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Response of Mungbean to Different Level of Macro and Micronutrient

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ABSTRACT

An experiment was carried out at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka during Kharif I season 2024, in order to investigate the effects of zinc and calcium on growth and yield of BARI mug 6. Three levels of zinc (0, 1.5 and 3.0 kg ha^{-1}) and four levels of calcium (0,50,75,100 ppm) were applied for the study. BARI mug 6 was used as plant material. The experiment was set up in randomized complete block design with three replications. Almost all the parameters were significantly influenced by different levels of Zn, Ca and their combinations. Considering interaction of Zn and Ca, the highest plant height (66.29 cm), number of flowers plant^{-1} (29.00) and number of nodules plant^{-1} (29.32) were obtained from the treatment combination of Zn_3Ca_4 where the highest chlorophyll content (Chl-a = 1.03 µg g^{-1}, Chl-b = 1.32 µg g^{-1} and total = 2.48 µg g^{-1}) were obtained from the treatment combination of Zn_3Ca_3.The highest dry weight plant^{-1} (24.70 g), number of pods plant^{-1} (23.24), number of seeds pod^{-1} (11.86), number of fertile seeds pod^{-1} (10.00), pod length (cm) (7.80), weight of 1000 seed (46.49), weight of seeds plant^{-1} (12.69), seed yield (1257 kg ha^{-1}), stover yield (1566 kg ha^{-1}), biological yield (2923 kg ha^{-1}) and harvest index (43.87%) were achieved from the treatment combination of Zn_2Ca_3.

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INTRODUCTION

Legumes (Fabaceae/Leguminosae) are considered the second most important human food crops, just after the cereals (Gramineae). However, legume seeds constitute an essential part of the human diet as they are excellent sources of proteins, bioactive compounds, minerals, and vitamins, in comparison with cereals, and are referred to as "the poor man's meat" (Hall *et. al.* 2017; Sing *et. al.* 2017). Mungbean (*Vigna radiata* L.**)** is one of the important pulse crops of Bangladesh, as it is an excellent source of easily digestible protein (Kaul, 1982). It belongs to the family Leguminosae. It holds the 3rd position in protein content and 4th in both acreage and production in Bangladesh (Sarkar *et al*., 2012). In Bangladesh, daily consumption of pulses is only 14.30 g capita^{-l} day^{-1} (BBS, 2010), while World Health Organization (WHO) suggested 45g capita^{-l} day^{-1} for a balanced diet. Mungbean is a rich source of vegetable protein. It is considered as poor man's meat containing almost triple amount of protein as compared to rice. It contains 25% protein,1-3% fat, 50.4% carbohydrates, 3.5-4.5% fibers and 4.5- 5.5% ash, while calcium and phosphorus are 132 and 367 mg per 100 grams of seed, respectively (Frauque *et al*., 2000). Hence, on the nutritional point of view, mungbean is the best of all other pulses (Khan, 1981). Besides being a rich source of protein, it maintains soil fertility through biological nitrogen fixation in soil and thus plays a vital role in sustainable agriculture (Kannaiyan, 1999). Mungbean fixes 63-342 kg N ha^{-1} per season in soil by biological nitrogen fixation (Kannaiyan, 1999). Fertilizer is one of the most important factors that affect crop production. Fertilizer recommendation for soils and crops is a dynamic process and the management of fertilizers is one of the important factors that greatly affect the growth, development and yield of mungbean. Calcium (a macronutrient) is part of every plant cell. Much of the Ca in plants is part of the cell walls in a compound called calcium pectate. Without adequate Ca, cell walls would collapse and plants would not remain upright. Calcium is not mobile in plants. It does not easily move from old leaves to young leaves. Deficiency symptoms for Ca are rare in agriculture (Rehm, 1994). Calcium also has a positive effect on soil properties. This nutrient improves soil structure thereby increasing water penetration, and providing a more favorable soil environment for growth of plant roots and soil microorganisms (McLean *et al*., 1983). The soils of different parts of Bangladesh are more or less deficient in zinc and molybdenum as well as nitrogen fixing bacteria (Rhizobium sp.) which causes poor yield of mungbean. However, there is a great possibility to increase its production by cultivating HYV with balanced fertilization including micronutrient.

Micronutrients play an important role in increasing yield of pulses and oilseed legumes through their effects on the plant itself and on the nitrogen fixing symbiotic process. Deficiencies of these nutrients have been very pronounced under multiple cropping systems due to excess removal by HYV of crops and hence their exogenous supplies are urgently required. The Zinc (Zn) essentially is being employed in functional and structural component of several enzymes, such as carbonic anhydrase, alcohol dehydrase, alkaline phosphatase, phospholipase, carboxypeptidase (Coleman, 1991) and RNA polymerase (Romheld and Marschner, 1991). Further, plants emerging from seeds with lower Zn could be highly sensitive to biotic and abiotic stresses (Obata *et al*., 1999). Zn enriched seeds performs better with respect to seed germination, seedling growth and yield of crops (Cakmak *et al*., 1996). Considering the above facts this study has been undertaken to investigate the response of mungbean to different level of macro and micronutrient.

MATERIALS AND METHODOLOGY

The experiment was conducted in the experimental field of Department of Agricultural Botany, SAU during Kharif I season, 2024.

Plant materials: For the current investigation, the mungbean variety BARI Mug 6 was used. The plant attains a height of 55-65 cm, the leaves look light green and its life duration is about 75-80 days. Seeds are larger than local variety and light brown-yellow in color. Seed contains 20-25% protein. 1000seed weight is 35-40g. Under proper management practices it may give 1.6-2.0 t ha^{-1} seed yield.

Plan of action: The Bangladesh Agricultural Research Institute (BARI), located in Joydevpur, Gazipur, provided the seeds for BARI mug 6. In 2003, BARI released this variety also known as BARI Mug 6 for general cultivation following multilocation trials.

Experimental site: The experiment was conducted at Sher-e-Bangla Agricultural University farm, Dhaka, Bangladesh.

Soil and climate: The soil of the experimental field belongs to the Joydebpur series of shallow red terrace loamy soil and the experiment was under sub-tropical zone.

Experimental design and layout: The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of doses of Zinc (Zn) and Calcium (Ca). The 12 treatment combinations of the experiment were assigned at random into 36 plots. The size of each unit plot 3.0 m× 3.0 m. The distance between blocks and plots were 1.0 m and 0.5 m respectively.

Treatments: There will be two factors in this experiment as follows-

Factor A: Calcium (Ca)	Factor B: Zinc (Zn)
1. Ca_1= 0 ppm	1. Zn_1= 0 kg ha^{-1}
2. Ca_2= 50 ppm	2. Zn_2= 1.5 kg ha^{-1}
3. Ca_3= 75 ppm	3. Zn_3= 3 kg ha^{-1}
4. Ca_4 = 100 ppm	

*****Ca = Calcium, Zn = Zinc

Treatment combinations: (3×4) = 12

Zn_1Ca_1, Zn_1Ca_2, Zn_1Ca_3, Zn_1Ca_4, Zn_2Ca_1, Zn_2Ca_2, Zn_2Ca_3, Zn_2Ca_4, Zn_3Ca_1, Zn_3Ca_2, Zn_3Ca_3, Zn_3Ca_4.

Zinc and calcium were applied as zinc sulphate ($ZnSO_4.7H_2O$) and gypsum ($CaSO_4.2H_2O$) respectively. Zinc sulphate contains 23%Zn and gypsum contains 33% Ca.

Fertilization: The fertilizer N, P and K were applied @ 20.7 kg N/ha, 48 kg P_2O_5/ha, 34.8 kg K_2O/ha in the form of urea, TSP and MOP respectively during final land preparation as basal dose. Zn was applied in the form of $ZnSO_4.7H_2O$ as per treatment during final land preparation. Ca was applied in the form of$CaSO_4.2H_2O$ as per treatment at 30DAS and 45 DAS through foliar spray.

Preparation of the main field and seed sowing: The plot selected for the experiment was opened in the first week of March, 2024 with a power tiller and was exposed to the sun for a week, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for sowing. Seeds are sown on 15 March 2024.

Intercultural Operation: After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the mungbean. Over-head irrigation was provided with a watering can to the plots once immediately after germination in every alternate day in the evening. Further irrigation was done when needed. Stagnant water was effectively drained out at the time of heavy rains. Several weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. First weeding was done at 20 days after sowing (DAS), 2nd and 3rd weeding was done at 35 and 50 DAS, respectively. At early stage of growth few hairy caterpillar and virus vectors (jassid) attacked the young plants and at later stage of growth pod borer attacked the plant. Hairy caterpillar and pod borer were successfully controlled by the application of Diazinon 50 EC and Ripcord @ 1 L ha^{-1} on the time of 50% pod formation stage.

Harvesting, threshing and cleaning: The crop was harvested at full maturity from 3rd May, 2024. Harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of mungbean seed. Fresh weight of seed and stover were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The stover was sun dried and the yields of seed and stover $plot^{-1}$ were recorded and converted to kg ha^{-1}.

Data collection and recording: Ten plants were chosen at random from each unit plot to record data on crop parameters, and yield was calculated plot by plot. During the study, the following parameters were recorded:

Plant height (cm): The height of plant was recorded in centimeter (cm) at different days after sowing of crop duration. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaves.

Leaf area index: Leaf area index was determined by counting number of leaves/plant, leaf length and breadth & then multiplying leaf area per m^2. The leaf area index (LAI) was worked out by using the following formula.

$$\text{LAI} = \frac{\text{Total leaf area m}^{-2}}{\text{Ground area (1 m}^2\text{)}}$$

Dry weight $plant^{-1}$ (g): Five sample plants in each plot were selected at random in the sample rows outside the central 1 m^2 of effective harvesting area and cut close to the ground surface at different days of crop duration. They were first air dried for one hour, then oven dried at 80(±5) °C till a constant weight was attained. Mean dry weight was expressed as per plant basis.

Chlorophyll content (mg g^{-1}): The leaves of the mungbean plants were extracted with 80% acetone. The leaf extract was centrifuged and the supernatant was collected.Chlorophyll content was estimated using the method described by Witham *et al.* (1986). The absorbance of the supernatant was recorded at 645 and 663 ηm for chlorophyll 'a' and 'b' contents respectively. Theamount of chlorophylls was expressed as μg g^{-1} fresh weight.

Days to first flowering: Days to 1st flowering was measured from the date of sowing when 1st of the mungbean plants flowered.

Number of flowers plant^{-1}: Number of flowers plant^{-1} was calculated from pre-selected 10 plants at a certain duration from 1st flowering to harvest an mean was calculated per plant basis.

Days to 100% maturity: Days to 100% maturity was measured from the date of sowing when at least 90% of the mungbean pods was matured. It was measured at harvest from pre-selected 10 plants from each plot.

Number of nodules plant^{-1}: Number of nodules plant^{-1} was collected from pre-selected uprooted 10 plants at harvest. Number of total nodules of ten plants from each plot was noted and the mean number was expressed per plant basis.

Number of pods plant^{-1}: Number of total pods of 10 plants from each plot was noted and the mean number was expressed per plant basis.

Number of seeds plant^{-1}: Number of total seeds of ten plants from each plot was noted and the mean number was expressed per plant basis.

Number of fertile seeds plant^{-1}: Number of fertile seeds of ten plants from each plot was noted and the mean number was expressed per plant basis.

Pod length (cm): Length of 10 pods of 10 selected plants from each plot was noted and the mean number was expressed per pod basis.

Weight of 1000 seeds (g): One thousand cleaned and dried seeds were counted randomly form 1m^2 area and weight by using a digital electric balance and the weight was expressed in gram.

Weight of seeds plant^{-1} (g): Seeds weight of ten plants from each plot was noted and the mean weight was expressed per plant basis.

Seed yield (kg ha^{-1}): The plants of the central 1.0 m^2 from the plot were harvested for taking grain yield. The grains were threshed from the plants, cleaned, dried and then weighed. The yield of grain in kg plot^{-1} was adjusted at 12% moisture content of grain and then it was converted to t ha^{-1}.

Stover yield (kg ha^{-1}): The stover of the harvested crop in each plot was sun dried to a constant weight. Then the stovers were weighted and thus the stover yield plot^{-1} was determined. The yield of stover in kg plot^{-1} was converted to kg ha^{-1}.

Biological yield (kg ha^{-1}): Grain yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Stover yield.

Harvest index (%): Harvest index was calculated from the ratio of grain yield to biological yield and expressed in percentage. It was calculated by using the following formula.

$$\text{HI (\%)} = \frac{\text{Seed yield}}{\text{Biological yield (Seed yield + Stover yield)}} \times 100$$

Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Deferent Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant height: Significant variation was found on plant height of mungbean influenced by combined effect of Zn and Ca at all growth stages (Table 1). It seems from the results that combination of Zn_3Ca_4 showed the highest plant height at 25, 40 DAS and at harvest, respectively which was statistically identical with Zn_3Ca_3 and statistically similar with Zn_2Ca_3 and Zn_2Ca_4 at harvest. The lowest plant height at 25, 40 DAS and at harvest, respectively was obtained from the treatment combination of Zn_1Ca_1 which was immediate lower than the treatment combination of Zn_1Ca_2.

Table 1. Effect of Zn and Ca on plant height

Treatment	Plant height (cm)		
	25 DAS	**40 DAS**	**At harvest**
Zn_1Ca_1	28.36 g	52.02 e	57.76 g
Zn_1Ca_2	28.49 f	57.16 d	60.49 f
Zn_1Ca_3	30.36 de	58.59 cd	63.29 d
Zn_1Ca_4	30.39 de	59.19 c	63.52 d
Zn_2Ca_1	28.76 ef	58.02 cd	61.62 e
Zn_2Ca_2	30.59 d	59.21 c	64.06 cd
Zn_2Ca_3	31.06 cd	61.56 b	65.19 ab
Zn_2Ca_4	32.52 bc	62.16 b	65.66 ab
Zn_3Ca_1	29.79 def	58.66 cd	62.06 e
Zn_3Ca_2	30.92 d	61.46 b	64.76 bc
Zn_3Ca_3	32.79 b	63.29 ab	65.92 a
Zn_3Ca_4	34.36 a	64.86 a	66.29 a
$LSD_{0.05}$	0.506	0.776	0.032
CV (%)	7.267	9.521	10.313

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly.
Zn_1= 0 kg Zn ha^{-1}, Zn_2= 1.5 kg Zn ha^{-1}, Zn_3= 3 kg Zn ha^{-1}, Ca_1= 0 ppm Ca, Ca_2= 50 ppm Ca, Ca_3= 75 ppm Ca, Ca_4= 100 ppm Ca

Leaf area index: Leaf area index of mungbean was found significant due to different treatment combination of Zn and Ca (Table 2). Results revealed that the highest leaf area index at 25, 40 DAS and at harvest, respectively was obtained from the treatment combination of Zn_3Ca_4 followed by Zn_2Ca_3. The lowest leaf area index at 25, 40 DAS and at harvest, respectively was obtained from the treatment combination of Zn_1Ca_1 that was immediately lower than Zn_1Ca_2 but significantly different.

Table 2. Effect of Zn and Ca on leaf area index

Treatment	Leaf area index		
	25 DAS	40 DAS	At harvest
Zn_1Ca_1	1.66 e	6.39 d	10.32 f
Zn_1Ca_2	2.79 d	7.06 bc	11.92 e
Zn_1Ca_3	3.12 c	7.12 bc	12.79 c
Zn_1Ca_4	2.69 d	6.79 c	12.32 d
Zn_2Ca_1	3.22 c	7.19 bc	12.86 c
Zn_2Ca_2	3.36 bc	7.36 b	12.92 c
Zn_2Ca_3	3.96 a	8.06 a	13.56 b
Zn_2Ca_4	3.56 b	7.42 b	13.09 c
Zn_3Ca_1	3.32 bc	7.22 bc	12.89 c
Zn_3Ca_2	3.39 bc	7.39 b	13.00 c
Zn_3Ca_3	3.89 a	7.42 b	13.09 c
Zn_3Ca_4	4.00 a	8.12 a	14.00 a
$LSD_{0.05}$	0.306	0.390	0.342
CV (%)	2.752	5.213	5.523

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly. Zn_1= 0 kg Zn ha^{-1}, Zn_2= 1.5 kg Zn ha^{-1}, Zn_3= 3 kg Zn ha^{-1}, Ca_1= 0 ppm Ca, Ca_2= 50 ppm Ca, Ca_3= 75 ppm Ca, Ca_4= 100 ppm Ca

Table 3. Effect of Zn and Ca on dry weight $plant^{-1}$

Treatment	Dry weight $plant^{-1}$ (g)		
	25 DAS	40 DAS	At harvest
Zn_1Ca_1	4.79 h	10.47 i	16.66 i
Zn_1Ca_2	4.96 h	12.46 h	18.73 gh
Zn_1Ca_3	5.09 gh	13.17 g	19.47 fg
Zn_1Ca_4	4.90 h	11.91 h	18.18 h
Zn_2Ca_1	5.32 fg	13.71 fg	19.87 ef
Zn_2Ca_2	5.87 de	14.31 ef	20.61 e
Zn_2Ca_3	7.61 a	16.84 a	24.70 a
Zn_2Ca_4	7.03 b	16.17 b	23.35 b
Zn_3Ca_1	5.61 ef	14.06 f	20.35 ef
Zn_3Ca_2	6.41 c	15.42 cd	22.21 cd
Zn_3Ca_3	6.77 b	15.75 bc	22.73 bc
Zn_3Ca_4	6.14 cd	14.87 de	21.57 d
$LSD_{0.05}$	0.329	0.515	0.832
CV (%)	3.726	7.234	7.149

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly. Zn_1= 0 kg Zn ha^{-1}, Zn_2= 1.5 kg Zn ha^{-1}, Zn_3= 3 kg Zn ha^{-1}, Ca_1= 0 ppm Ca, Ca_2= 50 ppm Ca, Ca_3= 75 ppm Ca, Ca_4= 100 ppm Ca

Dry weight plant^{-1}: Combined effect of Zn and Ca had significant effect on dry weight plant^{-1} at different growth stages of mungbean (Table 3). It was found that the highest dry weight plant^{-1} at 25, 40 DAS and at harvest, respectively was obtained from the treatment combination of Zn_2Ca_3 followed by Zn_2Ca_4 and Zn_3Ca_3. The lowest dry weight plant^{-1} at 25, 40 DAS and at harvest, respectively was obtained from the treatment combination of Zn_1Ca_1 which was nearest to the treatment combinations of Zn_1Ca_4 but significantly different to each other.

Chlorophyll content: Treatment combination of Zn and Ca showed significant variation on chlorophyll content of mungbean recorded at 45 DAS (Table 4). Results signified that the highest chlorophyll-a and chlorophyll-b content of leaves were obtained from the treatment combination of Zn_3Ca_3 which was statistically identical with Zn_3Ca_4. The lowest chlorophyll-a and chlorophyll-b content was obtained from the treatment combination of Zn_1Ca_1 which was statistically identical with Zn_1Ca_2 in terms of chlorophyll-a. Regarding total chlorophyll content of leaves the highest was also obtained from the treatment combination of Zn_3Ca_3 which was statistically identical with Zn_3Ca_4 and closely followed by Zn_2Ca_3. The lowest total chlorophyll content of leaves was obtained from the treatment combination of Zn_1Ca_1 which was statistically identical with Zn_1Ca_2.

Table 4. Effect of Zn and Ca on Chlorophyll content

Treatment	Chlorophyll (Chl) content at 45 DAS (µg g^{-1})		
	Chl-a	**Chl-b**	**Total**
Zn_1Ca_1	0.310 g	0.382 g	0.792 g
Zn_1Ca_2	0.336 g	0.422 f	0.858 g
Zn_1Ca_3	0.360 fg	0.580 de	1.130 e
Zn_1Ca_4	0.636 c	0.821 c	1.557 c
Zn_2Ca_1	0.420 f	0.500 e	1.120 ef
Zn_2Ca_2	0.552 d	0.678 c	1.330 d
Zn_2Ca_3	0.856 b	1.126 b	2.142 ab
Zn_2Ca_4	0.720 b	1.030 b	1.860 bc
Zn_3Ca_1	0.465 ef	0.655 cd	1.320 d
Zn_3Ca_2	0.621 cd	0.760 c	1.581 cd
Zn_3Ca_3	1.03 a	1.32 a	2.480 a
Zn_3Ca_4	1.01 a	1.29 a	2.369 a
$LSD_{0.05}$	0.106	0.230	0.251
CV (%)	2.203	2.456	3.049

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly. Zn_1= 0 kg Zn ha^{-1}, Zn_2= 1.5 kg Zn ha^{-1}, Zn_3= 3 kg Zn ha^{-1}, Ca_1= 0 ppm Ca, Ca_2= 50 ppm Ca, Ca_3= 75 ppm Ca, Ca_4= 100 ppm Ca

Days to first flowering: Treatment combination of Zn and Ca showed significant variation on days to 1st flowering of mungbean (Table 5). Results indicated that the highest days to first flowering was obtained from the treatment combination of Zn_3Ca_4 followed by Zn_3Ca_3. The lowest days to first flowering was obtained from the treatment combination of Zn_1Ca_1 followed by Zn_1Ca_4 and Zn_3Ca_1.

Number of flowers plant^{-1}: Significant variation was observed on number of flowers plant^{-1} influenced by combined effect of Zn and Ca (Table 5). Results showed that the highest number of flowers plant^{-1} was obtained from the treatment combination of Zn_3Ca_4 followed by Zn_2Ca_3. The lowest number of flowers plant^{-1} was obtained from the treatment combination of Zn_1Ca_1 which was statistically similar with Zn_1Ca_2.

Days to 100% maturity: Days to 100% maturity of mungbean at harvest was found Significant due to different treatment combination of Zn and Ca (Table 5). The highest days to 100% maturity was obtained from the treatment combination of Zn_3Ca_4 which was statistically identical with Zn_2Ca_4 and which was statistically similar with Zn_3Ca_3. The lowest days to 100% maturity was obtained from the treatment combination of Zn_1Ca_1 which was immediate lower than Zn_1Ca_2, Zn_1Ca_3 and Zn_1Ca_4 but significantly different.

Number of nodules plant^{-1}: Treatment combination of Zn and Ca showed significant variation on number of nodules plant^{-1} of mungbean (Table 5). The highest number of nodules plant^{-1} was obtained from the treatment combination of Zn_3Ca_4 which was statistically similar with Zn_3Ca_3. The lowest number of nodules plant^{-1} was obtained from the treatment combination of Zn_1Ca_1 which was nearest to Zn_1Ca_2 but significantly different.

Table 5. Effect of Zn and Ca on Yield contributing parameters

Treatment	Yield contributing parameters			
	Days to first flowering	Number of flowers plant^{-1}	Days to 100% maturity	Number of nodules plant^{-1}
Zn_1Ca_1	34.00 e	17.50 g	50.39 h	10.32 i
Zn_1Ca_2	35.32 c	18.33 fg	51.29 g	14.00 h
Zn_1Ca_3	36.00 b	19.80 ef	51.59 g	18.32 g
Zn_1Ca_4	34.66 d	19.66 ef	51.19 g	21.00 f
Zn_2Ca_1	35.00 cd	20.64 de	53.00 f	20.66 f
Zn_2Ca_2	35.32 c	21.79 d	53.79 de	24.00 d
Zn_2Ca_3	36.00 b	26.07 b	54.19 cd	27.00 c
Zn_2Ca_4	36.00 b	19.46 ef	55.09 a	28.32 b
Zn_3Ca_1	34.66 d	24.21 c	53.39 ef	22.66 e
Zn_3Ca_2	36.00 b	19.32 ef	54.59 bc	28.00 b
Zn_3Ca_3	36.32 b	19.94 e	55.00 ab	28.66 ab
Zn_3Ca_4	39.00 a	29.00 a	55.29 a	29.32 a
$LSD_{0.05}$	0.351	1.246	0.343	0.834
CV (%)	9.265	7.181	8.442	10.308

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly. Zn_1= 0 kg Zn ha^{-1}, Zn_2= 1.5 kg Zn ha^{-1}, Zn_3= 3 kg Zn ha^{-1}, Ca_1= 0 ppm Ca, Ca_2= 50 ppm Ca, Ca_3= 75 ppm Ca, Ca_4= 100 ppm Ca

Number of pods plant^{-1}: Significant variation was observed on number of pods plant^{-1} influenced by combined effect of Zn and Ca (Table 6). Results showed that the highest number of pods plant^{-1} was obtained from the treatment combination of Zn_2Ca_3 which was significantly different from all other treatment combinations. The lowest number of pods plant^{-1} was obtained from the treatment combination of Zn_1Ca_1 which was statistically similar with Zn_3Ca_1.

Number of seeds pod^{-1}: Number of seeds pod^{-1} of mungbean at harvest was found Significant due to different treatment combination of Zn and Ca (Table 6). Results indicated that the highest number of seeds pod^{-1} was obtained from the treatment combination of Zn_2Ca_3 which was statistically identical with Zn_2Ca_4 and Zn_3Ca_3. The lowest number of seeds pod^{-1} was obtained from the treatment combination of Zn_1Ca_1 which was nearest to Zn_1Ca_2 but significantly different.

Number of fertile seeds pod^{-1}: Treatment combination of Zn and Ca showed significant variation on number of fertile seeds pod^{-1} of mungbean (Table 6). The highest number of fertile seeds pod^{-1} was obtained from the treatment combination of Zn_2Ca_3 which was significantly different from all other treatment combinations followed by Zn_2Ca_4, Zn_3Ca_2 and Zn_3Ca_3. The lowest number of fertile seeds pod^{-1} was obtained from the treatment combination of Zn_1Ca_1 which was statistically similar with Zn_1Ca_2.

Pod length (cm): Significant variation was observed on pod length influenced by combined effect of Zn and Ca (Table 6). Results verified that the highest pod length (cm) was obtained from the treatment combination of Zn_2Ca_3 followed by Zn_2Ca_4 and Zn_1Ca_3. The lowest pod length (cm) was obtained from the treatment combination of Zn_0Ca_0 which was statistically identical with Zn_1Ca_2, Zn_1Ca_4, Zn_2Ca_1 and Zn_2Ca_2.

1000 seed weight (g): Weight of 1000 seed of mungbean was found significant due to different treatment combination of Zn and Ca (Table 6). Results signified that the highest weight of 1000 seed was obtained from the treatment combination of Zn_2Ca_3 followed by Zn_2Ca_4. The lowest weight of 1000 seed was obtained from the treatment combination of Zn_1Ca_1 which was statistically similar with Zn_1Ca_4.

Weight of seeds plant^{-1} (g): Combined effect of Zn and Ca exposed significant variation on seed weight plant^{-1} (Table 6). It was found that the highest weight of seeds plant^{-1} was obtained from the treatment combination of Zn_2Ca_3 followed by Zn_1Ca_2 and Zn_2Ca_4. The lowest weight of seeds plant^{-1} was obtained from the treatment combination of Zn_1Ca_1 which was significantly different from all other treatment combinations.

Table 6. Effect of Zn and Ca on yield contributing parameters

Treatment	Yield contributing parameters					
	Number of pods plant^{-1}	Number of seeds pod^{-1}	Number of fertile seeds pod^{-1}	Pod length (cm)	1000 seed weight (g)	Weight of seeds plant^{-1} (g)
Zn_1Ca_1	11.26 g	9.19 e	7.25 e	6.79 e	42.52 g	5.36 e
Zn_1Ca_2	21.44 b	10.32 cd	7.74 de	6.82 e	43.19 f	11.09 b
Zn_1Ca_3	13.72 e	10.59 b-d	7.93 d	7.26 bc	43.32 ef	6.56 d
Zn_1Ca_4	16.87 d	10.26 d	7.26 e	6.90 e	42.82 fg	7.82 c
Zn_2Ca_1	13.59 e	10.66 bc	8.01 d	6.84 e	43.49 ef	6.11 de
Zn_2Ca_2	13.08 ef	10.79 b	8.59 bc	6.89 e	44.39 d	6.54 d
Zn_2Ca_3	23.24 a	11.86 a	10.00 a	7.80 a	46.49 a	12.69 a
Zn_2Ca_4	18.71 c	11.72 a	9.00 b	7.45 b	45.39 b	10.69 b
Zn_3Ca_1	12.11 fg	10.72 b	8.25 cd	6.87 e	43.96 de	5.91 de
Zn_3Ca_2	13.53 e	11.00 b	8.78 b	7.16 cd	44.89 bc	7.01 cd
Zn_3Ca_3	14.23 e	11.52 a	9.09 b	6.93 de	45.00 bc	7.77 c
Zn_3Ca_4	13.54 e	10.86 b	8.72 bc	7.18 cd	44.66 c	6.88 cd
$LSD_{0.05}$	1.045	0.3592	0.4819	0.2454	0.6358	1.020
CV (%)	7.228	5.429	6.371	4.217	8.392	6.274

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly. Zn_1= 0 kg Zn ha^{-1}, Zn_2= 1.5 kg Zn ha^{-1}, Zn_3= 3 kg Zn ha^{-1}, Ca_1= 0 ppm Ca, Ca_2= 50 ppm Ca, Ca_3= 75 ppm Ca, Ca_4= 100 ppm Ca

Seed yield (kg ha^{-1}): Combined effect of Zn and Ca designated significant variation on seed yield of mungbean (Table 7). Results indicated that the highest seed yield was obtained from the treatment combination of Zn_2Ca_3 followed by (second highest seed yield) the treatment combination of Zn_2Ca_4. The lowest seed yield was obtained from the treatment combination of Zn_1Ca_1 where second lowest seed yield was from the treatment combination of Zn_1Ca_4. All the treatment combinations under the present study on seed yield were significantly different to each other.

Stover yield (kg ha^{-1}): Combined effect of Zn and Ca demonstrated significant influence on stover yield of mungbean (Table 7). It was observed that the highest stover yield was obtained from the treatment combination of Zn_2Ca_3 followed by Zn_2Ca_4 where the lowest stover yield was obtained from the treatment combination of Zn_1Ca_1 that was nearest to the treatment combination of Zn_1Ca_4 but significantly different.

Biological yield (kg ha^{-1}): Significant difference was also recorded for the combined effect of Zn and Ca in terms of biological yield of mungbean (Table 7). The highest biological yield was obtained from the treatment combination of Zn_2Ca_3 followed by Zn_2Ca_4. The lowest biological yield was obtained from the treatment combination of Zn_1Ca_1 which was nearest to the treatment combination of Zn_1Ca_4 but significantly different.

Harvest index (%): Combined effect of Zn and Ca recorded significant influence on harvest index of mungbean (Table 7). Results indicated that the highest harvest index was obtained from the treatment combination of Zn_2Ca_3 which was statistically similar with Zn_2Ca_4. The lowest harvest index was obtained from the treatment combination of Zn_1Ca_1 which was immediate lower than Zn_1Ca_4 but significantly different.

Table 7. Effect of Zn and Ca on yield parameters

Treatment	Yield Parameter			
	Seed yield (kg ha^{-1})	**Stover yield (kg ha^{-1})**	**Biological yield (kg ha^{-1})**	**Harvest index (%)**
Zn_1Ca_1	757.20 l	1253.0 l	2110.0 l	37.78 h
Zn_1Ca_2	846.70 j	1325.0 j	2272.0 j	38.90 fg
Zn_1Ca_3	903.00 i	1365.0 i	2367.0 i	39.62 ef
Zn_1Ca_4	808.40 k	1286.0 k	2194.0 k	38.59 g
Zn_2Ca_1	932.00 h	1388.0 h	2420.0 h	39.95 de
Zn_2Ca_2	1039.00 f	1433.0 f	2572.0 f	41.61 c
Zn_2Ca_3	1257.00 a	1566.0 a	2923.0 a	43.87 a
Zn_2Ca_4	1219.00 b	1553.0 b	2872.0 b	43.36 ab
Zn_3Ca_1	975.00 g	1403.0 g	2478.0 g	40.70 d
Zn_3Ca_2	1132.00 d	1488.0 d	2720.0 d	42.69 b
Zn_3Ca_3	1176.00 c	1529.0 c	2805.0 c	42.93 b
Zn_3Ca_4	1080.00 e	1472.0 e	2652.0 e	41.88 c
$LSD_{0.05}$	9.23	10.09	10.77	0.81
CV (%)	12.569	15.274	11.394	8.356

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly. Zn_1= 0 kg Zn ha^{-1}, Zn_2= 1.5 kg Zn ha^{-1}, Zn_3= 3 kg Zn ha^{-1}, Ca_1= 0 ppm Ca, Ca_2= 50 ppm Ca, Ca_3= 75 ppm Ca, Ca_4= 100 ppm Ca

CONCLUSION

Based on the findings, it can be stated that the treatment Zn_2Ca_3 (1.5 kg ha^{-1} + 75 ppm) produced the greatest results in the majority of yield and yield contributing parameters. In terms of mungbean growth, treatments Zn_3Ca_4 (3.0 kg ha^{-1} + 100 ppm) produced the highest results. As a result, this treatment (Zn_2Ca_3 (1.5 kg ha^{-1} + 75 ppm) can be considered the best of the treatments investigated during the crop period. For a final recommendation, additional experiments including many other plant growth regulators, including the currently examined factors, can be done in other sites throughout Bangladesh. According to the findings of this study, the treatment Zn_2Ca_3 (1.5 kg ha^{-1} + 75 ppm) can be employed as a viable treatment for mungbean production to increase mungbean yield.

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COMPETING INTERESTS

There are no competing interests in this research article.

AUTHORS' CONTRIBUTIONS

This work was carried out by PAB. Author PAB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript, managed the literature searches, read and approved the final manuscript.

REFERENCES

1. BBS. (2010). Statistical Year Book of Bangladesh. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh. Dhaka. pp. 64-79.
2. Cakmak, I., Torun, B., Erenoglu, B., Kalayci, M., Yilmaz, A., Ekiz, H., and Brun,Coleman, J.E. (1991). Zinc proteins: Enzymes, storage proteins, transcription factors and Replication Proteins. Ann. Rev. Biochem. 61: 897-946.
3. Frauque, A., Haraguchi, T., Hirota, O. and Rahman, M. A. (2000). Growth analysis, yield, and canopy structure in maize, mungbean intercropping. Bu. Inst. of Tropical Agric. Kyushu University Fukuoka, Japan, 23: 61-69.
4. Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Resserch (2nd Edn.Int. Rice Res. Inst., A Willey Int. Sci., Pub. Pp: 28-192.
5. H.J. (1996). Zinc deficiency in soils and plants in Turkey and plant mechanism involved in zinc deficiency. Turk. J. Agric. 13- 23.
6. Hall C., Hillen C., Garden Robinson J. Composition, nutritional value, and health benefits of pulses. Cereal Chem. 2017; 94:11–31. doi: 10.1094/CCHEM-03-16-0069-FI.
7. Kannaiyan, S. (1999). Bioresource technology for sustainable agriculture. Associated Publishing Company. New Delhi, pp: 422.

8. Kaul, A. K. (1982). Pulses in Bangladesh. BARC, Farm Gate, Dhaka. p. 27.
9. Khan, M. R. I. (1981). Nutritional quality characters in pulses. In: Proc. MAT. Workshop Pulses. pp. 199 -206.
10. McLean, E.O., Hartwig, R.C., Eckert D.J. and Triplett, G.B. (1983). Basic cation saturation ratios as a basis for fertilizing and liming agronomic crops: II. Field Studies. Agron. J. 75:635-639.
11. Obata, H., Kawamura, S., Senoo, K. and Tanaka, A. (1999). Changes in the level of protein and activity of Cu/Zn Superoxide dismutase in Zinc deficient rice plants. Oryza savita L. Soil Sci. Plant Nutr. 45: 891-896.
12. Rehm, G. (1994). Soil cation ratios for crop production. North Central Regional Extension Publication 533. www.extension.umn.edu/distribution/crop systems/DC6437.html
13. Romheld, V. and Marschner, H. (1991). Function of micronutrients in plants. Micronutrients in Agriculture, ln JJ Mortvedt, FR Cox, LM Shuman, RM Welch, eds, Ed 2. Soil Science Society of America, Madison, Wl, pp. 297- 328.
14. Sarkar, P.K., Haque, M.S. and Karim, M.A. (2012). Effects of GA3, IAA and their frequency of application on morphology, yield contributing characters and yield of mungbean. Bangladesh J. Agril. Res. 1: 119-122.
15. Singh B., Singh J.P., Shevkani K., Singh N., Kaur A. Bioactive constituents in pulses and their health benefits. J. Food Sci. Technol. 2017; 54:858–870. doi: 10.1007/s13197-016-2391-9