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AGRONOMY | ORIGINAL ARTICLE

Foliar Zinc Application Enhances the Grain Yield of Mungbean (*Vigna radiata* L.)

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ABSTRACT

Mungbean (*Vigna radiata* L.) is a legume widely recognized for diverse uses. Like other legumes, mungbean plants also possess a remarkable ability to interact with nitrogen-fixing bacteria by inhabiting plant roots. This experiment aimed to investigate the effects of foliar Zn application on the growth and yield contributing traits of mungbean, and to determine the best Zn fertilizer management for optimum mungbean growth and yield. The experiment was comprised of one factor, *viz.* management of the zinc fertilizer, and seven treatments, *viz.* (i) No zinc application (Control) [T1], (ii) Basal application of $ZnSO_4.7H_2O$ @ 10 kg ha^{-1} [T2], (iii) Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at pre-flowering stage (i.e. 40 days after sowing (DAS)) [T3], (iv) Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at flowering stage (i.e., 50 DAS) [T4], (v) Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at pod formation stage (i.e. 60 DAS) [T5], (vi) Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at 40 DAS and 50 DAS [T6], (vii) Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at 40, 50 and 60 DAS [T7]. The experimental treatments were laid out in a randomized complete block design (RCBD) with three replications. Plant characteristics such as plant height, shoot dry weight, root dry weight, and yield contributing characteristics including number of pods $plant^{-1}$, number of good pods $plant^{-1}$, number of grains pod^{-1}, and weight of 1000 grains were significantly influenced by Zn fertilization. The highest values for all parameters, including maximum grain yield (0.84 ± .06 t ha^{-1}) and stover yield (4.64 ± 0.85 t ha^{-1}), were recorded at T7, where foliar application of 0.5% $ZnSO_4.7H_2O$ was applied at 40, 50 and 60 DAS.

1. Introduction

Mungbean (*Vigna radiata* L.) is a widely grown short-duration pulse crop cultivated in almost all regions in Bangladesh. It is known for its early maturity, protein quality, detoxifying properties, and ability to boost soil fertility through N_2 fixation (Phoomthaisong et al., 2003). It is one of the most crucial legume crops with good digestibility, flavor, and nutritional attributes. It is utilized in the summer to freshen the mind, prevent heat exhaustion, and lessen edema (Tang et al., 2014). Mungbean is characterized by high-quality proteins that can be consumed as whole grains, deals, or sprouts and is an excellent supplement to rice in terms of balanced human nutrition (Nair et al., 2013) . Mungbean grains generally contain 22-28% protein, 60-65% carbohydrates, 1.5% fat, 3.5-4.5% fiber, and a significant amount of antioxidants, vitamins, and minerals (Jahan et al., 2020) and have become integral to meals with plant-based proteins, such as egg and meat alternatives (Somta et al., 2022). In Bangladesh, mungbean production is deficient, accounting for 41 metric tons (BBS, 2021). Micronutrients enhance crop nutritional quality, yield, biomass production, and resilience to drought, pests, and diseases, with positive effects ranging from 10% to 70%. However, a deficit of one micronutrient can cause a devastating loss in crop production even when all other micronutrients are present. Micronutrient deficit might be one of the prominent reasons behind this low production of mungbean in Bangladesh.

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Zinc is an essential micronutrient engaged in a wide range of physiological activities by activating enzymes, and it is involved in protein synthesis as well as carbohydrate, nucleic acid, and lipid metabolism. Besides, Zn is necessary for synthesizing tryptophan, which serves as a precursor to indole-3-acetic acid (IAA) (Alloway). However, when Zn accumulates in excess in plant tissues, it causes alteration in crucial growth processes such as photosynthesis and chlorophyll production (Stoyanova & Doncheva, 2002). Zn appears to alter plant water absorption and transport capacity and mitigate the adverse effects of heat or salt stress (Disante et al., 2011; Peck & McDonald, 2010). Since Zn is vital for many physiological and chemical processes in plants. Therefore, deficiency of this nutrient is considered a critical yield-limiting factor in mungbean production (Rehman et al., 2012).

During foliar fertilization, the plant absorbs essential nutrients through its foliage. However, the amount obtained is relatively low compared to its overall requirement (Hussain et al., 2021). Foliar fertilization promotes nutrient uptake from the soil, benefiting plants with nutrient deficiencies (Islam et al., 2024; Rahman et al., 2023; Rashid et al., 2023). Crops respond to soil-applied fertilizer in 5 to 6 days, while responses can be seen within 3 to 4 days in foliar fertilization (Fageria et al., 2009). When plant roots are not well developed at the early growth stage, foliar fertilization is more advantageous in absorption than soil application. However, foliar treatment is particularly effective for micronutrients, whereas soil application is effective for both macro and micronutrients. Though many experiments have already been conducted on the effects of zinc fertilizer management on legume crops, research on their foliar application is scarce. Thus, this research was conducted (i) to assess the effect of foliar application of Zn on the growth and yield contributing characteristics of mungbean, and (ii) to find out the best Zn fertilizer management for mungbean for optimum growth and yield.

2. Materials and Methods

2.1. Experimental site and soil

The experiment was conducted in the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. The site is located at 24.75° N latitude and 90.50° E longitude, in the southwest part of the Old Brahmaputra River at an altitude of 18 m. The topography of the experimental site was classified as medium-high, attributed to the Sonatala soil series within the Agro-Ecological Zone-9 (AEZ-9) named Old Brahmaputra Floodplain, which is characterized by non-calcareous dark grey floodplain soil. The site was in a sub-tropical region characterized by elevated temperature, abundant rainfall from April to September, and low rainfall associated with moderately low temperature from October to March. Throughout the experimental period, the recorded average temperature ranged from a maximum of 33.50 °C to a minimum of 23.76 °C, whereas the maximum relative humidity reached 77.67%, and the total rainfall was 208.2 mm. The soil type was sandy loam, with a pH of 7.30.

2.2. Experimental treatments and design

The experiment only included one component *viz.* management of the zinc fertilizer, which had seven treatments *viz.* (i) No zinc application (Control) [T1], (ii) Basal application of ZnSO4.7H2O @10kg/ha [T2], (iii) Foliar application of 0.5% ZnSO4.7H2O solution at pre-flowering stage (i.e. 40 days after sowing (DAS)) [T3], (iv) Foliar application of 0.5% ZnSO4.7H2O solution at flowering stage (i.e., 50 DAS) [T4], (v) Foliar application of 0.5% ZnSO4.7H2O solution at pod formation stage (i.e. 60 DAS) [T5], (vi) Foliar application of 0.5% ZnSO4.7H2O solution at 40 DAS and 50 DAS [T6], (vii) Foliar application of 0.5% ZnSO4.7H2O solution at 40, 50 and 60 DAS [T7]. The experiment was set up utilizing a randomized complete block design (RCBD) with four replications. The site was divided into four blocks, each representing one of the four replications to minimize soil heterogeneity. Within each replication, there were a total of 7 plots. Thus, the study consisted of 28 plots, each encompassing 4 m × 2.5 m. The spacing between block-to-block and individual plots within a block was 1.0 m and 0.5 m, respectively. Seven treatment combinations were distributed randomly within every replication.

2.3. Plant material

Binamoog-5 served as the plant material for the experiment. Seeds of Binamoog-5 were collected from the Bangladesh Institute of Nuclear Agriculture (BINA), Ishwardi Substation, Pabna. Binamoog-5 is a summer mungbean variety released by the Bangladesh Institute of Nuclear Agriculture in 1998. The maturity period of Binamoog-5 spans from 70 to 80 days. Maximum seed yield is about 2.0 t ha^{-1} with an average of 1.45 t ha^{-1}. Seeds are medium in size, green and shiny in color, and contain higher protein content (~23%). Nearly all the pods mature at the same time, making it convenient for harvesting. Characterized by short height, the plants display high tolerance to the Cercospora leaf spot and yellow mosaic virus (YMV) disease, making them suitable for cultivation in pulse-growing areas in Bangladesh.

2.4. Crop husbandry and data collection

Land preparation was started on April 10, 2022, involving finer tillage with a power tiller to ensure proper seed-sowing conditions. Spading was done at the corners of the field to break large clods. During the final land preparation, urea, triple super phosphate (TSP), muriate of potash (MoP), and gypsum were applied at 35 kg ha^{-1}, 50 kg ha^{-1}, 35 kg ha^{-1}, and 30 kg ha^{-1}, respectively. Zinc fertilization followed experimental treatments.

Seeds were sown continuously in lines with 30 cm spacing on April 18, 2022, at a rate of 4 kg ha^{-1}. After 20 days of sowing, thinning was carried out to maintain a plant-to-plant distance of 10 cm. Weeding and thinning were simultaneously performed, and a second round was carried out 35 days after planting. No irrigation or disease control was necessary due to the absence of moisture stress and disease incidence.

Insecticide (Gain) was applied at a rate of 1.7 L ha^{-1} to manage pod borers that attacked the field. Harvesting involved the central 1.0 m^2 area of each plot, where data on yield components and overall yield were recorded. Data collection on various parameters, such as plant height, number of pods $plant^{-1}$, number of fertile pods $plant^{-1}$, weight of 1000 grains, number of grains pod^{-1}, root dry weight, and shoot dry weight, was done by uprooting five randomly selected plants from each plot. After harvesting, crop bundles were sun-dried on the threshing floor for two days, and grains were extracted by beating the bundles with wooden sticks. The collected grains were sun-dried to reduce their moisture content by about 14%, and subsequently, both grains and stover from each plot were cleaned and weighed.

2.5. Data analysis

The data recorded for various parameters were compiled and organized into a structured table and subjected to statistical analysis utilizing the statistical package 'R.' Analysis of Variance (ANOVA) was conducted using 'agricolae' package of 'R' (R Core Team, 2021). Tukey's post hoc test was employed to assess and determine the differences among the means of different treatments.

3. Results and Discussion

3.1. Plant characteristics

Zn fertilizer management significantly influenced the shoot dry weight, plant height, and root dry weight of Binamoog-5 at a 1% level of significance. T7 (Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at 40, 50, and 60 DAS) resulted in the tallest plant height (93.05 ± 5.79 cm). In contrast, T1 (No Zn application) had the shortest plant height (58.65 ± 5.37 cm). Zn application at the flowering stage (T4) had a similar effect to treatments beyond the flowering stage (T5, T6, and T7), indicating a significant relationship of Zn with plant height. A study conducted by Kothaipriya et al. (2021) reported that 0.5% foliar application of Zn with chelated zinc formulation at a rate of 7.5 kg ha^{-1} contributed to the highest plant height in the vegetative stage, tasseling stage, and at harvest. In another study, Habbasha et al. (2013) found that applying 0.2% $ZnSO_4$ to chickpeas during the grain-filling stage led to the tallest plants (81.43 cm). Similarly, shoot dry weight was highest in T7 (12.57 ± 2.86 g) and lowest in T1 (3.17 ± 0.51 g). Zn application at the pod formation stage (T5) showed a similar effect as beyond the pod formation stage (T6 and T7) in shoot dry weight. Regarding root dry weight, Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at 40, 50, and 60 DAS [T7] (2.6 ± 0.26 g) resulted in the highest and statistically similar to T6 (2.22 ± 0.19 g). The lowest root dry weight was in T1 (0.97 ± 0.1 g), similar to T2 (1.22 ± 0.13 g), demonstrating a significant relationship of Zn with shoot and root dry weight. Haider et al. (2018) found a similar result where foliar application of Zn at 5% resulted in the maximum shoot dry weight, plant height, and root dry weight compared to other plots where no zinc application was carried out.

3.2. Yield contributing characters

Zn fertilization significantly affected the number of pods $plant^{-1}$, good pods per $plant^{-1}$, grains pod^{-1}, and weight of 1000 grains. T7, where the foliar application of Zn was carried out at 40, 50, and 60 DAS, exhibited the maximum number of pods $plant^{-1}$ (344 ± 86.9). In contrast, T1, where no zinc application was carried out, resulted in the lowest (164 ± 35.48). Zn application at the flowering stage (T4) had a similar effect to treatments beyond the flowering stage (T5, T6, and T7). Similarly, T7 showed the highest number of good pods $plant^{-1}$ (286 ± 67.37), statistically identical to T6, T5, and T4. Conversely, T1 exhibited the lowest number of good pods $plant^{-1}$ (142 ± 30.2), similar to treatments beyond the control (T2, T3, T4, T5 and T6), indicating a significant relationship between Zn and the number of good pods per plant. In a study conducted by Karmakar et al. (2015), Zn application at a rate of 3 kg ha^{-1} led to the highest number of pods $plant^{-1}$, grains pod^{-1}, resulting in maximum grain yield.

Treatment T7 exhibited the highest number of grains pod^{-1} (72.2 ± 21.32), statistically identical to T6, T5, and T4, where 57.65 ± 9.85, 55.3 ± 9.99, and 47.95 ± 14.45 grains pod^{-1} were recorded, respectively. Conversely, T1 displayed the lowest number of grains pod^{-1} (28.75 ± 7.61), showing statistical similarity to T2, T3, T4, and T5, displaying a significant relationship between Zn fertilizer application and the number of grains pod^{-1}. According to Praveena et al. (2018) , the basal application of Zn at a rate of 5.5 kg ha^{-1} resulted in more grains pod^{-1} than other plots. Hence, T7 recorded the maximum 1000- grain weight (26.62 ± 0.1 g), statistically indistinguishable from the second (26.35 ± 0.09 g) and third (26.22 ± 0.05 g) highest 1000- grain weights. The lowest 1000- grain weight (25.5 ± 0.2323 g) was found in the plot where no zinc application was carried out (T1), displaying statistical similarity to T2 and T3. Begum et al. (2015) showed that the application of Zn at a rate of 2 kg ha^{-1}, when combined with B, resulted in the highest weight of 1000 grains.

3.3. Grain and stover yield

Zn fertilizer application significantly impacted the grain and stover yield of Binamoog-5. The highest grain yield (0.84 ± 0.06 t ha^{-1}) was recorded in T7, identical to T6 (0.72 ± 0.08 t ha^{-1}). This increase in grain yield can be attributed to a higher number of pods per plant, number of grains per pod, and higher 1000- grain weight. On the other hand, T1 had the lowest grain yield (0.21 ± 0.05 t ha^{-1}), showing statistical similarity to T2 (0.31 ± 0.06 t ha^{-1}). Similarly, the highest stover yield (4.64 ± 0.85 t ha^{-1}) was observed in T7, while the lowest stover yield (1.2 ± 0.33 t ha^{-1}) was obtained from T1 (control).

Applying Zn at the pod formation stage (T5) had a similar effect to treatments beyond the pod formation stage (T6 and T7), indicating a significant relationship between Zn with grain and stover yield. Rahman et al. (2015) observed that adding Zn to mungbean increases overall output, with doses of 3 kg Zn ha^{-1} producing the highest grain yield (1.45 t ha^{-1}) and stover yield (2.42 t ha^{-1}).

Table 1. Effect of zinc fertilizer management on plant characters and growth of mungbean

Treatments	Plant height (cm)	No. of pods plant^{-1}	No. of good pods plant^{-1}	No. of grains pod^{-1}	Weight of 1000 grains	Root dry weight (g)	Shoot dry weight (g)
T1	58.6 ± 5.37 d	164± 35.48 d	142 ± 30.2 b	28.75 ± 7.61 c	25.5 ± 0.23 e	0.97 ± 0.1 e	3.17 ± 0.51 d
T2	67.05 ± 7.52 cd	184 ± 28.47 cd	148 ± 30.98 b	33.75 ± 5.61 bc	25.67 ± 0.27 de	1.22 ± 0.13 de	4.3 ± 0.68 cd
T3	73 ± 4.07 bc	200.8 ± 25.01 bcd	156.3 ± 27.08 b	37.15 ± 7.92 bc	25.91 ± 0.3 cde	1.54 ± 0.2 cd	5.51 ± 0.68 cd
T4	83.85 ± 6.26 ab	238 ± 45.43 abcd	198 ± 52.41 ab	47.95 ± 14.45 abc	26.09 ± 0.06 bcd	1.82 ± 0.2 bc	7.22 ± 1.23 bcd
T5	85.95 ± 6.65 ab	276 ± 35.48 abc	226 ± 39.4 ab	55.3 ± 9.99 abc	26.22 ± 0.05 abc	2.08 ± 0.26 b	8.48 ± 3 abc
T6	89.35 ± 6.65 a	291.7 ± 38.16 ab	242.8 ± 46.16 ab	57.65 ± 9.85 ab	26.35 ± 0.09 ab	2.22 ± 0.19 ab	10.44 ± 2.45 ab
T7	93.05 ± 5.79 a	344 ± 86.9 a	286 ± 67.37 a	72.2 ± 21.32 a	26.62 ± 0.1 a	2.6 ± 0.26 a	12.57 ± 2.86 a
CV (%)	7.79	19.09	22.03	25.30	0.71	11.06	26.02
Sig. level	0.01	0.01	0.01	0.01	0.01	0.01	0.01

T1: No Zn application (control), T2: Basal application of $ZnSO_4.7H_2O$ @ 10 kg/ha, T3: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at pre flowering stage (i.e. 40 Days after sowing (DAS)), T4: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at flowering stage (i.e. 50 DAS), T5: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at pod formation stage (i.e. 60 DAS), T6: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at 40 DAS and 50 DAS, and T7: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at 40, 50 and 60 DAS; vertical lines associated with bars are standard deviation of mean; bars with similar letter are not statistically significant at P = 0.05.

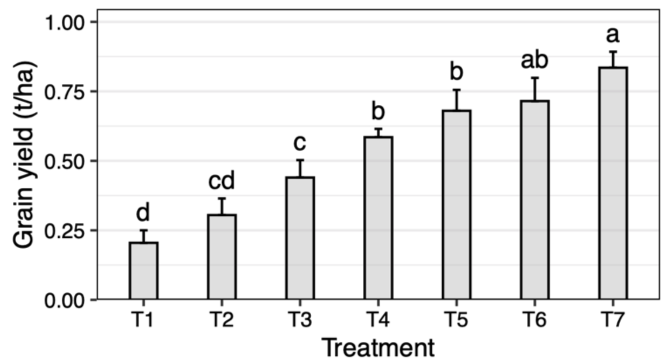

Figure 1. Effect of Zinc fertilizer management on grain yield of mung bean. T1: No Zn application (control), T2: Basal application of $ZnSO_4.7H_2O$ @ 10 kg/ha, T3: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at pre flowering stage (i.e. 40 Days after sowing (DAS)), T4: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at flowering stage (i.e. 50 DAS), T5: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at pod formation stage (i.e. 60 DAS), T6: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at 40 DAS and 50 DAS, and T7: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at 40, 50 and 60 DAS; vertical lines associated with bars are standard deviation of mean; bars with similar letter are not statistically significant at P = 0.05.

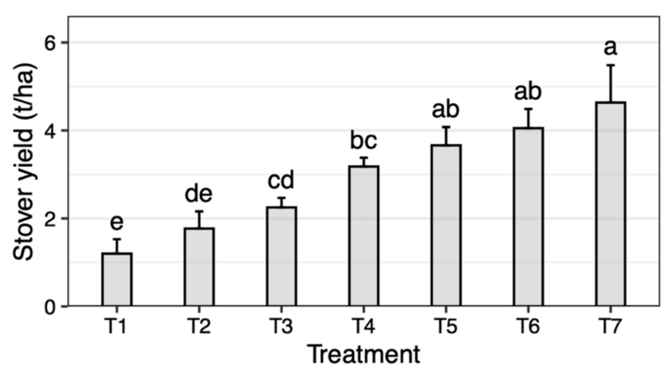

Figure 2. Effect of Zinc fertilizer management on Stover yield of mung bean. T1: No Zn application (control), T2: Basal application of $ZnSO_4.7H_2O$ @ 10 kg/ha, T3: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at pre flowering stage (i.e. 40 Days after sowing (DAS)), T4: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at flowering stage (i.e. 50 DAS), T5: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at pod formation stage (i.e. 60 DAS), T6: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at 40 DAS and 50 DAS, and T7: Foliar application of 0.5% $ZnSO_4.7H_2O$ solution at 40, 50 and 60 DAS; vertical lines associated with bars are standard deviation of mean; bars with similar letter are not statistically significant at P = 0.05.

Malik et al. (2015) found that Zn application influences grain yield significantly, and the highest grain yield per plant was recorded from the plot where 20 ppm Zn was applied. Jamal et al. (2018) reported that an increased grain and stover yield was observed when plants were combinedly fertilized with Iron and Zn at a rate of 5 kg ha^{-1} and 10 kg ha^{-1}, respectively.

4. Conclusion

From the above findings it may be concluded that higher grain yield of mung bean could be obtained with the application of Zinc @ 40 DAS, 50 DAS and 60 DAS. This treatment gave highest grain yield compared to other treatment combinations. This conclusion has been made based on the results of the study that was conducted in Kharif-I season only. More experiments may be carried out with other different doses of Zn.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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