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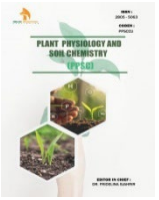

RESEARCH ARTICLE

IMPACT OF PHOSPHORUS AND ZINC FERTILIZATION ON GROWTH, YIELD, AND SEED QUALITY OF MUNGBEAN VARIETIES

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ABSTRACT

This research was conducted to evaluate the interactive effects of three mungbean varieties (BARI Mung-6, BARI Mung-7, and Binamoog-8) and five combined phosphorus (P) and zinc (Zn) fertilization levels (control to 150% Recommended Dose, RDF) on growth, yield, and seed quality of Vigna radiata L. Both variety and P+Zn fertilization significantly influenced all measured attributes. The highest fertilization level (150% RDF) significantly increased grain yield to 1.51 t/ha compared to the control (1.11 t/ha). Among varieties, Binamoog-8 (Experiment variety 3, V3) outperformed others, showing the greatest 1000-seed weight (51.42 g) and pods per plant (26.48). A strong synergistic interaction was evident, with the Binamoog-8 × 150% RDF combination yielding the highest grain output (1.66 t/ha) alongside superior seed quality, including a 95.81% germination rate. Conversely, BARI Mung-7 without fertilization demonstrated the lowest productivity and seed quality. These findings indicate that combining high-yielding varieties like Binamoog-8 with an enhanced P and Zn fertilization regime (150% RDF) is an effective strategy to maximize mungbean productivity and seed quality in the targeted agro-ecological zone. This research provides valuable guidance for optimizing fertilization and variety selection to improve mungbean yield and ensure better seed performance under field conditions.

KEYWORDS

Fertilization, Agronomy, Mungbean, Seed Quality, Metal

1. INTRODUCTION

Mungbean (*Vigna radiata* L.) is a widely cultivated, short-duration legume crop of considerable economic importance across Asia, Africa, and other tropical and subtropical regions (Ahmad et al., 2018). It serves as a vital source of plant-based protein, dietary fiber, and essential micronutrients, substantially contributing to food security and nutritional health, especially in developing countries. Beyond its role as a food crop, mungbean significantly enhances sustainable agricultural practices through biological nitrogen fixation via symbiotic relationships with rhizobia, thereby improving soil fertility and reducing dependence on synthetic nitrogen fertilizers while boosting the productivity of subsequent crops in rotations (Habibullah, 2012). Despite its recognized benefits, mungbean productivity in many regions, including Bangladesh, remains below potential owing to abiotic and biotic stresses, with inadequate nutrient management being a key limitation (Singh et al., 2013). Among essential nutrients, phosphorus (P) and zinc (Zn) play critical roles in ensuring optimal plant growth, reproductive development, and yield formation. Phosphorus, a macronutrient, is integral to energy transfer mechanisms, notably ATP synthesis, nucleic acid and phospholipid composition, which govern photosynthesis, root growth, flowering, and seed development (Ahmad et al., 2021; Islam et al., 2005; Rahman et al., 2015). Zinc, a micronutrient, is indispensable as a cofactor in enzymatic systems regulating carbohydrate metabolism, protein synthesis, and hormone activity, directly affecting plant development and stress resilience (Ahmad et al., 2021; Masih et al., 2020). Deficiencies in either nutrient adversely affect physiological functions, leading to reduced growth, flowering, pod formation, and yield losses (Islam et al., 2016). Although individual effects of P and Zn are well documented, their combined fertilization frequently produces synergistic benefits by improving nutrient use efficiency, enhancing yield, and improving seed nutritional quality, while mitigating P-induced Zn antagonism (Soykot, 2022; Ahmad et al., 2018). Moreover, varietal differences significantly influence the efficiency of nutrient uptake and utilization, with genetic variability driving differential responses among mungbean cultivars to fertilization regimes (Hossain et al., 2017; Ravi Kumar et al., 2013). Despite the critical importance of assessing such interactions, comprehensive studies exploring the interactive effects of varying P and Zn levels on growth, yield, and seed quality across distinct mungbean varieties under agro-climatic conditions relevant to Bangladesh are limited. Addressing this gap, the present study evaluates the individual and combined effects of phosphorus and zinc fertilization on three prominent mungbean varieties—BARI Mung-6, BARI Mung-7, and Binamoog-8—with an emphasis on optimizing growth, yield attributes, seed quality, and identifying the best variety-fertilizer combination suitable for the target agro-ecological zone. These insights aim to inform nutrient management strategies promoting sustainable, high-yield mungbean production.

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2. Materials And Methods

2.1. Materials

The study was conducted at Dhaka, Bangladesh (23°77′N, 90°33′E; elevation 8.2 m), on a silty clay loam soil with a pH of 6.1 and 0.45% organic carbon content. The climate of the region is subtropical with distinct wet and dry seasons. Three mungbean varieties were selected for evaluation: BARI Mung-6 (V1), BARI Mung-7 (V2), and Binamoog-8 (V3). Five phosphorus (P) and zinc (Zn) combined fertilization levels were used: F0 (no P+Zn control), F1 (75% of recommended dose), F2 (recommended dose of fertilizer, RDF), F3 (125% of RDF), and F4 (150% of RDF). Recommended fertilizer doses applied were 40 kg N ha^{-1} (urea), 80 kg P ha^{-1} (triple super phosphate), 30 kg K ha^{-1} (muriate of potash), and 1 kg Zn ha^{-1} (zinc sulphate). P and Zn were applied during final land preparation.

2.2. Methods

The experiment followed a two-factor Randomized Complete Block Design (RCBD) with three replications. Seeds were sown on March 15, 2022, in rows spaced 30 cm apart with 10 cm plant-to-plant distance, at a rate of 40 kg ha^{-1}. Land preparation involved three ploughings and laddering to achieve optimal tilth. Standard agronomic practices including supplemental irrigation, weed control, and pest management were applied throughout the crop cycle.

2.3 Experimentation

The experiment was set up following a Factorial Randomized Complete Block Design (RCBD) with three replications. The treatments involved two factors:

2.3.1 Factor A: Mungbean Varieties (V):

- V1: BARI Mung-6
- V2: BARI Mung-7
- V3: Binamoog-8

2.3.2 Factor B: P and Zn Fertilization Levels (F): (Based on a Recommended Dose of Fertilizer (RDF) of 80 kg P2O5/ha and 1 kg Zn/ha):

- F0: Control (0% RDF)
- F1: 75% RDF
- F2: 100% RDF (Recommended Dose)
- F3: 125% RDF
- F4: 150% RDF

Each treatment combination was randomly assigned to individual plots measuring 2 m x 1.5 m = 3.0 m2). The total number of plots was 3 Varieties x 5 Fertilization Levels x 3 Replications = 45 plots.

2.4 Data Collection

Data collection included growth parameters (plant height and dry weight at 30, 40, 50 days after sowing and at harvest), yield-contributing traits (number of primary branches per plant, pods per plant, pod length, seeds per pod, 1000-seed weight), yield parameters (grain and stover yield in t ha^{-1}, and harvest index calculated as grain yield divided by biological yield multiplied by 100), and seed quality attributes (germination percentage, seedling height, dry weight of seedling plant).

2.5 Data Analysis

Data on growth and yield components were collected from 10 randomly selected plants from the inner rows of each plot. Plant height and dry matter accumulation were recorded at three specific intervals (30, 40, and 50 Days After Sowing (DAS)) and at final physiological maturity. All collected data were analyzed using the Analysis of Variance (ANOVA) technique appropriate for the RCBD. Means were compared using the Duncan's Multiple Range Test (DMRT) at a 5% level of significance (0.05), using MSTAT-C.

3. Results

3.1 Growth Parameters

Significant variations were observed in plant height and dry weight among different mungbean varieties and combined P+Zn fertilization treatments across growth stages. Binamoog-8 (V3) consistently outperformed BARI Mung-6 (V1) and BARI Mung-7 (V2), with V2 showing the lowest growth values. At harvest, V3 reached the highest plant height (65.29 cm) and dry weight per plant (7.21 g). Increasing P+Zn levels positively influenced these parameters, with the highest values recorded under 150% of Recommended Dose (F4). The interaction between variety and fertilization was significant; notably, the V3F4 combination resulted in the tallest plants (71.08 cm) and highest dry weight (7.87 g), whereas the V2F0 combination had the lowest values (Table 1).

Table 1 : Combined effect of variety and phosphorus + zinc on plant height of mungbean

Treatments	Plant height (cm)			
	30 DAS	40 DAS	50 DAS	At harvest
V_1F_0	21.63 f	30.01 gh	39.95 hi	55.17 hi
V_1F_1	22.48 f	31.32 fg	41.52 g	60.05 ef
V_1F_2	24.28 d	33.75 e	44.25 e	62.12 de
V_1F_3	27.72 b	36.90 bc	47.53 c	66.13 c
V_1F_4	28.43 ab	37.70 b	48.92 b	67.83 bc
V_2F_0	19.27 g	26.37 i	38.07 j	51.74 j
V_2F_1	22.64 ef	29.47 h	39.18 ij	54.38 i
V_2F_2	23.54 de	32.85 e	40.88 gh	57.21 gh
V_2F_3	25.69 c	35.64 cd	45.24 de	62.51 d
V_2F_4	26.62 c	36.46 bcd	46.31 cd	63.12 d
V_3F_0	20.25 g	32.58 ef	40.81 gh	58.75 fg
V_3F_1	24.22 d	33.69 e	42.94 f	61.37 de
V_3F_2	26.27 c	35.24 d	46.70 c	66.38 c
V_3F_3	28.68 ab	39.40 a	50.81 a	68.88 ab
V_3F_4	29.43 a	40.60 a	51.37 a	71.08 a
$LSD_{0.05}$	1.024	1.402	1.293	2.296
CV(%)	5.56	7.46	10.25	8.22

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = BARI mung-6, V_2 = BARI mung-7, V_3 = Binamoog-8

F_0 = control (No P+Zn), F_1 = 75% of P+Zn, F_2 = RDF of P+Zn, F_3 = 125% of P+Zn, F_4 = 150% of P+Zn

3.2 Yield Contributing Parameters

Varietal differences, P+Zn treatments, and their interaction significantly affected yield attributes. Although the number of primary branches per plant and seeds per pod showed no significant varietal variation, Binamoog-8 exhibited significantly higher pods per plant (23.08), pod length (8.59 cm), and 1000-seed weight (48.79 g). The highest fertilization (F4) corresponded with maximal improvement in yield traits, often statistically comparable to 125% RDF (F3). Interactions between $V_3 \times F_4$ showed synergistic enhancement of nearly all measured yield components, as detailed in Tables 2.

Table 2 : Combined effect of variety and phosphorus + zinc levels on yield contributing parameters of mungbean

Treatments	Yield contributing parameters				
	No. of primary branches $plant^{-1}$	No. of pods $plant^{-1}$	Pod length (cm)	No. of seeds $pods^{-1}$	Weight of 1000 seeds (g)
V_1F_0	1.83 g	17.05 i	7.35 h	9.05 h	44.25 g
V_1F_1	2.15 f	19.03 g	7.65 g	9.22 h	45.01 fg
V_1F_2	2.57 e	22.08 e	7.83 fg	9.45 g	46.85 de
V_1F_3	3.23 c	24.38 c	8.97 c	10.45 c	48.85 c
V_1F_4	3.33 bc	25.21 bc	9.04 bc	10.80 b	49.15 bc
V_2F_0	1.73 g	16.81 i	6.91 j	8.36 j	41.59 h
V_2F_1	1.87 g	17.11 i	7.01 ij	8.42 j	42.08 h
V_2F_2	2.48 e	18.15 h	7.23 hi	8.75 i	42.59 h
V_2F_3	2.93 d	20.78 f	8.56 d	9.83 f	45.09 fg

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Table 2 (cont) : Combined effect of variety and phosphorus + zinc levels on yield contributing parameters of mungbean					
V_2F_4	3.22 c	21.37 ef	8.81 cd	10.02 e	45.55 efg
V_3F_0	2.13 f	19.60 g	7.95 ef	9.71 f	46.03 ef
V_3F_1	2.52 e	20.67 f	8.02 ef	10.12 de	47.78 cd
V_3F_2	2.89 d	23.07 d	8.16 e	10.23 d	48.01 cd
V_3F_3	3.43 ab	25.57 b	9.26 b	10.91 b	50.72 ab
V_3F_4	3.63 a	26.48 a	9.55 a	11.13 a	51.42 a
$LSD_{0.05}$	0.198	0.8512	0.259	0.183	1.616
CV(%)	4.45	6.40	3.27	5.10	8.09

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = BARI mung-6, V_2 = BARI mung-7, V_3 = Binamoog-8

F_0 = control (No P+Zn), F_1 = 75% of P+Zn, F_2 = RDF of P+Zn, F_3 = 125% of P+Zn, F_4 = 150% of P+Zn

3.3 Yield Parameters

Both variety and P+Zn fertilization significantly influenced grain and stover yields. Binamoog-8 produced the highest grain (1.46 t/ha) and stover yields (1.95 t/ha), outperforming other varieties, with BARI Mung-7 exhibited the lowest yields. Fertilizer application increased yields progressively, with F4 treatment giving the maximum grain (1.51 t/ha) and stover yields (1.97 t/ha). Interaction effects were significant, where the V3F4 combination achieved peak grain (1.66 t/ha) and stover (2.22 t/ha) yields, while V2F0 had the lowest. Harvest index values did not differ significantly among treatments but showed interaction trends in Table 3.

Table 3 : Combined effect of variety and phosphorus + zinc levels on yield parameters of mungbean			
Treatments	Yield parameters		
	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
V_1F_0	1.06 h	1.48 h	41.76 h
V_1F_1	1.15 fg	1.62 fg	41.47 h
V_1F_2	1.30 e	1.69 ef	43.44 bc
V_1F_3	1.38 d	1.75 de	44.08 a
V_1F_4	1.49 c	1.92 c	43.63 ab
V_2F_0	1.00 i	1.42 h	41.31 h
V_2F_1	1.11 gh	1.48 h	42.68 efg
V_2F_2	1.20 f	1.58 g	43.07 cde
V_2F_3	1.29 e	1.69 ef	43.29 bcd
V_2F_4	1.38 d	1.77 d	43.71 ab
V_3F_0	1.26 e	1.64 fg	43.45 bc
V_3F_1	1.36 d	1.82 d	42.75 efg
V_3F_2	1.46 c	1.99 c	42.28 g
V_3F_3	1.55 b	2.10 b	42.52 fg
V_3F_4	1.66 a	2.22 a	42.87 def
$LSD_{0.05}$	0.053	0.075	0.5018
CV(%)	6.16	7.26	6.32

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = BARI mung-6, V_2 = BARI mung-7, V_3 = Binamoog-8

F_0 = control (No P+Zn), F_1 = 75% of P+Zn, F_2 = RDF of P+Zn, F_3 = 125% of P+Zn, F_4 = 150% of P+Zn

3.4 Seed Quality Parameters

Significant varietal and fertilization effects were detected for seed germination, seedling height, and seedling dry weight. Binamoog-8 consistently showed superior seed quality, with highest germination (92.14%) and seedling height (5.31 cm). The highest fertilization level (F4) enhanced seed quality parameters, with the V3F4 treatment yielding maximal germination (95.81%) and seedling vigor. Lowest seed quality was observed in V2F0 (Table 4).

Table 4 : Effect of variety on seed quality parameters of mungbean			
Treatments	Seed quality parameters		
	Germination (%)	Seedling height (cm)	Dry weight of seedling $plant^{-1}$ (g)
V_1	91.59 a	4.63 b	0.23
V_2	89.44 b	3.56 c	0.22
V_3	92.14 a	5.31 a	0.25
$LSD_{0.05}$	1.725	0.164	0.047^{NS}
CV(%)	5.37	3.09	4.21

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

V_1 = BARI mung-6, V_2 = BARI mung-7, V_3 = Binamoog-8

3.5 Discussion

The findings of this study align closely with previous research demonstrating the positive effects of phosphorus and zinc fertilization on mungbean growth and yield. For instance, similar to our results, a study reported that increasing phosphorus and zinc levels significantly enhanced plant height, number of pods per plant, 1000-seed weight, and ultimately, grain and stover yields of mungbean (BARI Mug-6) (Ahmad et al., 2019). They observed maximum grain yields of approximately 1.53–1.94 t/ha under combined P (20–25 kg ha^{-1}) and Zn (4 kg ha^{-1}) applications, which parallels the 1.66 t/ha grain yield obtained in our best treatment (Binamoog-8 × 150% RDF) (Juniper Publishers, 2019). Likewise, the synergistic influence of combined P and Zn application on mungbean seed quality parameters, corroborating our findings of significantly improved germination rates and seedling vigor in fertilized treatments (Singh et al., 2023).

In contrast, lower yields and growth metrics under unfertilized or control treatments, as observed in our BARI Mung-7 without P+Zn, reflect the nutrient deficiency constraints documented by multiple studies (Oad et al. 2018; Mallik et al., 2018, Soykot, 2022). Our varietal comparison also supports the notion that genetic variability strongly governs nutrient use efficiency, consistent variable responses to micronutrient fertilization among mungbean cultivars (Hossain et al., 2017).

4. Conclusion

This study unequivocally demonstrates the pivotal role of varietal selection combined with phosphorus (P) and zinc (Zn) fertilization on optimizing mungbean growth, yield, and seed quality. Among the tested varieties, Binamoog-8 consistently showed superior agronomic performance, characterized by enhanced growth metrics, yield-contributing attributes, and the highest grain and stover yields compared to BARI Mung-6 and BARI Mung-7. The application of P and Zn proved indispensable for maximizing these traits, with the 150% P+Zn fertilization level yielding significant improvements across all measured parameters relative to lower doses and the unfertilized control. Importantly, the synergistic interaction between Binamoog-8 and the highest fertilizer rate (V3F4) produced the most favorable outcomes, including maximum plant height, biomass, seed yield (1.66 t/ha), and superior seed quality such as germination percentage. Conversely, BARI

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Mung-7 without P and Zn fertilization exhibited the poorest results. These findings provide compelling evidence that integrating high-performing cultivars with optimized P and Zn management is essential for sustainable intensification of mungbean production under similar agro-ecological conditions.

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