5 t ha^{-1} as basal; T_6: Urea-165 kg ha^{-1} basal as well as split at 20, 40, 60 DAT, TSP- 125 kg ha^{-1} , MoP- 50 kg ha^{-1} , Gypsum 72 kg ha^{-1}, compost 5 t ha^{-1} as basal and 0.2% Zinc chelate and Boric acid applied as foliar spray at 40, 60 DAT.) Intercultural operations were done in several intervals as per field conditions. Weeding and irrigation were done four times on regular basis at 15 days interval. Plant height and other relevant data was recorded at 40, 60 and 80 DAT. Sex pheromone trap was set up on 11, November, 2021 to protect the field from the attack of *Spodoptera litura*. After first harvesting on February, 2021 weight (kg) of curd was recorded from randomly selected 10 plants and at final harvest on March, 2021 the yield (t/ha) of curd and straw (from inner 2 lines) were collected. Again, post cauliflower and pre- mungbean soil samples were collected for chemical analysis that was required fertilizer recommendation for mungbean. According to the cropping pattern, the 3rd crop (Kharif-1) mungbean (BARI mung-6) was cultivated in the same plot like earlier crop cauliflower with similar treatments having different fertilizer doses of mungbean. Land preparation was done by several tillage and leveling. Fertilizer application rates and time and methods were done asper treatments (T_1: No fertilizer applied; T_2: Urea- 45kg ha^{-1}, TSP- 100 kg ha^{-1}, MoP- 50kg ha^{-1}, Gypsum-90 kg ha^{-1}, Zinc sulfate monohydrate-10 kg ha^{-1} as basal; T_3: Urea- 45 kg ha^{-1}, TSP- 100 kg ha^{-1}, MoP-50 kg ha^{-1} , Gypsum-90 kg ha^{-1} as basal and 0.2% Zinc chelate- as foliar application before flowering, T_4: Urea- 45 kg ha^{-1}, TSP- 100 kg ha^{-1}, MoP- 50 kg ha^{-1}, Gypsum-90 kg ha^{-1} as basal and 0.2 % Zinc chelate and Boric acid as foliar application before flowering; T_5: Urea- 22.5 kg ha-1 , TSP-50 kg ha-1 , MoP- 62.5 kg ha^{-1}, Gypsum-45 kg ha^{-1}, Compost- 2.5 t ha^{-1} as basal; T_6: Urea- 50 kg ha^{-1} basal as well as split before flowering, TSP-50 kg ha^{-1}, MoP- 62.5 kg ha^{-1}, Gypsum-45 kg ha^{-1}, Compost- 2.5 t ha^{-1} as basal and 0.2 % Zinc chelate and Boric acid as foliar application before flowering). Mungbean seeds were sown in line on 18th March, 2021. Afterwards, thinning and gap filling were done to maintain 30 cm × 10 cm spacing. Intercultural operation was done according to the field condition.

First flowering was recorded on 5th June 2021 and the pod matured on 25th June 2021. Post-harvest data like 1000 seeds weight, grain yield (t ha^{-1}), stover yield (t/ha) were recorded after final harvest on 10th July 2021. After each crop harvest there were 30 plant and 30 edible part samples were collected. Accordingly, after third crop harvests there were 90 plant and 90 edible part samples were collected for chemical analysis. Soil pH was determined by Glass Electrode pH meter method with soil water ratio 1:2.5 (McLean, 1982), Organic matter by Walkley-Black method (Nelson and Sommers, 1982), Total N by Kjeldhal system (Bremner and Mulvaney, 1982), available P by Bray and Kurtz Method (1945), K by ammonium acetate extraction method (Barker and Surh, 1982), available S was determined by Turbidimetric method (Page *et al.,* 1989), available Zn was determined by DTPA Extraction method and B was determined by Calcium chloride extraction method (Page *et al.,* 1989), whereas total Zn, B of the plant parts were determined by the acid digestion method (Jones and case, 1990; Watson and Issac, 1990). Statistix10 software (Tallahassee, 2013) was used to analyze the data. ANOVA and univariate analysis were performed. Means were separated by LSD at 5% level of significance.

3. Results and Discussions

3.1 Effect of fertilizer management on grain yield, straw yield of T. aman rice

The effect of fertilizer treatments was found insignificant on 1000 grains weight of rice but their effect was found significant on grain yield and straw yield. The highest grain and straw yield were found in T_4 treatment (5.15 t ha^{-1} and 9.24 t ha^{-1}, respectively) which was statistically identical to the yield of T_2, T_3, T_5 and T_6 while the lowest grain and straw yield was found in T_1 treatment (Table 1). All recommended fertilizer doses along with foliar application of zinc, boron and 50% RFD + 50% organic matter more or less balance fertilizer application which ultimately affected the grain and straw yield of T. aman rice.

Table 1. Effect of fertilizer management on grain yield, straw yield of T. aman rice

Treatments	Wt. of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T1	30.29	4.49 b	8.09 b
T2	30.50	4.93 ab	8.93 ab
T3	30.52	4.84 ab	8.55 ab
T4	32.20	5.15 a	9.24 a
T5	29.73	4.69 ab	8.84 ab
T6	30.55	4.68 ab	8.98 ab
LSD (0.05)	3.903 (NS)	0.487	0.998
CV (%)	9.66	7.69	8.62

T_1 = Farmers practice, T_2 = Recommended Fertilizer Dose of NPKS (RFD) with Zn as basal, T_3 = RFD with Zn as foliar spray, T_4 = RFD with Zn & B as foliar spray, T_5 = 50% RFD + 50% Organic manure, T_6 = 50% RFD + 50% Organic manure + Zn & B as foliar spray

Table 2. Effect of fertilizer management on protein, zinc and boron content in rice grain and straw

Treat.	Protein (%)		Zn (mg kg^{-1})		B (mg kg^{-1})	
	Rice grain	Rice straw	Rice grain	Rice straw	Rice grain	Rice straw
T1	7.06c	5.35c	23.07c	109.25b	24.57c	8.45b
T2	8.83ab	6.60b	25.86b	127.17ab	26.66bc	8.77b
T3	8.75ab	6.65b	28.65a	125.83ab	27.06bc	9.98b
T4	8.98a	7.88a	29.99a	137.09a	32.15a	11.04a
T5	8.02b	7.13ab	24.27bc	116.46ab	28.59ab	10.85a
T6	8.71ab	8.00a	30.15a	131.49ab	31.72a	11.74a
SE (±)	*0.435*	*0.565*	*1.321*	*10.97*	*2.292*	*0.632*
CV (%)	*8.21*	*12.88*	*7.74*	*13.94*	*10.50*	*10.03*

3.2 Effect of fertilizer management on protein, zinc and boron content of rice grain

Fertilizer management significantly affected the protein content in unpolished rice grain. The highest protein in unpolished rice grain was found in T_4 treatment (8.98%) which was statistically identical to T_2, T_3 and T_6 treatments while the lowest protein (7.06%) was observed in T_1 treatment. Generally long grain dry white rice contains 8.0% protein. The protein content of brown rice of IR480-5-9 varied from 9.5 to 10.2% without application of N

(De Datta, 1972). The test crop of the present study was Zn fortified BINA dhan-20 where the highest protein in unpolished dry grain was obtained in different RFD treatments ranges from 8.02% -8.98%, except farmers practice. Present study is an agreement of the earlier statements. Fertilizer management also significantly affected the crude protein content in rice straw. The highest crude protein in rice straw was found in T_6 treatment (8.00%) which was statistically identical to T_4 and T_5 treatments while the lowest crude protein (5.35%) was observed in T_1 treatment (Table 2). There is linear relationship between applied nitrogen and crude protein. Straw nitrogen is influenced by the application of nitrogenous fertilizer. Application of 100 kg ha^{-1} nitrogen can increase the grain and straw nitrogen 2.50% and 1.19% of its dry biomass (Malav and Ramani, 2016) which contribute to increase protein in rice grain and straw. In the present study straw nitrogen ranged from 1.06 to 1.28%, obtained in RFD which is aligned to J. K. Malav and V.P. Ramani, 2016 study findings.

Fertilizer management significantly affected the Zn content of in rice grain. The highest Zn content was observed in T_6 treatment (30.15 (mg kg^{-1}) which was statistically identical to T_3 and T_4 treatments while the lowest Zn in rice was found in T_1 (23.07 (mg kg^{-1}) treatment which was statistically identical to T_5 treatment. Fertilizer management also significantly affected the Zn content in rice straw. The highest Zn in rice straw was found in T_4 treatment (137.09 (mg kg^{-1}) which was statistically identical to T_2, T_3, T_5 and T_6 treatments while the lowest Zn content (109.25 (mg kg^{-1}) was found in T_1 treatment (Table 2). Zinc concentration ranged from 14.5 to 35.3 (mg kg^{-1}) in unpolished, brown rice. There was substantial loss of iron than zinc, upon polishing. In the present study where test crop was Zn fortified BINA dhan-20. The highest Zn concentration in rice grain 30.15 mg/kg where foliar application was done with Zn chelate and Boric acid. Present study findings are an agreement of the previous findings. Bio-fortification with micronutrients in edible parts of crop can be achieved by utilizing crop and soil management (Zuo and Zhang, 2011). Rice feeds almost 50-58% of the world's population, hence can be considered as a global grain. Therefore, even a small increase in the nutritive value of rice can be highly significant for human nutrition (Zhang *et al.,* 2012).

Fertilizer management significantly affected the B content in the rice grain. The highest B content was observed in T_4 treatment (32.15 mg kg^{-1}) which was statistically identical to T_5 and T_6 treatments while the lowest B in rice was found in T_1 (24.57 mg kg^{-1}) treatment which was statistically identical to T_2 and T_3 treatments. Fertilizer management also significantly affected the B content in rice straw. The highest B in rice straw was found in T_6 treatment (11.74 mg kg^{-1}) which was statistically identical to T_4 and T_5 treatments while the lowest B content (8.45 mg kg^{-1}) was found in T_1 treatment (Table 2) which was statistically similar to T_2 and T_3 treatments. Boron is a limiting factor in crop productivity in rice-based cropping system. Such a deficiency of boron has emerged as an important micronutrient problem in Indian soils and crops next to zinc. Calcareous soils with a light (sandy) texture and low organic matter content suffer from boron deficiency. An increase in the calcium carbonate content raises soil pH, limiting the availability of B by serving as a sink for B in soil, where it is involved in the surface adsorption of a large portion of the soluble B, thus decreasing its availability for plant uptake. Present study finding is aligned with the earlier statements.

3.3 Effect of fertilizer management on yield and other yield attributes of cauliflower

The effect of fertilizer management was found significant on flowering duration, curd weight, biomass weight, curd yield and biomass yield of cauliflower. It was found that the present farmers practice needed maximum duration (89 days) for 1st flowering duration while the lowest duration (84 days) was observed in T_6 treatment where 5 t ha^{-1} manure was applied. The highest curd weight (1.47 kg plant^{-1}), biomass weight (1.06 kg plant^{-1}), curd yield (54.04 t ha^{-1}) and biomass yield (38.25 t ha^{-1}) were observed in T_1 treatment which was statistically identical to T_2, T_3 and T_4 treatments. The lowest curd weight (0.99 kg plant^{-1}), biomass weight (0.84 kg plant^{-1}), curd yield (36.29 t ha^{-1}) and biomass yield (30.75 t ha^{-1}) were observed in T_5 treatment respectively, which was statistically similar to T_6 treatment (Table 3).

Table 3. Effect of fertilizer management on yield and characters of cauliflower (Snow white - Hybrid)

Treatments	First Flowering Duration (days)	Curd wt. (kg plant^{-1})	Biomass wt. (kg plant^{-1})	Curd yield (t ha^{-1})	Biomass yield (t ha^{-1})
T1	89.00 a	1.47 a	1.06 a	54.04 a	38.25 a
T2	87.00 b	1.34 a	0.94 ab	48.71 a	33.85 ab
T3	87.20 b	1.30 ab	1.00 ab	48.97 a	36.22 ab
T4	86.80 b	1.42 a	0.98 ab	51.85 a	35.29 ab
T5	84.60 c	0.99 c	0.84 b	36.29 b	30.75 b
T6	84.40 c	1.13 bc	0.86 b	41.28 b	31.18 b
LSD $_{(0.05)}$	0.565	0.163	0.173	5.525	5.944
CV (%)	0.49	1.19	13.87	8.94	13.15

Farmers were applying excess fertilizer than the recommended doses of present study. They used 1.36, 2.64, 2.05 and 1.43-fold higher doses of urea, TSP, MoP and Gypsum fertilizer, respectively. Farmers were applying excess fertilizer than the recommended doses of present study. They used 1.36, 2.64, 2.05, 1.43 and 2.1 -fold higher doses of urea, TSP, MoP, Gypsum and $ZnSO_4.H_2O$ fertilizer, respectively. Excess use of fertilizer in farmers practice, T_1 treatment might had affected on delay flowering as well as higher yield and other yield attributes of cauliflower.

3.4 Effect of fertilizer management on protein, zinc and boron content in cauliflower leaves

Highest content of crude protein in leaves and curd of cauliflower was observed in T_1 and

T_4 treatments which were 2.57% and 1.91%, respectively while the lowest protein content in leaves and curd was found in T_3 and T_1 treatments which were 2.49% and 1.85%, respectively (Fig. 1a). Highest Zn concentration in leaves and curd of cauliflower was observed in T_4 and T_6 treatments which were 81.14 mg kg^{-1} and 74.06 mg kg^{-1}, respectively while the lowest Zn concentration in leaves and curd was found in T_2 and T_1 treatments which were 73.41 mg kg^{-1} and 65.81 mg kg^{-1}, respectively (Fig. 1b). Highest B concentration in leaves and curd of cauliflower was observed in T_4 and T_6 treatments which were 39.59 mg kg^{-1} and 32.62 mg kg^{-1}, respectively while the lowest B concentration in leaves and curd was found in T_1 treatments which were 17.46 mg kg^{-1} and 16.23 mg kg^{-1} respectively (Fig. 1c). Seed priming in 0.05% Zn and 0.01% solution showed the highest potentiality to increase Zn and B in cauliflower plant and in cauliflower curd which support the results of present study (BARI, 2020-2021). The higher cauliflower leaf (81.14 mg kg^{-1}) and curd (72.96 mg kg^{-1}) Zn concentrations were obtained from T_4 treatment (RFD with Zn & B as foliar spray) which was closely similar to T_6 treatment. Similarly, the highest leaf (39.59 mg kg^{-1}) and curd (32.62 mg kg^{-1}) B concentrations were recorded in T_4 and T_6 treatments, respectively.

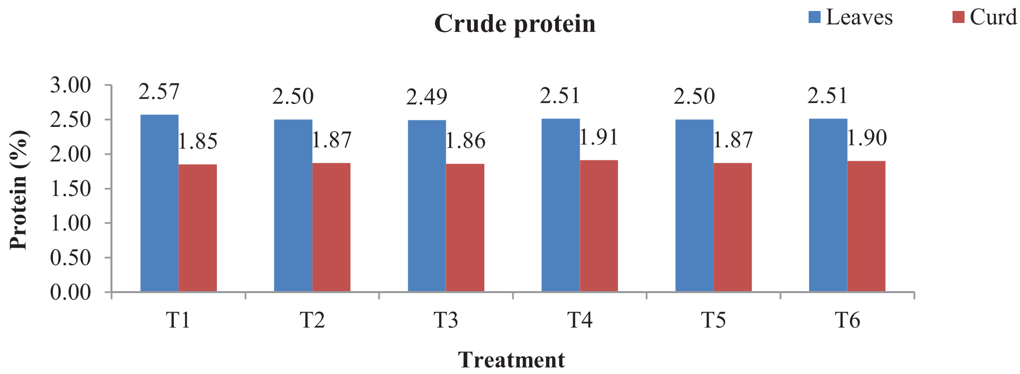

Fig. 1a Effect of fertilizer management on protein content of cauliflower leaves and curd

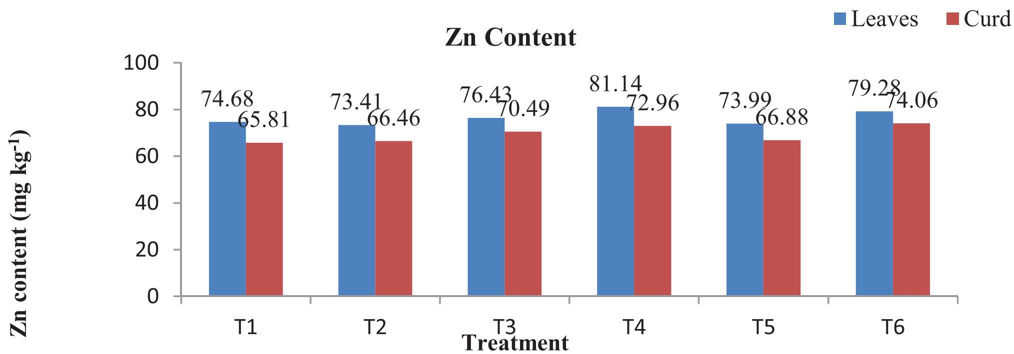

Fig.1b Effect of fertilizer management on zinc content of cauliflower leaves and curd

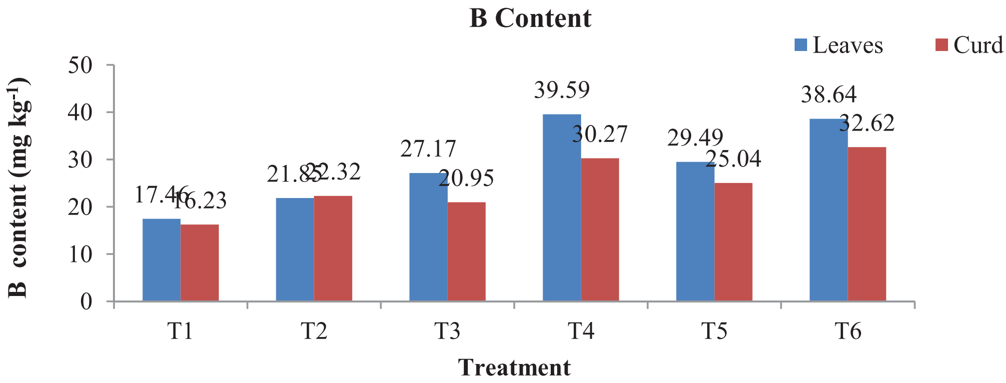

Fig.1c Effect of fertilizer management on boron content of cauliflower leaves and curd

3.5 Effect of fertilizer management on yield attributes, seed yield and straw yield of mung bean

Fertilizer management affect was found significant on the duration of first flowering of mungbean. The significantly maximum days of 1st flowering was found in T_3 treatment (34.80 days) which was statistically similar to T_2 treatment while the lowest 1st flowering days was recorded in T_1 treatment (33.20 days) which statistically identical to T_4, T_5 and T_6 treatments. Fertilizer affect was found significant on 1000 seed weight. The significantly highest 1000 seed weight (49.62 g) was found in treatment T_4) while the lowest yield (45.64 g) was recorded in T_5 treatment. Fertilizer management effect was also significant on seed yield and the highest seed yield (1.47 t ha^{-1}) was recorded in T_4 treatment which was statistically similar to T_1, T_3 and T_6 treatments while the lowest seed yield was recorded in T_5 treatment (1.20 t ha^{-1}) which was statistically similar to T_2 treatment. Mungbean was the subsequent crop of cauliflower where farmers used 1.36, 2.64, 2.05, 1.43 and 2.1 -fold higher doses of urea, TSP, MoP, Gypsum and $ZnSO_4.H_2O$ fertilizer, respectively which might had affected on mungbean seed yield. Therefore, in the farmers practice the yield of mungbean was statistically identical to the recommended fertilizer dose. Fertilizer management effect on straw yield was found insignificant (Table 4).

Table 4. Fertilizer management practices on yield attributes, seed yield, straw yield of mung bean

Treatments	Duration of first flowering (day)	Wt. of 1000 seeds (g)	Seed yield (t ha^{-1})	Straw yield (t ha^{-1})
T1	33.20 b	45.74 b	1.33 ab	1.94
T2	34.60 a	47.00 b	1.30 b	2.01
T3	34.80 a	47.54 b	1.36 ab	2.09
T4	33.80 b	49.62 a	1.47 a	2.08
T5	33.40 b	45.64 b	1.25 b	1.94
T6	33.60 b	46.44 b	1.33 ab	1.96
LSD (0.05)	0.751	2.055	0.147	NS
CV (%)	1.68	3.31	8.31	6.76

Table 5. Crude protein, zinc and boron content in mungbean seed and straw

Treat.	Crude Protein (%)		Zn (mg kg^{-1})		B (mg kg^{-1})	
	Seed	Straw	Seed	Straw	Seed	Straw
T1	23.28b	11.73c	42.91c	60.29b	5.62c	22.75c
T2	23.63ab	13.78ab	45.66c	64.39ab	6.28b	30.32b
T3	24.41a	14.27ab	56.61ab	69.09ab	5.68bc	29.14b
T4	24.47a	13.13b	57.97a	71.21a	7.33a	35.50a
T5	23.98ab	13.13b	52.94b	64.63ab	6.12bc	30.64b
T6	24.10ab	14.15a	57.77a	68.91a	7.22a	34.85a
SE (±)	*0.482*	*0.096*	*1.980*	*4.420*	*0.030*	*1.694*
CV (%)	*3.18*	*3.18*	*5.99*	*5.99*	*7.63*	*7.93*

3.6 Fertilizer management on protein, zinc and boron content in mungbean seed and straw

Fertilizer management significantly affected the protein content of mungbean seed. The highest protein content (24.47%) was observed in T_4 treatment which was statistically similar to T_2, T_3, T_5 and T_6 treatments while the lowest protein content (23.28%) was found in T_1 treatment. Fertilizer management significantly affected the crude protein content in mung bean straw. The highest crude protein content (14.15%) in mungbean straw was observed in T_6 treatment which was statistically similar to T_2 and T_3 while the lowest crude protein content (11.73%) in mungbean straw was found in T_1 treatment. Fertilizer management significantly affected the Zn content of mungbean seed. The highest Zn content was observed in T_4 treatment (57.97 mg kg^{-1}) which was statistically similar to T_3 and T_6 treatments while the lowest Zn content (42.91 mg kg^{-1}) was found in T_1 treatment. Fertilizer management significantly affected the Zn content of mungbean straw. The highest Zn content in mungbean straw was observed in T_4 treatment (71.21 mg kg^{-1}) which was statistically similar to T_2, T_3, T_5 and T_6 treatments respectively, while the lowest Zn content

(60.29 mg/kg) was found in T_1 treatment. Fertilizer management significantly affected the B content of mungbean seed. The highest B content of mungbean seed (7.33 mg kg^{-1}) was observed in T_4 treatment which was statistically similar to T_6 treatment while the lowest B content (5.62 mg kg^{-1}) was found in T_1 treatment which was statistically similar to T_3 and T_5 treatments. Fertilizer significantly affected the B content of mungbean straw. The highest B content of mungbean straw was observed in T_4 treatment (35.50 mg kg^{-1}) which was statistically similar to T_6 treatment while the lowest B content (22.75 mg kg^{-1}) in mungbean straw was observed in T_1 treatment (Table 5).

Generally, mungbean contains 20-25 percent protein. BARI mungbean-6 is a good source of protein and various important micronutrients. It contains 24.5% protein (Afzal *et al.,* 2004). Present study finding is quietly aligned with the findings of Afzal *et al.,* 2004. Foliar application of Zn and B along with 50% nutrient from compost +50% from chemical fertilizer showed the better performance in contest of protein and other nutrient content, yield and yield contributing attributes. Organic matter is the main source of micronutrients. Along with foliar application of Zn and B and 50% nutrient from compost +50% from chemical fertilizer showed the potentiality to increase protein, Zn and B content of mungbean seed and straw. Zinc being essential nutrient plays a significant role in stomata regulation and reducing the tensions of less water by creating ionic balance in plants system and is involved in various physiological processes such as synthesis of protein and carbohydrates. Similarly, B application improves growth, and enhances stress tolerance in plants and improves grain production. Legume crops required more amount of B compared to most field crops as B plays vital role in proper development of reproductive organs Zn and B are the essential plant micronutrients and their importance for crop productivity is similar to that of major nutrients. Both play an important role in the basic plant functions like photosynthesis, proteins and chlorophyll synthesis. Application of micronutrient fertilizers through soil application is easier but its distribution and uptake in most cases might not be uniformed. The amount of nutrient required for soil application is much higher compared to foliar application. In many cases, aerial spray of nutrients is preferred which provides quicker and better results than the soil application. Foliar feeding practice would be more useful in early maturing short duration crops, where the soil applied fertilizer may not become fully available before maturity of crop.

5. Conclusions

It was found that T_6 treatment where 50% RFD of NPKS + 50% organic manure along with foliar application of Zn and B in rice cultivation at anthesis stage Zn content in rice grain was 4.39 mg kg^{-1} higher and B content was 5.06 mg kg^{-1} higher than the RFD of NPKS along with soil application of Zn and B but very little or no significant change of protein content in rice grain was found. Similarly, 50% RFD of NPKS + 50% organic manure along with foliar application of Zn and B in cauliflower cultivation at 40-45 DAT and 60-65 DAT, Zn content in cauliflower curd was 7.60 mg kg^{-1} higher and B content was 10.30 mg kg^{-1} higher than the RFD of NPKS along with soil application of Zn and B. Here also found no remarkable increment of protein content in cauliflower curd. In the same treatment in case of mungbean cultivation 0.47% seed protein, 12.11 mg kg^{-1} Zn and 0.98 mg kg^{-1} B content were found higher than the RFD of NPKS along with soil application of Zn and B fertilizers. Among the six treatments it might be concluded that soil application of recommended doses of macronutrient fertilizers and foliar application of Zn and B were found more efficient in increasing nutrient elements like protein, zinc and boron content in edible parts as well as plant parts.

Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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