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Impact of Zinc, Boron and Molybdenum Addition in Soil on Mungbean Productivity, Nutrient Uptake and Economics

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Abstract

Zinc (Zn), boron (B) and molybdenum (Mo) are essential to increase the productivity of mungbean (*Vigna radiata* L.) and help to maintain the soil fertility but mostly ignored. Hence, an experiment was conducted during the years of 2016 and 2017 to know the impact of Zn, B and Mo on mungbean yield, nutrient uptake, economics and soil fertility improvement. The experiments were planned in randomized complete block design including of eight treatments with three replications. The treatments were T_1 = Control, T_2 = Zn 2 kg ha^{-1}, T_3 = B 1.5 kg ha^{-1}, T_4 = Mo 1 kg ha^{-1}, T_5 = $Zn_2B_{1.5}$, T_6 = Zn_2Mo_1, T_7 = $B_{1.5}Mo_1$ and T_8 = $Zn_2B_{1.5}Mo_1$. The other fertilizers, N, P, K and S at 20, 20, 30 and 10 kg ha^{-1}, respectively were used in all treatments. The results indicate that the highest seed yield (1522 kg ha^{-1}) was obtained from T_8 treatment followed by T_7. The highest percent seed yield increment (51.6%) over control was achieved in T_8 treatment. Most of the growth and yield contributing characters of mungbean were recorded highest in T_8 treatment. The maximum nodulation (37.6) and highest amount of protein (24.3%) was also obtained from T_8 treatment. The T_8 treatment contributed positively to attain higher total uptake of N, P, K, S, Zn and B by mungbean. The combination of Zn, B and Mo is showed more productive compare to sole or couple use of these micronutrients. The T_8 ($Zn_2B_{1.5}Mo_1$ kg ha^{-1}) treatment exhibited helpful effects on soil organic matter, total N, available P, Zn and B. This treatment also showed economically better on the basis of net return. Results of the present study suggest that the combination of Zn, B and Mo applied at 2, 1.5 and 1 kg ha^{-1}, respectively could be recommended for mungbean cultivation.

Keywords: zinc, boron, molybdenum, mungbean yield, quality, nutrient uptake, economics

1. Introduction

Current pulses demand of Bangladesh is rising quickly for rapid growing population. But the national production of the pulses is not sufficient to meet the demand. Because, the area and production of the pulses are decreasing day by day due to occupy the boro rice and maize in cropping system through creation of irrigation facilities (Rahman, 2015). Pulses production is being also hampered due to the reduced of soil fertility making by the inappropriate and non-judicious use of inorganic fertilizers (Tarafder et al., 2020). Among pulses, mungbean (*Vigna radiata* L.) is the third most important pulse crop in terms of area and production in Bangladesh belonging to the family Fabaceae (Salam et al., 2017). The total area of mungbean cultivation in Bangladesh is 41421 ha with the production of 34783 m tones per year while the average yield is 840 kg ha^{-1} (BBS, 2018) which indicates very low compare to potential yield (1500 kg ha^{-1}). Farmers of Bangladesh are generally cultivated it in Kharif-I (March to June) season, but in the Southern belt of Bangladesh it has been cultivated in late Rabi (last week of January to April) season. It is an important source of protein (21 to 32.6%) and several essential nutrients (Hou et al., 2019). The mungbean sprout is used as vegetable rich in different vitamins and amino acids (Ullah et al., 2014). It improves the fertility status of soil through atmospheric nitrogen fixation (Afloabi et al., 2014). There are many reasons for low yield of mungbean. Nutrients deficiency among them, especially micronutrients like Zn, B and Mo. Soils in the Gangetic plains of Bangladesh are more or less deficient in zinc, boron and molybdenum as well as nitrogen fixing bacteria (*Rhizobium* sp.) which are caused poor yield of mungbean (Quddus, 2011). Micronutrient deficiency in soil is declining the crop productivity and increasing the condition of malnutrition (Ryan et al., 2013).

However, there is great opportunity for increasing the production of mungbean globally with balanced and judicious fertilization including micronutrient using high yielding variety. Micronutrient plays an important role for improving the pulses growth, development and productivity through fixing of nitrogen by symbiotic process (Monika et al., 2020). Micronutrient like Zn plays a major role in plant growth and development (A. B. Raj & S. K. Raj, 2019). Zinc is also involved in plant metabolism and synthesis of auxins, carbohydrate, phosphate and nucleic acid (Latef et al., 2016). It influences the activities of enzymes (*e.g.*, dehydrogenase and carbonic anhydrase, proteinases, and peptidases), and cytochrome c synthesis, stabilization of ribosomal fractions and protection of cells against oxidative stress (Malik et al., 2015). Zinc influences the capacity of water uptake in plant and transports (Disante et al., 2011) and reduces the adverse effects of short periods of heat stress (Peck & McDonald, 2010) or of salt stress (Tavallali et al., 2010). Zinc deficiency depressed root and shoot growth and chlorophyll concentration (Malik et al., 2015). Boron is another micronutrient essential for cell division, cell wall biosynthesis, pod and seed formation (Goldberg & Su, 2007). It is involved in the process of nodule formation (Bolanos et al., 2001). Reproductive growth, especially flowering, fruit and seed set is more sensitive to B deficiency than vegetative growth (Islam et al., 2017). Boron enhances the flower development, pollen grain formation, pollen viability, pollen tube growth and seed development in green gram (Praveena et al., 2018). The other micronutrient- Mo is an essential component of nitrogen fixing enzyme nitrogenase and nitrate reductase (FRG, 2018). The nitrate reductase is essential in the assimilation of nitrates since it catalyses the first step of the reduction of NO_3 to NH_3. The other major molybdo-protein of plants includes nitrogenase, which fixes atmospheric nitrogen to NH_3, which is assimilated by plants (Adesoji et al., 2009). Molybdenum deficiency in soil induced nitrogen deficiency in legumes relying on N_2 fixation (Weisany et al., 2013). Molybdenum application is significantly increased the canopy, nodule formation and yield of crop (Khan et al., 2019). However, the combination of Zn, B and Mo with macronutrients can be augmented the productivity of any legume crops (Islam et al., 2018). The encouraging effects of Zn, B and Mo on several crops like chickpea, lentil, groundnut etc. have already been visible. On the other hand, their impacts on mungbean productivity, nutrient uptake and economics have not been explored properly. The present study was, therefore, undertaken (i) to evaluate the impacts of Zn, B and Mo on mungbean productivity, nutrient uptake and economics and the nutrient status of postharvest soil and (ii) to explore the suitable combination of micronutrient.

2. Materials and Methods

2.1 Brief of Site, Soil and Climate

The field experiment was carried out at the research field of Regional Agricultural Research Station (RARS), Bangladesh Agricultural Research Institute (BARI) in Jashore during the *kharif-I* season of 2016 and 2017. The experimental site was geographically placed at 23°11′15″ N latitude and 89°11′06″ E longitude and raised of 6.71 m above the sea level. Land type of the trial was high and belongs to Gopalpur soil series under the agroecological zone (AEZ-11), High Ganges River Floodplain.The sub-order of the soil is ochrepts under the order inceptisols.The nature of the soils are calcareous and the texture of the soil was silt loam. Starting soil pH value of the experimental field was 8.2, organic carbon was 8.55 g kg^{-1}, total N was 0.77 g kg^{-1}, and exchangeable K was 0.14 meq. 100 g^{-1}, exchangeable Ca was 19.0 meq. 100 g^{-1}, available P, S, Zn and B was 14.6 mg kg^{-1}, 15.2 mg kg^{-1}, 0.84 mg kg^{-1} and 0.16 mg kg^{-1}, respectively (Table 6). The climate of experimental site is subtropical and the experimental period was March to June. The rainfall was acquired from 7.9 mm to 165 mm during March to June. The mean minimum and maximum air temperatures of March to June were 18.6 and 37.9 °C, respectively. In the period of study, average humidity (%) was ranged from 76.9 to 84.6 during March to June (Table 1).

Table 1. Weather data during the experiment period

Months	Avg. Temperature (°C)				Avg. Humidity (%)		Rainfall (mm)	
	2016		2017		2016	2017	2016	2017
	Min.	Max.	Min.	Max.				
March	18.6	30.4	14.7	32.5	84.4	76.9	20	7.9
April	24.6	37.9	16.5	33.5	79.8	78.4	45	107
May	23.5	36.6	21.4	36.2	82.2	81.4	165	148
June	25.9	31.4	20.1	34.5	84.6	82.6	149	156

Source: Weather Centre, BARI, Jashore.

2.2 Execution Procedure of Experiment

Tractor driven disc plough was used for exposing the land and then the soil of land was prepared thoroughly by plough of a power tiller followed by laddering and leveling. Weed and stubbles was cleaned from the experimental field. The field experiment was planned in randomized complete block design including of eight treatments with three replications. The treatments were viz.T_1 = Control, T_2 = Zn 2 kg ha^{-1}, T_3 = B 1.5 kg ha^{-1}, T_4 = Mo 1 kg ha^{-1}, T_5 = $Zn_2B_{1.5}$, T_6 = Zn_2Mo_1, T_7 = $B_{1.5}Mo_1$ and T_8 = $Zn_2B_{1.5}Mo_1$. The other fertilizers, N, P, K and S at 20, 20, 30 and 10 kg ha^{-1}, respectively were used in all treatments. The unit plot size of the trial was 4 m × 3 m which separated from each other by an alley of 50 cm width. The replicated blocks were alienated by the space of 75 cm width. Micronutrients (Zn, B and Mo) were applied as basal in the above- mentioned treatment plot. The other fertilizers were also applied as basal in all the treatment plot.The sources of N, P, K, S, Zn, B and Mo were urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate, boric acid and ammonium molybdate, respectively. The healthy seeds of mungbean (cv. BARI Mung-6) were sown continued in rows (10 rows in a plot) at 35 kg ha^{-1} maintained the space between row to row of 30 cm on 12 March 2016 and 13 March 2017. Hands weeding as well as thining of seedlings were done at 15 days after sowing (DAS) keeping the distance of plant to plant as 10 cm. The unit plot (12 m^2) was having about 400 plants.

2.3 Intercultural Operation

Another hand weeding was done at 40 days after seed sowing of mungbean. The Bavistin 50% WP fungicide was sprayed at 2 g L^{-1} in two times on 25 DAS and 35 DAS for controlling the leaf spot and rot diseases.The insects (pod borer and thrips) were reduced by spraying three times of insecticide Karate (Syngenta) at 2 ml L^{-1} at flowering and podding stage interval of 10 days. Irrigation was applied as and when necessary. The mature crop was harvested at two phases. First harvest was done at 2nd week of May and another was at 1st week of June in both the years. Treatment wise harvested pods of mungbean were sun dried in the threshing floor for separating seeds with the help of bamboo stick.

2.4 Data Collection

Ten plants of mungbean were randomly selected and tagged in each treatment plot at 1st harvest for recording the data of plant height, number of branch per plant, pod length, number of pods per plant and seeds per pod. Plant height and number of branches per plant was recorded from above ground part and averaged. Mature pods were detached from every plant and count the data of number of pods per plant and averaged. Ten pods were randomly separated from amalgamated pods of ten plant of each plot and then pod length was measured and averaged. The number of seeds per pod were counted from each pod of separated ten pods and averaged. Then treatment wise seeds of 10 plants were preserved in poly bag (15 × 10 cm). The number of nodules per plant was counted at flowering stage. Five plants from each plot were smoothly uprooted and carefully removed the soil from roots in the water of plastic container. Then washed the roots with fresh water, blotted with tissue paper and counted the number of nodules per plant and averaged. Active nodules were noted by selecting of inside light-pink or red colored. The seed and stover yield (kg ha^{-1}) per plot were recorded. Plot wise total seeds (seeds of ten plant+seeds of whole plot) were cleaned and sun dried adjusted at around 10% moisture level measured by digital seed moisture tester manual (Seedburo 1200D Digital Moisture Tester Manual, USA). Mature plants of each plot were harvested and sundried. The dried straws were weighed as kg ha^{-1}. The 100-seed weight (g) was determined using electronic balance by the counting of 100 seeds randomly from composite seeds of each plot.

2.5 Procedure of Soil Samples Analysis

Starting soil samples of the experimental field were collected (0-15 cm depth) from five spot using auger and amalgamated it carefully for laboratory analysis. Postharvest soil samples of the experimental plot were collected from 0-15 cm depth. The combined soil sample of each plot was carried to the laboratory and it was spread on a brown paper for air drying. The air-dried soil samples were ground and passed through a 20-mesh sieve. After sieving, the prepared soil samples were kept into plastic containers with proper label for chemical analysis. The following method was sketched such as soil pH was determined by glass electrode pH meter using a soil-water ratio was 1:2.5 (Page et al., 1982). Wet oxidation method was used for the determination of organic carbon (Page et al., 1982). Total N content was determined following micro Kjeldhal method (Page et al., 1982). Available P was measured by Olsen method (Page et al., 1982) and available S was determined by extracting the soil sample with 0.15 % $CaCl_2$ solution as described by Page et al. (1982). The reading was taken using UV visible Spectrophotometer (Varian Model 50 Conc.) at 720 nm and 420 nm wavelength for P and S, respectively. Exchangeable K and Ca were extracted with 1 M NH4OAc solution (pH = 7) (Thomas, 1982). For exchangeable K, the reading was taken directly using AAS (Chemito AA 203) at 766.5 nm wavelength. For Ca, 2 ml aliquot was diluted with 1 ml of La_2O_3 and 7 ml of distilled water and then reading was taken using AAS (Chemito AA 203). Available Zn was determined by DTPA method (Lindsay & Norvell, 1978); available B by azomethine-H method (Page et al., 1982). Available Mo was not determined due to lack of facility.

2.6 Plant Sample Analysis

Ground straw and seed samples were digested with di-acid mixture (HNO_3-$HClO_4$) (5:1) by Piper (1964) procedure for estimation of N content (Micro-Kjeldahl method), P (spectrophotometer method), K (atomic absorption spectrophotometer method) and S (turbidity method using $BaCl_2$ by spectrophotometer). Zinc content in the digest was directly measured by Atomic Absorption Spectrophotometer (VARIAN SpectrAA 55B, Australia). Boron content was estimated by spectrophotometer following azomethine-H method.

2.7 Protein Content Estimation

The protein content in seed of mungbean was calculated by using the constant food factor 6.25 that means (%N × 6.25) (Hiller et al., 1948)

2.8 Nutrient Uptake Determination

Nutrient (N, P, K, S, Zn and B) uptake by mungbean was measured from the results of crop yield and nutrient content in seed and straw (FRG, 2018).

2.9 Statistical Analysis

Analysis of variance was arranged following RCB design. Statistical analysis was done on nutrient (N, P, K, S, Zn and B) content, nodulation and protein content considering the average data of two years. All data including yield and yield contributing characters obtained from the present experiment were analyzed using the statistical software of Statistix-10 (Statistix-10, 1985). The means of all data were compared using the least significant difference (LSD) test in a significant level of $p \leq 0.05$.

2.10 Economic Analysis

In the experiment, treatment wise variable cost (cultivation cost) was measured by the addition of cost acquired from labours, ploughing and inputs. The seed yield of each treatment was converted as kg ha^{-1}. This yield was used to compute the gross return. The rent of experimental land and straw cost was not counted. Gross return of each treatment was calculated by multiplying with seed yield by the current unit price of mungbean. Net return was calculated by deducting the variable cost from gross return. Benefit cost ratio (BCR) was determined (Tithi & Barmon, 2018) by the formula:

$$BCR = \frac{GR}{VC} \tag{1}$$

3. Results and Discussion

3.1 Yields of Mungbean

The seed yield of mungbean was affected significantly by the application of Zn, B and Mo during the 1^{st} year and 2^{nd} year (Table 2). The highest seed yield (1485 kg ha^{-1}) was recorded from the treatment T_8 which was significantly higher over the other treatments, but statistically at par T_7 treatment in 1^{st} year while in 2^{nd} year, the seed yield was highest (1558 kg ha^{-1}) in the same T_8 treatment which showed statistically identical to T_7, T_6, T_5, and T_4 treatment. The lowest seed yield was in control (T_1) treatment. The mean seed yield ranged from 1005 to 1522 kg ha^{-1} across the treatments. In the experiment, increment of percent mean seed yield of mungbean over control was varied from 26.5 to 51.6% across the treatments, where the highest percent seed yield increment was calculated from the treatment T_8 and the lowest was from T_2 treatment. Results of the trial indicated that every micronutrient (Zn, B and Mo) contributed individually to help yield benefit over control. Micronutrients deficient soil is leading to low crops yield (Chude et al., 2004). However, zinc application might be boosted up the plant growth and yield of crops. In this study, Zn was significantly influenced to get seed yield increment about 26.5% over control because the status of available Zn in soil was low. The result is in agreement with the findigs of Rahman et al. (2017) in 50% yield benefits of maize compared to control. Zinc is the part of reversal enzymes. It may also be involved in synthesis of protein, part of tryptophan synthetase and regulating formation of tryptophan. Zinc acts in some oxidation reduction systems and its deficiency is lead to excessive oxidation of auxins and reduction of tryptophan, leading to retardation of elongation of stems (Malik et al., 2015). Essential micronutrient boron is required for plant growth and productivity. In this trial, boron contributed 29.1% yield increment of mungbean over control due to the status of available B in soil was low. However, Fageria et al. (2007) found that boron application significantly increased common bean yield. Boron might be involved in photosynthetic and metabolic activities which enhanced crop yield. Similar judgment stated by Lalit Bhott et al. (2004) and Sathya et al. (2009). Molybdenum plays a significant role for achieving higher productivity of legume compared to non-legume crops (Baily & Laidlaw, 1999). Molybdenum is the part of enzyme nitrogenase which is essential for the conversion of atmospheric N_2 to NH_3. However, Rahman et al. (2008) reported that application of molybdenum which is encouraged nodule formation and N_2 fixation. Molybdenum is also involved in various metabolic processes, *i.e.*, chlorophyll synthesis and leads to yield reduction of Mo deficiency (Liu, 2001). In this experiment, Mo significantly contributed to achieve 34.6% seed yield increment of mungbean over control. Result is in agreement with findings of Khan et al. (2019) who reported that Mo application significantly influenced to get higher biological yield of mungbean over control. On the other hand, application of double and triple micronutrients was performed better over single micronutrient although the combination of triple micronutrient which was played superior activities over paired micronutrient. Present experimental result is supported to the above explaination that triple micronutrient treatment T_8 ($Zn_{2.0}B_{1.5}Mo_{1.0}$ kg ha^{-1}) was contributed higher yield increment 10.6% over double micronutrient treatment $T_5 = Zn_{2.0}B_{1.5}$ kg ha^{-1}, 11.1% over treatment $T_6 = Zn_{2.0}Mo_{1.0}$ kg ha^{-1} and 6.06% over treatment $T_7 = B_{1.5}Mo_{1.0}$ kg ha^{-1}, respectively. Similar observation was made by Islam et al. (2017), and Alam and Islam (2016) who reported that combined application of Zn and B showed superior effect on the yield of mungbean than their single application.Yang et al. (2009) reported that the combined application of B with Mo or Zn resulted in higher seed yield than that of application of B, Mo, or Zn alone, while the combined application of B, Mo, and Zn increased the seed yield of rapeseed by 68.1% compared to control treatment.

Table 2. Effect of Zn, B and Mo on the yields of mungbean

Treatment	Seed yield (kg ha^{-1})			Straw yield (kg ha^{-1})			% Seed yield increase over control		
	1st Yr.	2nd Yr.	Mean	1st Yr.	2nd Yr.	Mean	1st Yr.	2nd Yr.	Mean
T_1 = Control	1031d	978c	1005	1874d	1832c	1853	-	-	-
$T_2 = Zn_2$ kg ha^{-1}	1208c	1327b	1268	2028cd	2277ab	2153	17.2	35.7	26.5
$T_3 = B_{1.5}$ kg ha^{-1}	1281bc	1311b	1296	2193bc	2160b	2177	24.2	34.0	29.1
$T_4 = Mo_1$ kg ha^{-1}	1296bc	1405ab	1351	2179bc	2416ab	2298	25.7	43.6	34.6
$T_5 = Zn_2B_{1.5}$	1349b	1402ab	1376	2262b	2354ab	2308	30.8	43.3	37.1
$T_6 = Zn_2Mo_1$	1358b	1381ab	1370	2326ab	2355ab	2341	31.7	41.2	36.5
$T_7 = B_{1.5}Mo_1$	1397ab	1472ab	1435	2334ab	2490a	2412	35.5	50.5	43.0
$T_8 = Zn_2B_{1.5}Mo_1$	1485a	1558a	1522	2508a	2531a	2520	44.0	59.3	51.6
CV (%)	5.42	8.15	-	5.26	6.82	-	-	-	-
LSD (0.05)	124	193	-	204	275	-	-	-	-

Note. Values within a column followed by different letters are significantly different according to the LSD test at $P \leq 0.05$. Least Significant Difference (LSD) test.

The mean straw yield of mungbean (average of two years) varied from 1853 to 2520 kg ha^{-1} across the treatments. The highest straw yield (2508 kg ha^{-1} in 1st year and 2531 kg ha^{-1} in 2nd year) was noted in T_8 treatment which was showed significantly variation with other treatments but statistically similar to T_7 and T_6 in 1st year and T_7, T_6, T_5, T_4, and T_2 in 2nd year. The lowest straw yield was from control (T_1) treatment. The trend of straw yield of mungbean was similar to seed yield (Table 2). However, combined application of micronutrient was resulted superior straw yield of mungbean over their single application. Similar observation was corroborated by Jamal et al. (2018); Divyashree et al. (2018). The following growth and yield contributing characters are played vital role to achieve the improved yield of mungbean.

3.2 Growth and Yield Attributes of Mungbean

Zinc, B and Mo application as singly or in combinations were exhibited significant effect on the growth and yield attributes of mungbean (Tables 3 and 4). The tallest plant (52.9 cm in 1st year and 53.2 cm in 2nd year) was recorded in the treatments T_8 which was statistically identical to the treatment T_7, T_6, T_5, T_4 and T_2 in 1st and 2nd year. Malik et al. (2015) reported that Zn and Mo enhanced to get higher plant height of mungbean. A similar finding was documented by Mevada et al. (2006) who reported that micronutrients (Zn, B, Mo and Fe) were influenced positively on plant height of urdbean. The mean plant height was varied from 44.9 to 53.1 cm across the treatments (Table 3). Significantly maximum number of branches per plant (2.45 in 1st year and 2.46 in 2nd year) was achieved in T_8 treatment. Roy (2017) reported that maximum branches per plant of mungbean were recorded by the combined application of micronutrient. The mean number of branches per plant (average of two years) was ranged from 2.13 to 2.46 among the treatments. In case of pod length, the largest pod (9.29 cm in 1st year and 9.14 cm in 2nd year) was observed in T_8 which was significantly dissimilar to other treatments, but it was statistically alike with T_7, T_6, and T_5 treatments in 1st year. Alam and Islam (2016) reported that combined micronutrients were contributed positively to achieve long pod of mungbean. The lowest values of all characters were obtained from the treatment T_1 (Table 3).

Table 3. Effect of Zn, B and Mo on plant height, number branches per plant and pod length of mungbean

Treatment	Plant height (cm)			No. of branches plant^{-1}			Pod length (cm)		
	1st Yr.	2nd Yr.	Mean	1st Yr.	2nd Yr.	Mean	1st Yr.	2nd Yr.	Mean
T_1 = Control	43.5c	46.3c	44.9	2.06c	2.20d	2.13	7.38d	8.07d	7.73
$T_2 = Zn_2$ kg ha^{-1}	50.2ab	50.6ab	50.4	2.20b	2.34bc	2.27	8.60c	8.34cd	8.47
$T_3 = B_{1.5}$ kg ha^{-1}	49.2b	48.6bc	48.9	2.16bc	2.38abc	2.27	8.91bc	8.42c	8.67
$T_4 = Mo_1$ kg ha^{-1}	51.5ab	52.7a	52.1	2.18b	2.37abc	2.28	8.96b	8.53bc	8.75
$T_5 = Zn_2B_{1.5}$	52.5a	53.0a	52.8	2.17bc	2.35abc	2.26	9.09ab	8.46bc	8.78
$T_6 = Zn_2Mo_1$	51.4ab	52.4ab	51.9	2.20b	2.32cd	2.26	9.05ab	8.47bc	8.76
$T_7 = B_{1.5}Mo_1$	50.6ab	51.3ab	51.0	2.23b	2.44ab	2.34	9.09ab	8.79b	8.94
$T_8 = Zn_2B_{1.5}Mo_1$	52.9a	53.2a	53.1	2.45a	2.46a	2.46	9.29a	9.14a	9.22
CV (%)	3.17	4.35	-	2.88	3.03	-	2.14	2.27	-
LSD (0.05)	2.79	3.88	-	0.12	0.13	-	0.33	0.34	-

Note. Values within a column followed by different letters are significantly different according to the LSD test at $P \leq 0.05$.

Number of pods per plant is particularly important yield contributing character which was highly reflected to obtain highest yield of mungbean. Significantly the highest number of pods per plant (28.7 in 1st year and 33.0 in 2nd year) and seeds per pod (12.1 in 1st year and 12.0 in 2nd year) were recorded from the treatment T_8 and the minimum of both characters were noted in T_1 treatment (Table 4). Valenciano et al. (2011) reported that combined application of Zn, B and Mo contributed to get maximum number of pods per plant of chickpea. Every micronutrient donated to obtain higher number of pods per plant. However, Karmakar et al. (2015) noted that Zn significantly influenced to attain maximum pods of mungbean. Maqbool et al. (2018) reported that yield attributes of mungbean responded to B in soil application when B availability is lower. Combined micronutrients (Zn, B and Mo) might be assisted in better utilization of the major nutrients (NPK) which contributed to increase the pods per plant and seeds per pod and ultimately produced the higher productivity. Similar observation was noted by Divyashree et al. (2018). In the experiment, the 100-seeds weight was significantly influenced by different treatments (Table 4). The highest 100-seed weight (5.01 g) was recorded in the treatment T_5 followed by T_8, T_6, T_4, T_3 and T_2 in 1st year and it was recorded highest (5.03 g) in T_2 followed by T_8, T_7, T_6, T_5, T_4 and T_3 treatments in 2nd year and the lowest was in control (T_1) treatment (Table 4). Results of the test weight was noticed that micronutrient as single or in combination might be helped to obtain higher 100-seed weight over control. The result is in agreement with the findings of Divyashree et al. (2018); Malik et al. (2015).

Table 4. Effect of Zn, B and Mo on number of pods per plant, number of seeds per pod and 100-seeds weight of mungbean

Treatment	No. of pods plant^{-1}			No. of seeds pod^{-1}			100-seeds wt (g)		
	1st Yr.	2nd Yr.	Mean	1st Yr.	2nd Yr.	Mean	1st Yr.	2nd Yr.	Mean
T_1 = Control	23.9d	26.1c	25.0	9.30d	10.0e	9.65	4.50b	4.35b	4.43
$T_2 = Zn_2$ kg ha^{-1}	26.4bc	28.5bc	27.5	10.9c	10.4cde	10.7	5.00a	5.03a	5.02
$T_3 = B_{1.5}$ kg ha^{-1}	25.4cd	29.4b	27.4	11.4bc	11.3abc	11.4	4.92a	4.80a	4.86
$T_4 = Mo_1$ kg ha^{-1}	26.6bc	31.1ab	28.9	11.6abc	11.0bcd	11.3	4.83ab	4.86a	4.85
$T_5 = Zn_2B_{1.5}$	27.2ab	30.2ab	28.7	11.8ab	11.1bcd	11.5	5.01a	4.67ab	4.84
$T_6 = Zn_2Mo_1$	27.7ab	30.5ab	29.1	11.7ab	10.3de	11.0	4.83ab	4.70ab	4.77
$T_7 = B_{1.5}Mo_1$	26.9bc	31.6ab	29.3	11.7ab	11.8ab	11.8	4.76ab	4.73ab	4.75
$T_8 = Zn_2B_{1.5}Mo_1$	28.7a	33.0a	30.9	12.1a	12.0a	12.1	4.84ab	4.87a	4.86
CV (%)	3.49	6.13	-	3.69	4.94	-	4.22	4.87	-
LSD (0.05)	1.63	3.22	-	0.73	0.95	-	0.36	0.41	-

Note. Values within a column followed by different letters are significantly different according to the LSD test at $P \leq 0.05$.

3.3 Number of Nodules Plant^{-1} and Protein Content of Mungbean

The number of nodules plant^{-1} of mungbean responded significantly by the application of Zn, B and Mo (Figure 1). In the experiment, application of Zn, B and Mo either single or in combination significantly gradually augmented the number of nodules plant^{-1} over control. The percent increment of nodules plant^{-1} was ranged from 17.5 to 40.3% across the treatment. The highest increment of nodulation (40.3%) was occurred in T_8 treatment. Nodulation result of the Figure 1 exhibited that the highest number of nodules plant^{-1} (37.6) was documented from T_8 treatment which was significantly different with the other treatments but statistically alike to T_7 (36.3), T_6 (36.9), T_5 (36.7) and T_4 (35.4) treatment. The lowest nodulation was found in control (T_1) treatment (Figure 1). The results also indicated that every micronutrient has an important role in nodule formation and N_2 fixation (O'Hara, 2001). Zinc involved in leg haemoglobin synthesis and nodulation (Das et al., 2012; Chauhan et al., 2013). Boron played a vital role for nodule formation and symbiotic N_2 fixation (Bolanos et al., 2001). Molybdenum is also a key element required to the microorganisms for nitrogen fixation (Monika et al., 2020). Application of Zn, B and Mo either alone or in combination contributed significantly to increase the protein content in seed of mungbean (Figure 1).The protein content among the treatments varied from 21.8 to 24.3%.The highest amount of protein (24.3 %) was obtained from T_8 which was significantly higher over the other treatments but statistically similar to T_7 (23.8%), T_6 (23.4%), T_5 (23.7%) and T_4 (22.5%) treatment. The lowest amount of protein (21.8%) was from control (T_1) treatment. Some similar results of protein content in different crops were corroborated by the previous studies of micronutrients application (Ram & Katiyar, 2013; Adesoji et al., 2009; Ganie et al., 2014; Afloabi et al., 2014).

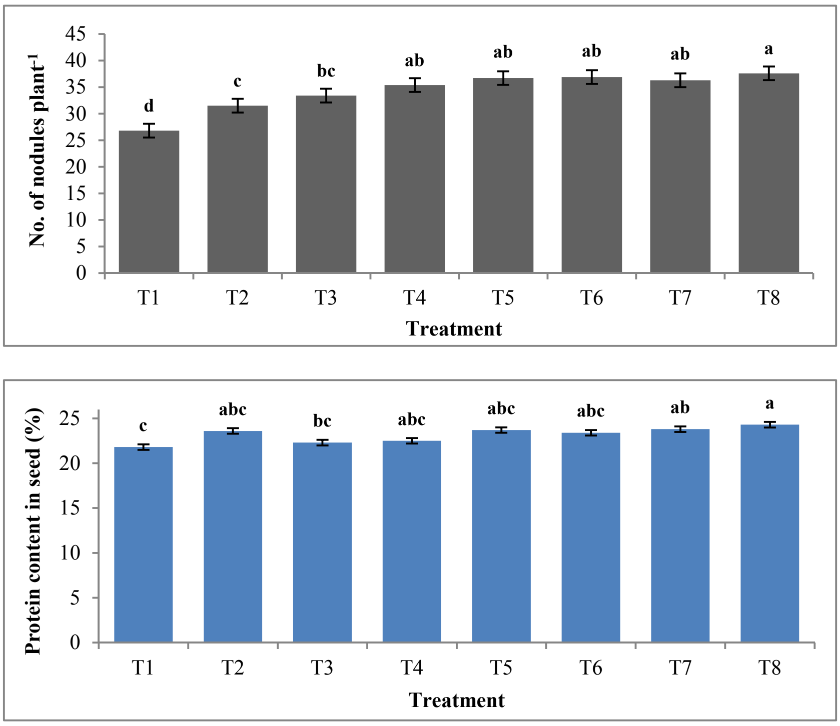

Figure 1. Effect Zn, B and Mo on number of nodules plant^{-1} and protein content in seed of mungbean (mean data of two years)

Note. T_1 = Control, T_2 = Zn 2 kg ha^{-1}, T_3 = B 1.5 kg ha^{-1}, T_4 = Mo 1 kg ha^{-1}, T_5 = $Zn_2B_{1.5}$, T_6 = Zn_2Mo_1, T_7 = $B_{1.5}Mo_1$ and T_8 = $Zn_2B_{1.5}Mo_1$, Error bars represent the SE (Standard Error).

Means followed by the uncommon letter (s) are significantly differ from each other according to the LSD test at $P \leq 0.05$.

3.4 Nutrient (N, P, K, S, Zn and B) Content in Seed and Straw of Mungbean

The content of N, P, K, S, Zn, and B in mungbean (seed and straw) was significantly influenced by the application of Zn, B and Mo (Table 5). In the study, the highest N content of mungbean (38.9 g kg^{-1} in seed and 17.3 g kg^{-1} in straw) was recorded from T_8 treatment, which was statistically equal with T_7, T_6, T_5, T_4 and T_2, although the lowest N content (34.8 g kg^{-1} in seed and 15.5 g kg^{-1} in straw) was obtained from the control (T_1) treatment. Higher N content in mungbean might be related with nodulation and N_2 fixation. Nitrogen fixation is responded to micronutrient application. Similar judgment was made by Islam et al. (2018) in lentil. The P content of mungbean (seed and straw) influenced significantly by the application of Zn, B and Mo as individually or in combination (Table 5). The highest amount of P (5.14 g kg^{-1} in seed and 2.69 g kg^{-1} in straw) was found in T_8 treatment, which was statistically alike with T_7, T_6, T_5, T_4, T_3 and T_2 treatment and the lowest P amount in both seed and straw of mungbean was in T_1 treatment. In the experiment, micronutrient (Zn, B, and Mo) had a significant impact on the K and S content in mungbean (seed and straw). The greatest amount of K (15.8 g kg^{-1} in seed and 21.9 g kg^{-1} in straw) and S (1.59 g kg^{-1} in seed and 1.39 g kg^{-1} in straw) was obtained from T_8 treatment which was non-significant to any other treatment except S content in straw that was showed significantly different with other treatment but statistically at par T_7, T_6 and T_5 treatment. The lowest amount of both K and S (seed and straw) was in T_1 (control) treatment (Table 5). In case of Zn and B content, the highest Zn content in mungbean (0.038 g kg^{-1} in seed and 0.0376 g kg^{-1} in straw) was attained from the T_8 treatment which was statistically comparable to T_6, T_5 & T_2 in seed and T_6 in straw. The lowest Zn content (0.031 g kg^{-1} in seed and 0.0339 g kg^{-1} in straw) was in control (T_1) treatment. The highest B content in mungbean (0.0374 g kg^{-1} in seed and 0.0342 g kg^{-1} in straw) was noted from the same T_8 treatment, which was statistically identical to T_7, T_6, T_5 & T_3 in seed and T_7 & T_5 in straw and the lowest B content (seed and straw) was from T_1 treatment (Table 5). The increased Zn and B content in seed and straw was showed only in the plot receiving of Zn and B containing fertilizers. Comparable results corroborated by the some earlier studies in different crops, where micronutrients application were influenced on the content of P, K, S, Zn, and B (Islam et al., 2018; Divyashree et al., 2018; A. B. Raj & S. K. Raj, 2019).

Table 5. Effect of Zn, B and Mo on nutrient content in seed and straw of mungbean (mean data of two years)

Treatment	N	P	K	S	Zn	B
	---- g kg^{-1} ----					
Seed						
T_1 = Control	34.8c	4.13b	15.1a	1.42a	0.031c	0.0346b
$T_2 = Zn_2$ kg ha^{-1}	37.7abc	4.56ab	15.5a	1.51a	0.035abc	0.0348b
$T_3 = B_{1.5}$ kg ha^{-1}	35.6bc	4.61ab	15.2a	1.54a	0.032bc	0.0360ab
$T_4 = Mo_1$ kg ha^{-1}	36.5abc	4.49ab	15.3a	1.47a	0.032bc	0.0351b
$T_5 = Zn_2B_{1.5}$	37.9abc	4.74ab	15.7a	1.62a	0.036ab	0.0365ab
$T_6 = Zn_2Mo_1$	37.4abc	4.68ab	15.3a	1.51a	0.036ab	0.0353ab
$T_7 = B_{1.5}Mo_1$	38.1ab	4.59ab	15.6a	1.54a	0.033bc	0.0368ab
$T_8 = Zn_2B_{1.5}Mo_1$	38.9a	5.14a	15.8a	1.59a	0.038a	0.0374a
CV (%)	4.82	9.39	4.66	9.83	7.35	3.53
LSD (0.05)	3.13	0.76	ns	ns	0.004	0.002
Straw						
T_1 = Control	15.5b	2.41b	21.1a	1.10c	0.0339d	0.0301e
$T_2 = Zn_2$ kg ha^{-1}	16.8ab	2.49ab	21.3a	1.20bc	0.0363b	0.0310de
$T_3 = B_{1.5}$ kg ha^{-1}	16.7ab	2.52ab	21.2a	1.24bc	0.0345cd	0.0330b
$T_4 = Mo_1$ kg ha^{-1}	16.2ab	2.47ab	21.1a	1.22bc	0.0340d	0.0313cd
$T_5 = Zn_2B_{1.5}$	17.1ab	2.57ab	21.4a	1.30ab	0.0368b	0.0334ab
$T_6 = Zn_2Mo_1$	16.9ab	2.56ab	21.3a	1.26ab	0.0369ab	0.0320c
$T_7 = B_{1.5}Mo_1$	17.0ab	2.61ab	21.5a	1.27ab	0.0347c	0.0339ab
$T_8 = Zn_2B_{1.5}Mo_1$	17.3a	2.69a	21.9a	1.39a	0.0376a	0.0342a
CV (%)	5.72	6.26	3.84	6.45	1.19	1.68
LSD (0.05)	1.67	0.28	ns	0.14	0.0074	0.0095

Note. Values within a column followed by the same letter are not significantly different ($P \leq 0.05$).

3.5 Total Uptake of Nutrient (N, P, K, S, Zn and B) by Mungbean (Seed and Straw)

Appplication of Zn, B and Mo as single or in combination had made significant effect on total uptake of N, P, K, S, Zn and B by mungbean (mean data of two years) (Figures 2 and 3). The total uptake of all nutrients by mungbean ranged across the treatment were from 63.6 to 103 kg N ha^{-1}, 8.61 to 14.6 kg P ha^{-1}, 54.3 to 79.1 kg K ha^{-1}, 3.47 to 5.92 kg S ha^{-1}, 0.094 to 0.153 kg Zn ha^{-1} and 0.091 to 0.143 kg B ha^{-1}. The treatment T_8 (combination of Zn, B and Mo) exhibited significantly higher uptake of total N, P, K, S, Zn and B by test crop over the other treatments. Divyashree et al. (2018) and Shashikumar et al. (2013) corroborated the similar observation in mungbean and blackgram.The lowest total uptake of all nutrients by mungbean was found in control (T_1) treatment. Results of the total uptake of all nutrients were followed the order: N > K > P > S > Zn > B (Figures 2 and 3).

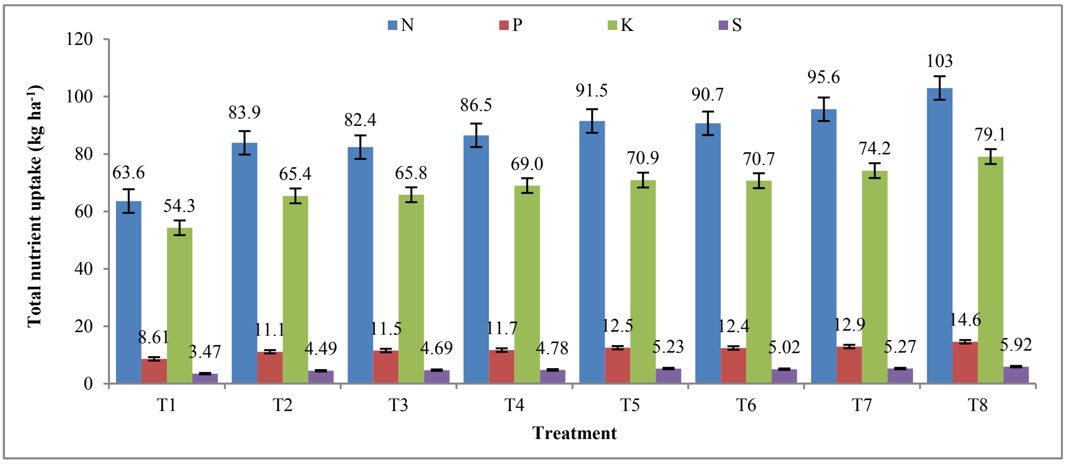

Figure 2. Effect of Zn, B and Mo on total uptake of N, P, K and S by mungbean (seed + straw)

Note. T_1 = Control, T_2 = Zn 2 kg ha^{-1}, T_3 = B 1.5 kg ha^{-1}, T_4 = Mo 1 kg ha^{-1}, T_5 = $Zn_2B_{1.5}$, T_6 = Zn_2Mo_1, T_7 = $B_{1.5}Mo_1$ and T_8 = $Zn_2B_{1.5}Mo_1$, Error bars represent the SE.

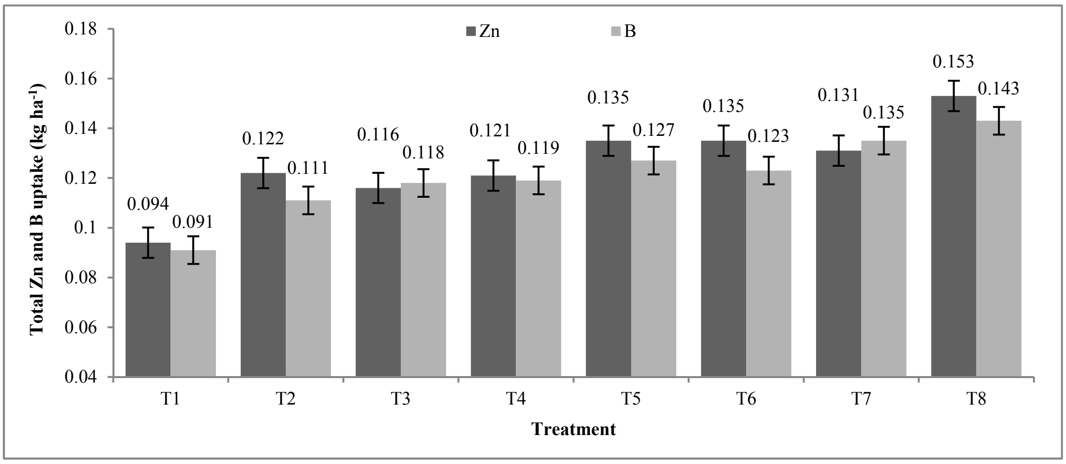

Figure 3. Effect of Zn, B and Mo on total uptake of Zn and B by mungbean (seed + straw)

Note. T_1 = Control, T_2 = Zn 2 kg ha^{-1}, T_3 = B 1.5 kg ha^{-1}, T_4 = Mo 1 kg ha^{-1}, T_5 = $Zn_2B_{1.5}$, T_6 = Zn_2Mo_1, T_7 = $B_{1.5}Mo_1$ and T_8 = $Zn_2B_{1.5}Mo_1$, Error bars represent the SE.

3.6 Effect of Zn, B and Mo on Postharvest Soil Properties

Postharvest soil status of the experimental plots was influenced significantly by the application of Zn, B and Mo as single or in combination (Table 6). It has been mentioned that the available Mo was not determined. The starting soil pH was 8.2, but after completion of 2 consecutive years of experiments, the soil pH was almost slightly decreased as compared to the starting value. This pH of alkaline soil might be decreased with the incorporation of stover/straw of mungbean in soil. The combined or single application of Zn, B and Mo contributed positive increased of organic carbon (OC) in postharvest soil. The percent increment of OC ranged over starting soil was from 11.6% to 21.6% across the treatment. The highest percent increment of OC was happened in T_8 treatment and lowest was in T_1 treatment. Different treatments contributed to conserve the initial fertility status of soil or slightly improved of total N and available P. But the available K, S and Ca content showed decreasing trend in all treatments with compared to the starting status. Postharvest soil status of available Zn and B content was slightly increased over starting status when the Zn and B containing fertilizers were applied, but decreased when these were not applied. In this experiment, most of the nutrient showed significantly variation among the different treatments (Table 6). The highest OC (10.4 g kg^{-1}) in soil was obtained from T_8 treatment which was significantly different with other treatment and the lowest OC (9.54 g kg^{-1}) was in control (T_1) treatment. Significantly highest total N (0.93 g kg^{-1}) was recorded from T_8 treatment and lowest (0.85 g kg^{-1}) was from control (T_1) treatment. Among the treatment, the highest available nutrient of P (15.8 mg kg^{-1}), S (15.1

mg kg^{-1}), Zn (0.93 mg kg^{-1}) and B (0.22 mg kg^{-1}) was significantly achieved in the same T_8 treatment (Table 6). The T_8 treatment contributed to produce higher amount of straw which might be more preferred to the soil microbial activities and biological properties improvement; however incorporation of straw in soil is eventually augmented the soil fertility. Kumar and Yadav (2018) corroborated the similar report.

Table 6. Effect of Zn, B and Mo on postharvest soil pH and fertility status (mean data of 2 years) with reference to starting soil

Treatment	pH	OC	Total N	Ca	K	P	S	Zn	B
		--------- g kg^{-1} --------		--- meq. 100 g^{-1} ---		--------------------- mg kg^{-1} ---------------------			
Starting	8.2	8.55	0.77	19.0	0.14	14.6	15.2	0.84	0.16
T_1	8.1a	9.54d	0.85f	17.5a	0.13a	14.1d	14.3b	0.82d	0.13e
T_2	8.0ab	10.1bc	0.88de	17.3b	0.13a	14.0d	15.0a	0.90c	0.14de
T_3	7.9b	10.0c	0.87e	17.4ab	0.13a	15.0bc	15.1a	0.83d	0.19c
T_4	8.0ab	10.1bc	0.89cd	17.3b	0.12a	15.0bc	15.0a	0.82d	0.15d
T_5	7.9b	10.2b	0.91b	17.1c	0.13a	15.2b	15.0a	0.91bc	0.20bc
T_6	7.9b	10.2b	0.90bc	17.4ab	0.13a	15.0bc	15.1a	0.92ab	0.14de
T_7	7.9b	10.2b	0.91b	17.0c	0.13a	14.7c	15.0a	0.83d	0.21ab
T_8	7.9b	10.4a	0.93a	17.1c	0.12a	15.8a	15.1a	0.93a	0.22a
CV (%)	0.94	0.91	0.99	0.54	6.95	1.87	0.59	1.02	5.31

Note. T_1 = Control, T_2 = Zn 2 kg ha^{-1}, T_3 = B 1.5 kg ha^{-1}, T_4 = Mo 1 kg ha^{-1}, T_5 = $Zn_2B_{1.5}$, T_6 = Zn_2Mo_1, T_7 = $B_{1.5}Mo_1$ and T_8 = $Zn_2B_{1.5}Mo_1$.

Values within a column followed by the same letter are not significantly different ($P \leq 0.05$).

3.7 Economic Analysis

Cost of cultivation, gross return, net return and benefit cost ratio (BCR) was influenced positively by the application of Zn, B and Mo (Table 7). The maximum cultivation cost (BDT 38700 ha^{-1} yr^{-1}) was spent in T_8 treatment followed by T_7 and T_6 treatment; however the lowest (BDT 27500 ha^{-1} yr^{-1}) cultivation cost was spent in control (T_1) treatment. In the study, the highest gross return (BDT 98930 ha^{-1} yr^{-1}) and net return (BDT 60230 ha^{-1} yr^{-1}), respectively was recorded from T_8 followed by T_7 treatment. The lowest gross return (BDT 65325 ha^{-1} yr^{-1}) and lowest net return (BDT 37825 ha^{-1} yr^{-1}) was found in control (T_1) treatment due to lower yield of mungbean. The benefit cost ratio (BCR) was obtained highest (2.91) from T_5 treatment and lowest was in control (T_1) plot. The percent increment of benefit cost ratio across the treatment over control was varied from 0.42 to 22.3%. The top increment of BCR was occurred in T_5 and lowest increment was in T_6 treatment (Table 7). This calculation indicated that the decreasing trend of BCR might be involved the high market price of Mo containing fertilizer. However, benefit cost ration is generated a suggestion to the Government of the People's Republic of Bangladesh for subsidizing in Mo containing fertilizer to the farmer for pulse crop production.

Table 7. Effect of Zn, B and Mo with other inputs[a] on economics of mungbean production during Kharif-I season

Treatment	Cultivation cost (BDT[b] ha^{-1} yr^{-1})	Gross return (BDT ha^{-1} yr^{-1})	Net return (BDT ha^{-1} yr^{-1})	BCR[d]	% increment of BCR over control
T_1 = Control	27500[c]	65325	37825	2.38	-
T_2 = Zn_2 kg ha^{-1}	29200	82420	53220	2.82	18.5
T_3 = $B_{1.5}$ kg ha^{-1}	29300	84240	54940	2.87	20.6
T_4 = Mo_1 kg ha^{-1}	35500	87815	52315	2.47	3.78
T_5 = $Zn_2B_{1.5}$	30700	89440	58740	2.91	22.3
T_6 = Zn_2Mo_1	37200	89050	51850	2.39	0.42
T_7 = $B_{1.5}Mo_1$	37300	93275	55975	2.50	5.04
T_8 = $Zn_2B_{1.5}Mo_1$	38700	98930	60230	2.56	7.56

Note. Output price: Mungbean seed at BDT 65 kg^{-1}.

[a] Input prices: Urea = BDT 20 kg^{-1}, T.S.P. = BDT 22 kg^{-1}, MoP = BDT 14 kg^{-1}, Gypsum = BDT 5 kg^{-1}, Zinc sulphate = BDT 140 kg^{-1}, Boric acid = BDT 145 kg^{-1}, Amonium molybdate = BDT 14000 kg^{-1}, Bavistin = BDT 200/100 g, Karate = BDT 450/500 ml, Plowing = BDT 1200 ha^{-1} (one pass), Wage rate = BDT 300 day^{-1}, Mungbean seed = BDT 80 kg^{-1}.

[b] BDT is Bangladeshi Taka (Currency); 1 USD = 82 BDT.

[c] Values are average of years.

[d] Benefit Cost Ratio.

The above results and discussions are clearly indicated that micronutrient (Zn, B and Mo) has significant contribution to increase the yield and quality of mungbean as well as help to sustain soil fertility.

4. Conclusion

Two years studied clarify that combined application of 2 kg Zn ha^{-1}, 1.5 kg B ha^{-1} and 1 kg Mo ha^{-1} in soil was significantly improved the productivity and quality of mungbean.The joint micronutrients (Zn, B and Mo) had donated of more pods setting; more seeds pod^{-1} and courageous seed, which eventually boosted the seed yield. Maximum number of nodules $plant^{-1}$ and the highest protein content in seed was achieved positively by the combined application of Zn, B and Mo. The total uptake of N, P, K, S, Zn and B was also highest in the plot receiving of 2 kg Zn ha^{-1}, 1.5 kg B ha^{-1} and 1 kg Mo ha^{-1}. The combination of Zn, B and Mo is showed more productive compare to sole or couple use of these micronutrients. The T_8 ($Zn_2B_{1.5}Mo_1$ kg ha^{-1}) exhibited helpful effects on soil organic carbon, total N, available P, Zn and B. This treatment also showed economically better results on the basis of net return except benefit cost ratio due to high market price of Mo containing fertilizer. Results of the present study suggest that the combination of Zn, B and Mo at 2, 1.5 and 1 kg ha^{-1}, respectively along with N, P, K and S applied at 20, 20, 30 and 10 kg ha^{-1}, respectively could be recommended for mungbean cultivation.

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