*J Bangladesh Agril Univ 23(1): **9–17, 2025*** https://doi.org/10.3329/jbau.v23i1.80818

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Effects of Zinc Fertilization on Various Mungbean Cultivars in the Madhupur Tract of Bangladesh

Tanvir Ahammad[1], Most. Zakiya Islam[1], Mohammed Ariful Islam[1], Marzia Habib[1], Md. Ashraf Hossain[2] and Md. Sirajul Islam Khan[1]✉

[1]Dept. of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh
[2]Pulse Crop Research Centre, Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh

ARTICLE INFO

Article history
Received: 8 December 2024
Accepted: 23 March 2025
Published: 31 March 2025

Keywords
Zn fertilization,
Mungbean cultivars,
Nutrient concentration,
Seed and stover yield

Correspondence
Md. Sirajul Islam Khan
✉: sirajsau@sau.edu.bd

OPEN ACCESS

ABSTRACT

Mungbean (*Vigna radiata*) is cultivated globally for its high protein content, yet its production remains limited due to zinc (Zn) deficiency in the soil. An experiment was performed to evaluate the response of different mungbean varieties to zinc fertilization. The treatments included two levels of zinc fertilization (0 and 2 kg ha^{-1}), and five mungbean varieties BARI Mung-4, BARI Mung-5, BARI Mung-6, BARI Mung-7, and BARI Mung-8. The research was laid out using a randomized complete block design (RCBD) with three replications. BARI Mung-6 exhibited the highest values for number of pods per plant (27.33), pod length (9.40 cm), seed yield (988.80 kg ha^{-1}), 100-seed weight (4.88 g), stover yield (2361.70 kg ha^{-1}), and biological yield (3350.50 kg ha^{-1}) over other tested varieties. Zinc fertilization increased by 9.845% in plant height, 8.045% of the number of pods plant^{-1}, 3.448% number of seeds pod^{-1}, 3.209% pod length, and 7.124% in the 100-seed weight compared to the control. The maximum 100-seed weight (5.06 g), seed yield (1044.00 kg ha^{-1}), number of pods per plant (29.00), pod length (9.50 cm), stover yield (2483.30 kg ha^{-1}), and biological yield (3527.30 kg ha^{-1}) were achieved in BARI Mung-6 fertilized with 2.0 kg Zn ha^{-1} among all treatment combinations. Additionally, the BARI Mung-6 fertilized with zinc superior concentrations of potassium (K), zinc (Zn), and boron (B) in both seed and stover, though phosphorus (P) and sulfur (S) concentrations did not vary significantly.

Introduction

Legumes are recognized globally as a vital source of protein. Among them, mungbean (*Vigna radiata*) is particularly noted for its high nutrient density and affordability, providing essential vitamins and proteins (Mehta et al., 2021).

This legume is a key food source for humans, and its residues are used as animal feed. It also improves soil fertility by enhancing the physical properties of soil and fixing atmospheric nitrogen (Naik et al., 2020). In Bangladesh, where the population is rapidly increasing and arable land is diminishing, there is a pressing need to maximize food production on limited land. The country's reliance on cereals, driven by basic food needs, has led farmers to prioritize cereal cultivation over pulses, including mungbeans. Despite being suitable for cultivation year-round in Bangladesh's agro-climatic conditions, mungbean yields remain low due to minimal ploughing, limited fertilizer use, insufficient irrigation, and a lack of improved varieties.

High-yielding varieties combined with balanced fertilization can enhance both yield and yield contributing parameters (Yin et al., 2018). Integrated application of micronutrients with macronutrients has improved grain yield, quality attributes, physiological traits, as well as overall plant growth (Saquee et al., 2023). Varietal differences are evident in growth habits, maturity durations, seed sizes, colors, and yield performances, which in turn affect plant height, branching, pod development, and seed yield (Dodwadiya and Sharma, 2012; Bhowaland and Bhowmik, 2014).

In Bangladesh, farmers typically rely on NPK fertilizers for mungbean cultivation, however, according to SRDI report, Zn deficiency is the most wide spread

Cite This Article
Ahammad, T., Islam, M.Z., Islam, M.A., Habib, M., Hossain, M.A. and Khan, M.S.I. 2025. Effects of Zinc Fertilization on Various Mungbean Cultivars in the Madhupur Tract of Bangladesh. *Journal of Bangladesh Agricultural University,* 23(1):9-17. https://doi.org/10.3329/jbau.v23i1.80818

micronutrient deficiency problem in Bangladesh, typically found in calcareous, sandy soils, peat soils, and soils with high phosphorus and silicon (Sarkar et al., 2008; Hasan et al., 2020). Zinc deficiency in plants leads to reduced leaf size, stunted growth, spikelet sterility, and leaf chlorosis (Kirkby et al., 2023). For human and animal growth, zinc is essential (Basta et al., 2023). It is vital for numerous plant processes, including enzyme functions, nitrogen metabolism, protein synthesis, auxin and chlorophyll synthesis, and carbohydrate transformation (Zewdie and Sherefu, 2021; Tariq et al., 2023). Zinc also supports plant resilience against drought stress by improving osmolyte accumulation, photosynthesis, seed germination, water relations, stomatal control, cell membrane stability, and it reduces photooxidative damage under water shortage conditions (Umair et al., 2020; Javed et al., 2023). Insufficient zinc levels of seeds can significantly hamper germination of seeds and growth of seedling, even in different soil conditions (Candan et al., 2018).

Improved varieties and effective management techniques can boost up mungbean production (Uddin et al.,2009). Integrating zinc into a balanced fertilization regime improves the efficiency of macronutrient use, underscoring the importance of micronutrients in optimizing nutrient use efficiency. Although much research has been conducted previously on the effect of zinc fertilization on growth and yield for crops like rice and wheat, there is a lack of data regarding its effect on mungbean cultivation and nutrient concentration in seed and stover. Therefore, this study aimed to evaluate the response of various mungbean cultivars to zinc fertilization, independent of the application rate.

Material and Methods

Experimental location

The research field of the Soil Science Division at the Bangladesh Agricultural Research Institute (BARI) in Gazipur was the experimental location. The site belongs to ‘Madhupur Tract’ (AEZ 28) (90°24' E and latitude of 23°59' N). Initial soil zinc status and critical level of the experimental field were 1.64 and 0.6 µg g^{-1} soil, respectively.

Table 1. Weather data of Gazipur during crop growth period, 2018

Month	Air Temperature (°C)			Relative Humidity (%)	Rainfall (mm)
	High	Low	Average		
March	35	21	28	65	20
April	36	20	28	72	165
May	36	21	30	71	182
June	40	24	30	78	190

Source: Weather Station of Bangladesh Agricultural Research Institute (BARI)

Experimental design

The research was designed using a randomized complete block design (RCBD) involving two factors with three replications. Factor A: Variety, which included five types: V_1 (BARI Mung-4), V_2 (BARI Mung-5), V_3 (BARI Mung-6), V_4 (BARI Mung-7), and V_5 (BARI Mung-8); these varieties are high yielding and popular in Bangladesh because nearly all the pods mature simultaneously. Additionally, these are tolerant to yellow mosaic viral and leaf spot diseases. Factor B: Zinc fertilizer, which included two levels: Zn_0 = 0 kg Zn ha^{-1} and Zn_1 = 2.0 kg Zn ha^{-1}. The size of each unit plot was 3.0 m× 3.0 m. The basal dose consisted of urea, muriate of potash (MoP), triple super phosphate (TSP), gypsum, and boric acid at the rate of 45, 60, 100, 62.5, and 5.9 kg ha^{-1}, respectively. Zinc (Zn) was used as a treatment, applied in the form of $ZnSO_4 \cdot H_2O$. Seeds were sown on 21 March 2018. Mungbean pod was harvested at maturity from 25 May, 2018. Various intercultural operations were performed, including weeding, irrigation, drainage, and pest control measures to ensure maximum production. Pods of mungbean were manually harvested at maturity from each experimental plot.

Data Collection

Plant height (cm), 100-seeds weight pod length, number of seeds $plant^{-1}$, seed yield without husk, number of pods $plant^{-1}$, stover yield (kg ha^{-1}), biological yield (kg ha^{-1}), and nutrient content of the seeds and stover were collected to determine the impacts of Zn fertilizer on mungbean varieties.

Chemical analysis

The Macro Kjeldahl method was utilized to measure the total nitrogen content (Bremner and Mulvaney, 1982). Potassium levels were directly determined using a flame photometer, while available phosphorus was quantified colorimetrically employing the molybdovanadate yellow color method (Yoshida et al., 1976). Concentrations of sulfur, zinc, and boron were determined using a spectrophotometer and an atomic absorption spectrophotometer (Chapman and Pratt ,1961; Yoshida et al., 1976; Keren, 1996).

Statistical Analysis

The MSTAT-C software package was utilized to analyze the data collected on different parameters. The Least Significant Difference (LSD) test was carried out at a 5% probability level to determine the significant differences among treatment means (Gomez and Gomez, 1984).

Results

Effect of Zn fertilization on varieties growth and yield-related parameters

Table 2 presents the impacts of variety, zinc fertilization and their combined effects on the growth and yield-contributing parameters. Significant variation for most growth and yield parameters were observed in different mungbean varieties, except for plant height (cm). BARI Mung-6 demonstrated the highest performance in terms of pod length (9.40 cm), number of pods plant^{-1} (27.33), and 100-seed weight (4.88 g). All varieties exhibited improved performance in growth and yield parameters following zinc fertilization (Table 2). Zinc application at 2.0 kg ha^{-1} resulted in the increased pod length (8.04 cm), highest number of seeds pod^{-1} (11.10), maximum 100-seed weight (4.21 g), and maximum number of pods plant^{-1} (27.80) compared to the control. In case of combined effect, BARI Mung-6 with 2.0 kg Zn ha^{-1} resulted in the highest pod length (9.50 cm), number of pods plant^{-1} (29.00), and 100-seed weight (5.06 g) among other combination (Table 2).

Table 2. Crop characters and yield contributing parameters of mungbean as influenced by zinc

Treatments	Growth and yield contributing parameters at harvest				
	Plant height (cm)	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	100- seed weight (g)
Effect of variety					
V_1	41.85	27.00^{b}	6.97^{d}	12.12^{a}	3.21^{c}
V_2	42.35	26.83^{c}	8.87^{b}	10.23^{d}	4.24^{b}
V_3	41.93	27.33^{a}	9.40^{a}	10.41^{d}	4.88^{a}
V_4	41.95	25.67^{d}	7.05^{d}	10.74^{c}	4.84^{a}
V_5	41.87	27.00^{b}	7.28^{c}	11.08^{b}	3.19^{c}
$LSD_{0.05}$	1.05^{NS}	0.1272	0.188	0.2544	0.038
CV (%)	7.11	9.58	5.21	6.47	4.36
Effect of Zn					
Zn_0	40.02^{b}	25.73^{b}	7.79^{b}	10.73^{b}	3.93^{b}
Zn_1	43.96^{a}	27.80^{a}	8.04^{a}	11.10^{a}	4.21^{a}
$LSD_{0.05}$	1.023	0.714	0.411	0.376	0.256
CV (%)	7.11	9.58	5.21	6.47	4.36
Combined effect of variety and Zn					
V_1Zn_0	38.17^{f}	26.00^{e}	6.87^{f}	11.50^{b}	3.12^{ef}
V_1Zn_1	44.93^{ab}	28.00^{b}	7.07^{ef}	12.20^{a}	3.29^{e}
V_2Zn_0	39.77^{e}	25.33^{e}	8.67^{c}	10.03^{e}	4.12^{d}
V_2Zn_1	45.53^{a}	28.67^{a}	9.29^{ab}	10.43^{d}	4.35^{c}
V_3Zn_0	39.67^{e}	26.00^{de}	9.07^{b}	10.09^{e}	4.69^{b}
V_3Zn_1	44.20^{b}	29.00^{a}	9.50^{a}	10.73^{c}	5.06^{a}
V_4Zn_0	41.40^{cd}	24.67^{f}	6.90^{f}	10.67^{cd}	4.62^{b}
V_4Zn_1	42.50^{c}	26.00^{de}	7.20^{de}	10.82^{c}	5.03^{a}
V_5Zn_0	41.10^{d}	26.67^{d}	7.20^{de}	10.67^{cd}	3.08^{f}
V_5Zn_1	42.63^{c}	27.33^{c}	7.37^{d}	12.03^{a}	3.29^{e}
$LSD_{0.05}$	1.241	0.6441	0.266	0.2301	0.163
CV (%)	7.11	9.58	5.21	6.47	4.36

Means followed by same letter are not significantly different at 5% level by (LSD)
V_1 = BARI Mung-4, V_2 = BARI Mung-5, V_3 = BARI Mung-6, V_4 = BARI Mung-7, V_5 = BARI Mung-8, (Zn_0 = 0 Kg Zn ha$^{-1,}$ Zn_1 = 2.0 Kg Zn ha^{-1}**), NS=** Not significant

Varietal performance on yield parameters

The performance of various mungbean varieties on yield parameters influenced by zinc fertilization is shown in Table 3. Different mungbean varieties showed significant variation in yield parameters. Notably, BARI Mung-6 exhibited the highest performance in terms of seed yield ha^{-1} (988.80 kg), stover yield ha^{-1} (2361.70 kg), and biological yield ha^{-1} (3350.50 kg), followed by BARI Mung-7 and BARI Mung-4. Table 3 also indicates that all varieties showed significant improvement in yield parameters following zinc fertilization. Significant increase in seed yield (941.40 kg ha^{-1}), stover yield (2288.00 kg ha^{-1}), and biological yield (3229.40 kg ha^{-1}) were observed with the application of 2 kg Zn ha^{-1}. The BARI Mung-6 fertilized with 2.0 kg Zn ha^{-1} showed maximum stover yield (2483.30 kg), seed yield (1044.00 kg), and biological yield (3527.30 kg) ha-^{1} among all combinations.

Table 3. Yield parameters of mungbean influenced by variety, zinc and their combination

Treatments	Yield parameters		
	Seed yield ha^{-1} (kg)	Stover yield ha^{-1} (kg)	Biological yield ha^{-1} (kg)
Effect of variety			
V_1	851.30^d	2350.00^b	3201.30^b
V_2	899.00^b	1805.00^d	2704.00^e
V_3	988.80^a	2361.70^a	3350.50^a
V_4	867.20^c	2291.70^c	3158.90^c
V_5	781.80^e	2285.00^c	3066.80^d
$LSD_{0.05}$	4.391	7.148	10.95
CV (%)	9.59	11.62	12.79
Effect of Zn			
Zn_0	813.90^b	2149.30^b	2963.20^b
Zn_1	941.40^a	2288.00^a	3229.40^a
$LSD_{0.05}$	8.714	9.163	12.48
CV (%)	9.59	11.62	12.79
Combined effect of variety and Zn			
V_1Zn_0	763.00^h	2216.70^g	2979.70^f
V_1Zn_1	939.70^c	2406.70^b	3346.40^b
V_2Zn_0	839.00^e	1710.00^i	2549.00^h
V_2Zn_1	959.00^b	1900.00^h	2859.00^g
V_3Zn_0	933.30^d	2314.70^d	3248.00^c
V_3Zn_1	1044.00^a	2483.30^a	3527.30^a
V_4Zn_0	793.30^g	2266.70^e	3060.00^e
V_4Zn_1	941.00^c	2316.70^d	3257.70^c
V_5Zn_0	740.70^i	2236.70^f	2977.40^f
V_5Zn_1	823.00^f	2333.30^c	3156.30^d
$LSD_{0.05}$	5.968	8.477	9.433
CV (%)	9.59	11.62	12.79

Means followed by same letter are not significantly different at 5% level by (LSD), V_1 = BARI Mung-4, V_2 = BARI Mung-5, V_3 = BARI Mung-6, V_4 = BARI Mung-7, V_5 = BARI Mung-8, (Zn_0 = 0 Kg Zn $ha^{-1,}$ Zn_1 = 2.0 Kg Zn ha^{-1}**)**, **NS**=Not significant

Nitrogen, potassium, phosphorus, zinc, sulfur, and boron content in mungbean seeds and stover

The effects of mungbean variety, zinc application, and their interaction on nutrient concentrations (nitrogen, potassium, phosphorus, zinc, sulfur, and boron) in both seeds and stover are detailed in Table 4 and 5**.**

Nitrogen (N)

The impact of different varieties on nitrogen (N) concentration in seeds was significant (Table 4), whereas its effect on stover N concentration was not significant (Table 5). Among the evaluated varieties, BARI Mung-4 exhibited the highest nitrogen concentration in seeds, measuring 3.75%, followed by BARI Mung-6. N concentration in both seed and stover was significantly influenced by zinc (Zn) application. The highest N concentration in seeds (3.51%) and stover (2.08%) were achieved with 2.0 kg Zn ha^{-1}. Combined effect of variety and Zn application further significantly affected N concentration. The BARI Mung-4 fertilized with 2.0 kg Zn ha^{-1} showed the highest N concentration in seeds (3.84%) (Table 4), while in stover, BARI Mung-6 with 2.0 kg Zn ha^{-1} combination showed maximum N concentration (2.20%) (Table 5).

Phosphorus (P)

There was no significant variation in phosphorus (P) concentration in the seeds and stover among the different mungbean varieties (Table 4 and Table 5). Similarly, P concentration did not vary significantly in either seeds or stover from varying zinc doses. The highest phosphorus concentration in seeds (0.338%) and stover (0.188%) was recorded from the control treatment. Among the treatment combinations, the highest phosphorus concentration in seeds (0.357%) was achieved in BARI Mung-7 with 0 kg Zn ha^{-1}(Table 4), while in stover the maximum phosphorus concentration (0.199%) was found in BARI Mung-6 with 0 kg Zn ha^{-1} (Table 5).

Table 4. Effect of variety and zinc and their combination on nutrient concentration (N, P, K, S, Zn and B) in mungbean seed

Treatments	Quality parameters - nutrient concentration in seed					
	N (%)	P (%)	K (%)	S (%)	Zn (ppm)	B ppm)
Effect of variety						
V_1	3.75^a	0.340	1.337^c	0.195	25.00^c	22.81^c
V_2	3.33^c	0.338	1.392^b	0.196	26.00^b	23.56^b
V_3	3.44^b	0.342	1.500^a	0.235	26.67^a	24.64^a
V_4	3.22^d	0.341	1.345^c	0.207	23.67^d	23.36^b
V_5	3.31^c	0.310	1.357^{bc}	0.207	23.33^d	22.46^c
$LSD_{0.05}$	0.039	0.041^{NS}	0.036	0.038^{NS}	0.386	0.462
CV (%)	1.79	1.35	5.46	4.59	5.02	5.32
Effect of Zn						
Zn_0	3.31^b	0.338	1.339	0.203	23.07^b	21.71^b
Zn_1	3.51^a	0.331	1.433	0.213	26.80^a	25.02^a
$LSD_{0.05}$	0.05	0.107^{NS}	0.112^{NS}	0.108^{NS}	1.052	1.133
CV (%)	1.79	1.35	5.46	4.59	5.02	5.32
Combined effect of variety and Zn						
V_1Zn_0	3.66^b	0.340	1.293^f	0.190	23.00^e	21.12^{ef}
V_1Zn_1	3.84^a	0.340	1.380^{de}	0.200	27.00^b	24.81^b
V_2Zn_0	3.24^{ef}	0.343	1.327^{ef}	0.191	24.00^{de}	21.18^{ef}
V_2Zn_1	3.42^d	0.333	1.457^b	0.200	28.00^{ab}	25.97^a
V_3Zn_0	3.29^e	0.347	1.443^{bc}	0.227	25.00^{cd}	23.30^d
V_3Zn_1	3.58^c	0.337	1.557^a	0.243	28.33^a	26.00^a
V_4Zn_0	3.13^g	0.357	1.303^f	0.203	21.67^f	22.16^e
V_4Zn_1	3.30^e	0.327	1.387^{cd}	0.210	25.67^{cd}	24.56^{bc}
V_5Zn_0	3.21^f	0.327	1.327^{ef}	0.203	21.00^f	20.80^f
V_5Zn_1	3.42^d	0.293	1.387^d	0.210	25.67^c	23.75^{cd}
$LSD_{0.05}$	0.054	0.094^{NS}	0.051	0.055^{NS}	1.039	1.008
CV (%)	1.79	1.35	5.46	4.59	5.02	5.32

Means followed by same letter are not significantly different at 5% level by LSD
V_1 = BARI Mung-4, V_2 = BARI Mung-5, V_3 = BARI Mung-6, V_4 = BARI Mung-7, V_5 = BARI Mung-8, (Zn_0 = 0 Kg Zn $ha^{-1,}$ Zn_1 = 2.0 Kg Zn ha^{-1}), **NS**= Not significant

Table 5. Effect of variety and zinc and their combination on nutrient concentration (N, P, K, S, Zn, and B) in mungbean stover

Treatments	Quality parameters - nutrient concentration in stover					
	N (%)	P (%)	K (%)	S (%)	Zn (ppm)	B (ppm)
Effect of variety						
V_1	1.77	0.183	1.642^c	0.180	20.38^c	29.24^b
V_2	1.84	0.181	1.732^b	0.191	21.13^b	29.86^b
V_3	1.92	0.187	1.843^a	0.199	22.08^a	31.66^a
V_4	1.84	0.185	1.760^b	0.189	21.67^a	30.99^a
V_5	1.78	0.182	1.715^b	0.171	18.73^d	27.84^c
$LSD_{0.05}$	0.039^{NS}	0.038^{NS}	0.066	0.038^{NS}	0.4603	0.7458
CV (%)	4.17	4.44	3.24	2.63	8.39	6.67
Effect of Zn						
Zn_0	1.58^b	0.188	1.603^b	0.188	16.06^b	24.26^b
Zn_1	2.08^a	0.178	1.873^a	0.171	25.55^a	35.58^a
$LSD_{0.05}$	0.341	0.103^{NS}	0.105	0.108^{NS}	2.539	3.804
CV (%)	4.17	4.44	3.24	2.63	8.39	6.67
Combined effect of variety and Zn						
V_1Zn_0	1.53^e	0.188	1.47^e	0.180	15.67^f	24.01^d
V_1Zn_1	2.00^c	0.178	1.71^c	0.179	25.23^c	34.48^b
V_2Zn_0	1.58^{de}	0.188	1.60^d	0.189	16.13^{ef}	24.69^{cd}
V_2Zn_1	2.10^b	0.173	1.87^b	0.193	26.13^b	35.04^b
V_3Zn_0	1.64^d	0.199	1.70^c	0.205	16.72^e	25.65^c
V_3Zn_1	2.20^a	0.193	1.99^a	0.195	27.45^a	37.68^a
V_4Zn_0	1.61^{de}	0.174	1.68^c	0.182	16.23^{ef}	25.14^{cd}
V_4Zn_1	2.06^{bc}	0.176	1.84^b	0.195	27.12^a	36.84^a
V_5Zn_0	1.54^e	0.174	1.57^d	0.168	15.53^f	21.79^e
V_5Zn_1	2.02^c	0.190	1.96^a	0.173	21.80^d	33.88^b
$LSD_{0.05}$	0.050	0.051^{NS}	0.054	0.055^{NS}	0.8473	1.186
CV (%)	4.17	4.44	3.24	2.63	8.39	6.67

Means followed by same letter are not significantly different at 5% level by LSDV_1 = BARI Mung-4, V_2 = BARI Mung-5, V_3 = BARI Mung-6, V_4 = BARI Mung-7, V_5 = BARI Mung-8, (Zn_0 = 0 Kg Zn $ha^{-1,}$ Zn_1 = 2.0 Kg Zn ha^{-1}), **NS**= Not significant

Potassium (K)

Different mungbean varieties significantly influenced potassium (K) concentration in both seeds and stover (Table 4 and 5). The variety V_3 (BARI Mung-6) exhibited the highest K concentration, with values of 1.50% in seeds and 1.84% in stover. Although zinc application did not result in a significant variation in seeds K concentration, the maximum K concentration (1.433%) in seeds was recorded in 2.0 kg Zn ha^{-1} (Table 4). Conversely in stover, zinc applications significantly increased K concentration and the maximum concentration (1.873%) achieved with 2.0 kg Zn ha^{-1}) (Table 5). K concentration in both seeds and stover was affected significantly by the combined effect of variety and zinc application. The highest K concentrations in seeds (Table 4) and stover (Table 5) were obtained in BARI Mung-6 with 2 kg Zn ha^{-1} combination.

Sulfur (S)

Different mungbean varieties did not show significant variation in sulfur concentration (Table 4 and 5). Similarly, sulfur concentration in either seeds or stover did not varied significantly with varying zinc doses. However, the highest sulfur concentration in seeds (0.213%) was found with the Zn_1 treatment. While in stover, the maximum sulfur (188%) concentration was found from the control treatment (Zn_0). The combined effects of variety and zinc did not significantly impact sulfur concentration in mungbean seeds and stover.

Zinc (Zn)

Different mungbean varieties significantly influenced zinc (Zn) concentration in both seeds and stover (Table 4 and 5). BARI Mung-6 exhibited the maximum Zn concentrations, with 26.67 ppm in seeds and 22.08 ppm in stover. The application of different zinc doses also led to statistically significant variations in Zn concentrations in both the seeds and stover. Specifically, 2 kg Zn ha^{-1} showed the maximum Zn concentrations, with 26.80 ppm in seeds and 25.55 ppm in stover. The interaction between variety and zinc application further significantly affected Zn concentration. The highest Zn concentrations of seeds (28.33 ppm) and stover (27.45 ppm) were recorded in BARI Mung-6 with 2 kg Zn ha^{-1} combination.

Boron (B)

The study revealed that different mungbean varieties significantly influenced the boron (B) concentration in both mungbean seeds and stover, as detailed in Table 4 and 5. BARI Mung-6 exhibited the highest B concentration, with 24.64 ppm in seeds and 31.66 ppm in stover. Additionally, varying doses of Zn significantly affected the B concentration in mungbean seeds and stover. The highest B concentrations, 25.02 ppm in seeds and 35.58 ppm in stover, were observed with the Zn_1 treatment. Furthermore, the combined effect of variety and Zn treatment significantly impacted B concentration in both seeds and stover. The treatment combination BARI Mung-6 fertilized with 2 kg Zn ha^{-1} resulted in the highest B concentrations, with 26.00 ppm in seeds and 37.68 ppm in stover.

Discussion

The current results indicate that BARI Mung-6 showed superior performance in case of growth and yield parameters. It produced the highest pod length (cm), number of pods $plant^{-1}$, seed yield (kg ha^{-1}), 100-seed weight, stover yield (kg ha^{-1}), and biological yield (kg ha^{-1}) among the mungbean varieties evaluated. Previous research conducted in the same geographical region (Madhupur tract, AEZ-28) by Uddin et al. (2009). They observed the combined effect of fertilizers (NPK and biofertilizer) and variety in terms of growth and yield parameters of mungbean. They reported that BARI Mung-6 achieved the maximum pods $plant^{-1}$, number of seeds $plant^{-1}$, 1000-seed weight, and seed yield among the varieties evaluated. Tania et al. (2018) conducted a study to assess the impact of boron levels and variety on the growth and yield parameters of different summer mungbean under old Brahmaputra Floodplain 'AEZ-9'. Their findings suggest that BARI Mung-6 has been shown to excel over other varieties in terms of pod length, pods $plant^{-1}$, and 1000-grain weight, contributing to its highest seed yield.

Islam et al. (2020) evaluated the performance of different mungbean cultivars in coastal region of Bangladesh (Ganges Tidal Flood plain, AEZ-13). They reported that the highest seed yield and superior yield attributes like number of pods $plant^{-1}$, number of seeds pod^{-1} and 1000-seed weight was recorded in BARI Mung-6. Another experiment was conducted to evaluate the performance of two mungbean varieties in field conditions (Madhupur Tract, AEZ-28) under varying NPK fertilizer doses (Hossain et al., 2021). They found that BARI Mung-6 produced the highest seed yield, superior plant growth and straw yield compared to BARI Mung-5.

In the present study, all varieties exhibited significantly improved growth, yield-contributing parameters, and yield metrics when treated with 2.0 kg Zn ha^{-1} dose compared to the control. Specifically, the highest number of pods $plant^{-1}$, increased pod length, the greatest number of seeds pod^{-1}, maximum 100-seed weight, seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), and biological yield (kg ha^{-1}) were achieved with the application of 2.0 kg Zn ha^{-1}. The findings of this study are comparable with the results reported by Alam and Islam (2016). They reported that the number of branches $plant^{-1}$, the highest plant height, the highest

1000-seed weight, number of pods plant^{-1}, and highest seed yield were obtained from 2.0 kg Zn ha^{-1}. The yield was found to increase progressively with the higher Zn levels, reaching its peak at 2.0 kg ha^{-1}, but then declined when the Zn level was raised to 4.0 kg ha^{-1} (Alam and Islam, 2016). Habibullah et al. (2014) and Rahman et al. (2015) found significant increase in the number of branches plant^{-1}, plant height (cm), pod length (cm), number of pods plant^{-1}, number of grains pod^{-1}, grain yield (t ha^{-1}), 1000-grain weight (g), and stover yield (t ha^{-1}) in BARI Mung-6 due to the application of 3.0 kg ha^{-1} Zn, whereas the lowest values were observed from the control treatment. Islam et al. (2017) used 0, 1.5 and 3.0 kg ha^{-1} zinc levels to investigate their influence on the yield contributing characters of BARI Mung-5. They reported that the yield and its components in mungbean showed a gradual increase with up to 1.5 kg Zn ha^{-1} but began to decline when the Zn application reached 3.0 kg ha^{-1}. However, numerous studies have highlighted a positive relationship between higher zinc (Zn) doses and improvements in mungbean yield and its components (Roy et al., 2017; Solanki et al., 2017; Ahmed et al., 2018; Mubeen et al., 2020; Singh et al., 2023). Singh et al. (2023) conducted an experiment by using optimum soil application of Zn and varietal selection of mungbean in India. They observed that significant improvement in yield-attributing traits were recorded with the application of 5 kg Zn ha^{-1}, compared to the control and lower zinc levels. Solanki et al. (2017) reported similar findings.

The role of zinc (Zn) in enhancing nitrogen fixation and nodulation in leguminous crops can be attributed to the observed increases in yield and yield components of mungbean. Upadhya and Anita (2016) conducted a pot experiment to evaluate the effect of nitrogen and zinc on growth, yield and nodulation pattern of cowpea. They reported that the application of 15 kg Zn ha^{-1} significantly increased active nodules plant^{-1}, number of nodules plant^{-1}, and the grain yield because the synthesis of IAA was influenced by zinc in plantswhich in turn promoted improved growth, development, and nutrient absorption in the plants. Additionally, Zn is crucial for auxin synthesis, which contributes to increased plant height and cell volume (Oguchi et al., 2004; Wang et al., 2016). Both soil and foliar applications of Zn have been shown to improve yield parameters (Zafar et al., 2023).

The current study demonstrated 2.0 kg Zn ha^{-1} significantly increased nitrogen (N), zinc (Zn), and boron (B) concentrations in mungbean seeds and stover compared to control. Zinc also notably influenced the potassium (K) concentration in mungbean stover, although it did not significantly affect K concentration in seeds. However, varying zinc doses did not significantly alter phosphorus (P) or sulfur (S) concentrations in mungbean seeds or stover. The highest P concentrations in both seeds and stover were observed in the control treatment, with concentration decreasing following Zn application. These findings are well agreed with Hossain et al. (2008), they noted that while N and Zn concentrations in grain increased significantly with Zn application, the phosphorus concentration in grain tended to decrease, though not significantly, with higher Zn rates. Kumar et al. (2022) noted that zinc application did not exhibit a distinct trend concerning phosphorus (P) uptake and content, attributing this to the antagonistic relationship between phosphorus and zinc. Phosphorus and potassium concentrations in mungbean seeds were not significantly influenced by zinc application (Ranpariya et al., 2018). Significant increases in nitrogen (N), potassium (K), phosphorus (P), and sulfur (S) concentrations in mungbean seeds and stover were observed with Zn application up to 3 kg Zn ha^{-1} (Habibullah et al., 2014; Karmakar et al., 2015). However, zinc concentration in mungbean seeds and stover were not increased significantly with Zn application. Conversely, Roy et al. (2017) observed a marked rise in zinc concentration in both green gram straw and seeds, when zinc was applied via foliar spraying. Hussain et al. (2021) also reported that zinc application enhanced productivity with grain zinc concentration in mungbean. Furthermore, Palai et al. (2020) highlighted that total zinc uptake, along with nitrogen, phosphorus, and potassium (NPK), increased with zinc application through various zinc fertilizer sources.

Conclusion

This research focuses on the application of zinc fertilizer on different mungbean varieties to evaluate their individual and combined effect on the growth, yield parameters and nutrient content. The highest pod length, number of pods plant^{-1}, 100- seed weight, stover yield, seed yield and biological yield were obtained from BARI Mung-6 and plants fertilized with 2.0 Kg Zn ha^{-1}. It is revealed that the Zn level (2.0 Kg Zn ha^{-1}) is useful for obtaining superior growth and yield parameters as compared to the control. The treatment combination of BARI Mung-6 with 2.0 kg Zn ha^{-1}, among various mungbean varieties and Zn applications, resulted in the best growth, yield-related traits, and nutrient concentration in both seed and stover.

Acknowledgement

Authors in the present study acknowledge to Sher-e-Bangla Agricultural University Research System (SAURES) and Bangladesh Agricultural Research Institute (BARI) for their support to conduct the research successfully.

References

Ahmad, F., Ahmad, J., Shah, M.A., Iqbal, S., Mehmood, Z. and Abbas, W. 2018. Influence of different levels phosphorous and zinc on yield and yield attributes of mungbean [*Vigna Radiata* L.]. *Juniper online journal material science*, 5 (1):1-4. https://doi.org/10.19080/jojms.2018.05.555653

Alam, M.S. and Islam, M.F. 2016. Effect of zinc and boron on seed yield and yield contributing traits of mungbean in acidic soil. *Journal of Bioscience and Agriculture Research*, 11(02): 941-946. http://dx.doi.org/10.18801/jbar.110216.115

Basta, M., Yassin, H. A., Aly, R. G. and El Sayed, N. S. 2023. Possible protective effect of zinc administration on renal and cognitive changes occurring in uninephrectomized adult male Wistar rats. *Experimental physiology*, 108(2): 253-267. https://doi.org/10.1113/ep090735

Bhowaland, S.K. and Bhowmik, S.K. 2014. Performance of summer mungbean as affected by variety and date of harvest. *Trends in Bioscience*, 7 (13): 1534-1538. https://api.semanticscholar.org/CorpusID:88219959

Bremner, J.M. and Mulvaney**,** C.S**.** 1982. Nitrogen-Total. In: A.L. Page, R.H. Miller, D.R. Keeney (Eds), Methods of Soil Analysis, *Part 2,* Chemical and microbiological properties, 2nd Edn. pp. 595-624. Madison, Wisconsin, USA: American Society of Agronomy, Soil Science Society of America. https://doi.org/10.2134/agronmonogr9.2.2ed.c31

Candan, N., Cakmak, I. and Ozturk, L. 2018. Zinc-biofortified seeds improved seedling growth under zinc deficiency and drought stress in durum wheat. *Journal of Plant Nutrition and Soil Science*, 181(3): 388–395. doi:10.1002/jpln.201800014

Chapman, H.D. and Pratt, P.F. 1961. *Methods of analysis for soils, plants and waters*. University of California, Los Angeles: University of California.

Dodwadiya, K.S. and Sharma, A.R. 2012. Effect of tillage and method of sowing on performance of greengram (*Vigna radiata*) varieties during summer and rainy seasons. *The Indian Journal of Agricultural Sciences*, 82(5): 462–465. http://dx.doi.org/10.56093/ijas.v82i5.17814

Gomez, K.A. and Gomez, A.A. 1984. *Statistical procedures for agricultural research*. 2nd ed. New York: John Wiley and Sons.

Habibullah, M., Noor, T. A., Roni, M. Z. K., Shamsuddoha, A. T. M. and Uddin, A. J. 2014. Influence of Different Doses of Zn on Growth and Yield of Mungbean (*Vigna radiata* L.). *International Journal of Business, Social and Scientific Research*, 2(2): 169-172. http://www.ijbssr.com/currentissueview/14013071

Hasan, M.N., Bari, M.A. and Lutfar, M.R. 2020. Soil Fertility Trends in Bangladesh 2010 to 2020. SRSRF project. Soil Resource Development Institute, Ministry of Agriculture, Dhaka, Bangladesh. 84pp

Hossain, M. A., Jahiruddin, M., Islam, M. R. and Mian, M. H. 2008. The requirement of zinc for improvement of crop yield and mineral nutrition in the maize–mungbean–rice system. *Plant and Soil*, 306(1-2): 13–22. doi:10.1007/s11104-007-9529-5

Hossain, M. M., Yesmin, S., Islam, M. Z., Hossain, M. A. A. and Jahan, M. A. 2021. Physiological attributes of mungbean (*Vigna radiata* L.) influenced by different sources of nutrients (NPK) in Madhupur tract region of Bangladesh. *Journal of Science , Technology and Environment Informatics*, 11(01): 736-748. https://doi.org/10.18801/jstei.110121.74

Hussain, M., Shahid, M.Z., Mehboob, N., Minhas, W.A. and Akram, M. 2021.Zinc application improves growth, yield and grain zinc concentration of mung bean (*Vigna radiata* L.). *Semina: Ciências Agrárias*. 42(2): 487–500. https://doi.org/10.5433/1679-0359.2021v42n2p487

Islam, K.N., Khan, M.M.H., Islam, M. M., Uddin, M.M. and Latif, M.A. 2020. Performance of different cultivars of mungbean in coastal region of Bangladesh. *SAARC Journal of Agriculture*, 18(1): 161-172. https://doi.org/10.3329/sja.v18i1.48390

Islam, M.S., Hasan, K., Sabagh, A. E., Rashwan, E. and Barutçular, C. 2017. Yield and yield contributing characters of mungbean as influenced by zinc and boron. *Agricultural Advances,* 6(1): 391-397. http://dx.doi.org/10.14196/aa.v6i1.2362

Javed, M. S., Najam, T., Hussain, I., Idrees, M., Ahmad, A., Imran, M., Shah, S.S.A., Luque, R. and Han, W. 2022. Fundamentals and scientific challenges in structural design of cathode materials for zinc-ion hybrid supercapacitors. *Advanced Energy Materials*, 13(3): 2202303 https://doi.org/10.1002/aenm.202202303

Karmakar, P.C., Abdullah, A.H.M., Asrafuzzaman, M., Poddar, K.K. and Sarker, S. 2015. Effects of Zinc on the Concentrations of N, P, K, S and Zn in Mungbean (Bari Mug 6) Stover and Seed. *International Journal of Research & Review*, 2(6):307. https://www.ijrrjournal.com/IJRR_Vol.2_Issue6_June2015/IJRR0061.pdf

Keren, R. 1996. Boron. In: D.L. Sparks et al. (Eds), Methods of soil analysis, Part 3, pp. 603-625. Madison, Wisconsin, USA: American Society of Agronomy. https://doi.org/10.2136/sssabookser5.3.c21

Kirkby, E.A., Nikolic, M., White, P. J. and Xu, G. 2023. Mineral nutrition, yield, and source–sink relationships. In: Zed Rengel, Ismail Cakmak and Philip J. White, (Eds), Marschner's Mineral Nutrition of Plants 4th Edn, pp. 131-200. Academic press, https://doi.org/10.1016/C2019-0-00491-8

Kumar, S., Jat, M. K., Kumar, R., Kumar, S., Kumar, S. and Bhatia, R. 2022. Yield, nutrient content and their uptake by green gram (*Vigna radiata* L.) as affected by potassium and zinc application in course textured soil of south-west Haryana. *The Pharma Innovation Journal*, 11(3): 117-121. https://www.researchgate.net/publication/363614210

Mehta, N., Rao, P. and Saini, R. 2021.Exploration of the antibacterial, antioxidant and anticancer potential of the seed coat extract of mungbean (*Vigna radiata* L. Wilczek*). Plant Archives*, 21(1):1628–1633. https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no1.222

Mubeen, A.,Saeed, M. T., Saleem, M. F. and Wahid, M.A. 2020. Zinc and Boron Application Improves Yield, Yield Components and Gross Returns of Mungbean (*Vigna radiata* L.). *Journal of Arable Crops and Marketing*, 02 (02):79-87. https://doi.org/10.33687/jacm.002.02.3521

Naik, M.G., Abhirami, P. and Venkatachalapathy, N. 2020. Mung Bean. In: A. Manickavasagan, P. Thirunathan (Eds). Pulses, pp. 213–228. Springer, Cham, https://doi.org/10.1007/978-3-030-41376-7_12

Oguchi, K., Tanaka, N., Komatsu, S. and Akao, S. 2004. Methylmalonate-semialdehyde dehydrogenase is induced in auxin-stimulated and zinc-stimulated root formation in rice. *Plant cell reports*, 22(11):848-858. https://doi.org/10.1007/s00299-004-0778-y

Palai, J.B., Jena, J. and Lenka, S.K. 2020. Growth, Yield and Nutrient Uptake of Maize as Affected by Zinc Application – A Review., *Indian Journal of Pure* & Applied *Biosciences,*28(2): 332-339. doi: http://dx.doi.org/10.18782/2582-2845.8054

Quddus, M.A., Rashid, M. H., Hossain, M. A. and Naser, H. M. 2011.Effect of zinc and boron on yield and yield contributing characters of mungbean in low Ganges River floodplain soil at Madaripur, Bangladesh. *Bangladesh Journal of Agricultural Research*, 36(1): 75-85. https://doi.org/10.3329/bjar.v36i1.9231

Rahman, M. M., Adan, M. J., Chowdhury, M. S. N., Ali, M. S. and Mahabub, T.S. 2015. Effects of phosphorus and zinc on the growth and yield of mungbean (BARI mug 6). *International Journal of Science and Research.*, 5(2): 30-34. https://www.researchgate.net/publication/285581529

Ranpariya, V.S. and Polara, K.B. 2018. Effect of Potassium, Zinc and FYM on Content and Uptake of Nutrients of Summer Green Gram (*Vigna radiata* L.) at Different Growth Stages under South Saurashtra Region of Gujarat. *International Journal of Pure and Applied Bioscience*, 6(1): 997-1002.

http://dx.doi.org/10.18782/2320-7051.5141

Roy, P.D., Lakshman, K., Narwal, R. P., Malik, R. S. and Saha, S. 2017.Green Gram (*Vigna radiata* L.) Productivity and Grain Quality Enrichment through Zinc Fertilization. *International Journal of Current Microbiology and Applied Sciences*, 6(6):643-648. doi: https://doi.org/10.20546/ijcmas.2017.606.076

Saquee, F.S., Diakite, S., Kavhiza, N. J., Pakina, E. and Zargar, M. 2023.The Efficacy of Micronutrient Fertilizers on the Yield Formulation and Quality of Wheat Grains. *Agronomy*, 13(2): 566. 10.3390/agronomy13020566

Sarker, M. M. H., Moslehuddin, A. Z. M., Jahiruddin, M. and Islam, M. R. 2018. Available status and changing trend of micronutrients in floodplain soils of Bangladesh. *SAARC Journal of Agriculture*,,16(1): 35-48. http://dx.doi.org/10.3329/sja.v16i1.37421

Singh, U., Dev, P., Singh, L. N., Ram, M. and Choudhary, R .2023. Improved varietal selection and optimum soil application of Zn enhance mungbean (*Vigna radiata* L. Wilczek) productivity and profitability. *Annals of Agricultural Research*, 44 (1): 81-87. https://epubs.icar.org.in/index.php/AAR/article/view/134792

Solanki, D., Swetha, P. and Solanki, M.S. 2017. Growth, yield and yield attributes of summer green gram (*Vigna radiata* L.Wilczeck) under medium black calcareus soils as influenced by application of sulfur and zinc levels. *International Journal of Agricultural Science and Research,* **7**(4):663-668. https://www.academia.edu/35048669

Tania, S.A., Uddin, F. J. and Sarkar, M.A.R. 2018. Responses of selected mungbean (*Vigna radiata* L.) varieties to boron fertilization. *Fundamental and Applied Agriculture*, 4**(**1): 655–660. https://doi.org/10.5455/faa.815

Tariq, A., Zeng, F., Graciano, C., Ullah, A., Sadia, S., Ahmed, Z. and Zhang, Z. 2023. Regulation of Metabolites by Nutrients in Plants. In: Singh, V.P. Singh and M.H. Siddiqui (Eds), Plant Ionomics: Sensing, Signaling, and Regulation, pp. 1-18. https://doi.org/10.1002/9781119803041.ch1

Uddin, M. S., Amin, A. K. M. R., Ullah, M. J. and Asaduzzman, M. 2009. Interaction effect of variety and different fertilizers on the growth and yield of summer mungbean. *American-Eurasian Journal of Agronomy*, 2(3):180-184. http://www.idosi.org/aeja/2(3)09/11.pdf

Umair Hassan, M., Aamer, M., Umer Chattha, M., Haiying, T., Shahzad, B., Barbanti, L., Nawaz, M., Rasheed, A., Afzal, A., Liu, Y. and Guoqin, H. 2020. The Critical Role of Zinc in Plants Facing the drought Stress. *Agriculture,* 10(9): 396. https://doi.org/10.3390/agriculture10090396

Upadhyay, R.G. and Anita, S. 2016. Effect of nitrogen and zinc on nodulation, growth and yield of cowpea (*Vigna unguiculata*). *Legume Research*, 39(1): 149-151. doi: 10.18805/lr. v39i1.8880.

Wang, S., Ren, X., Huang, B., Wang, G., Zhou, P. and An, Y. 2016. Aluminium-induced reduction of plant growth in alfalfa (*Medicago sativa*) is mediated by interrupting auxin transport and accumulation in roots. *Scientific reports*, 6(1): 30079. DOI: 10.1038/srep30079

Yin, Z., Guo, W., Xiao, H., Liang, J., Hao, X., Dong, N., Leng, T., Wang, Y., Wang, Q. and Yin, F. 2018. Nitrogen, phosphorus, and potassium fertilization to achieve expected yield and improve yield components of mung bean. *PLOS One*, 13(10). https://doi.org/10.1371%2Fjournal.pone.0206285

Yoshida, S., Fomo, A.D., Clock, J.A. and Gomez, K.A. 1976. Physiological Studies of Rice, 2nd ed. Manila, Philippines: Int. Rice Res. Inst.

Zafar, M., Ahmed, S., Munir, M.K., Zafar, N., Saqib, M., Sarwar, M.A., Iqbal, S., Ali, B., Akhtar, N., Ali, B. and Hussain, S.2023. Application of zinc, iron and boron enhances productivity and grain biofortification of mungbean. *Phyton-International Journal of Experimental Botany*, 92(4):983-999. https://doi.org/10.32604/phyton.2023.025813

Zewide, I. and Sherefu, A. 2021. Review Paper on Effect of Micronutrients for Crop Production. *Journal of Nutrition and Food Processing*, 4(7): 1-8. https://doi.org/10.31579/2637-8914/063