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# Zinc and Boron Foliar Application Effects on Primed Mung Bean (*Vigna radiata* L.) Growth and Productivity

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## ABSTRACT

Mung bean is recognized for its abundant high-quality protein content. For human consumption, it is a high-quality protein source and also serves various purposes crops, its harvested residue is used for green manuring and also used for fodder purposes. The research aimed to assess the impact of foliar micronutrient application on primed mung bean (*Vigna radiata*). The experimental procedures were executed in the sandy loam soil prevalent in the central plain region of Punjab. The investigation was conducted during the Zaid season 2022, focusing on the (SML-1827) mung bean variety. Specifically, the research assessed the impact of foliar micronutrient applications involving zinc and boron at 15 and 45 days after sowing (DAS) on primed mung bean growth characteristics. The experimental design employed a Randomized Block Design, incorporating 11 distinct treatment combinations, each replicated thrice. The investigation revealed that foliar micronutrient treatment on primed mung bean substantially influenced growth and yield parameters. Growth indicators for mung bean exhibited a positive trend when zinc and boron were jointly applied to primed seeds with gibberellic acid, followed by a decline in the control group, which experienced typical growth conditions devoid of growth regulators and micronutrients. Specifically, the highest recorded plant height was 70.1 cm in the T9 (GA(50 mg.L$^{-1}$) + $ZnSO_4$ (0.5%) + B (1%)) treatment, while the lowest height was 58 cm in the T0 (control) treatment. Similarly, the most significant fresh weight was observed in T9 (GA (50 mg.L$^{-1}$) + $ZnSO_4$ (0.5%)+ B (1%)) treatments at 136.8 g, with the lowest weight recorded in T0 (control) treatments at 86.6g. the most significant grain yield was achieved in T9 112 g.m$^{-2}$, followed by T10 (SA(150 mg.L$^{-1}$)+ $ZnSO_4$ (0.5%)+B (1%)) at 105.7 g.m$^{-2}$. This study suggests micronutrients and growth regulators can be sustainable agricultural inputs to enhance soil health and productivity.

## INTRODUCTION

Micronutrients play a pivotal role in human health, plant growth, and agricultural development, with documented significance (Ahmad et al. 2022, Haider et al. 2022). All crops require micronutrients in small quantities for optimal growth and productivity (Nasiri et al. 2010). The global issue of micronutrient deficiency is particularly acute in underdeveloped nations (FAO 2017). Analyzing the nutritional composition of mung bean seeds reveals 367 mg phosphorus and 132 mg calcium per 100 g of seeds, accompanied by 50% carbohydrates, 26% protein, 4%-5% ash, 3%-4.5% fiber, and 3% lipids (Ahmed et al. 2000). Mung bean sprouts are notably rich in vitamin C (8 mg per 100 g). They are typically cultivated in semi-arid and arid climates (Haider et al. 2021). Mung beans boast a protein content of 25%, a carbohydrate content of 59.9%, and notable levels of lysine (460 mg.g$^{-1}$) and tryptophan (60 mg.g$^{-1}$). Sprouted mung beans exhibit significant quantities of ascorbic acid, riboflavin (0.21 mg per 100 g), minerals (3.84 g per 100 g), and calcium (75 mg per 100 g). Zinc insufficiency affects approximately 2 billion individuals globally (Gibson 2012) and ranks as the fifth leading cause of mortality in underdeveloped countries and the eleventh globally (Stevens et al. 2009). In Pakistan, around 33% of children and 40% of mothers experience zinc insufficiency, primarily in rural regions. Iron deficiency is another global concern impacting approximately 2 billion people, predominantly children and women, in Latin America, South Asia, and Africa (Glahn et al. 2021). Roughly 40% of women of reproductive age in South Asia are anaemic, accounting for 37.5% of all anaemic cases worldwide. In South America, the Caribbean, and Central America, approximately 46.2%, 42.9%, and 33.9% of the population are anemic, with a higher prevalence among children under 11 months (Hummel et al. 2020). In 2018-19, India cultivated mung beans over 4.1 million hectares, yielding 1.9 million tonnes with a productivity of 463 kg per hectare (Gowda et al. 2015). Major mung bean-producing states include Orissa, Maharashtra, Andhra Pradesh, Telangana, Madhya Pradesh, Karnataka, and Uttar Pradesh, with Orissa leading in acreage, output, and productivity, followed by Maharashtra and Andhra Pradesh in area and production. To meet the agricultural demands of the nation, the cultivation and production of agricultural seeds must be expanded (Alshikh 2019). Mung bean, classified as an annual vine with yellow blossoms and fuzzy brown pods, is further categorized into three subspecies, with *Vigna radiata* subsp. radiata being the cultivated variety. The plant ranges in height from 15 to 125 cm and boasts a robust root system characterized by numerous slender lateral roots and root nodules. The stems are densely branched, and exhibit twining at their tips, with young stems appearing purple or green and aging stems taking on a greyish-yellow or brown hue. Mung beans are predominantly self-pollinating, and their fruits are elongated cylindrical or flat cylindrical pods, typically yielding 30 to 50 pods per plant. According to Mina (2015), these pods measure 5-10 cm in length and 0.4-0.6 cm in width, containing 12-14 seeds separated by septa. Seed priming is a fundamental physiological approach for enhancing seed performance, facilitating swifter and more synchronized germination, and ultimately contributing to increased crop yield. Various methods encompass priming with chemicals, antioxidants, and hormones, guarding against cell death in the apical meristem, especially DNA damage (Hussain et al. 2016). Boron, vital for processes like cell wall construction, maintenance of biological membrane integrity, and the efficient transfer of sugar or energy to fuel plant growth (Qamar et al. 2016), becomes critical in the event of a boron deficiency. Such a deficiency hinders growth, reduces the root-to-shoot ratio, and limits essential nutrients such as phosphorus, potassium, and iron levels in plant roots and shoots (Broadley et al. 2012). Mung beans are a notable source of lysine, an amino acid often deficient in grains (Ntatsi et al. 2018). Despite the numerous advantages in crop management and nutritional value, the cultivation and production of mung beans are not expanding at the same pace as other cereals. Zinc sulfate treatment has been observed to enhance pod count per plant, seed output, and the vegetative growth of legumes (Singh et al. 2015). Gibberellic acid (GA3) has the potential to induce morphological and yield-related changes in various legume crops, including soybeans and mung beans (Sardoei et al. 2014). As a plant growth regulator, GA3 is increasingly important in agriculture for increasing production. Gibberellin seed priming is pivotal in influencing multiple aspects of plant life, including seed germination, leaf expansion, phloem loading, water, and mineral uptake, assimilate transportation, and yield index (Pasala et al. 2016). Salicylic acid may also play a crucial role in regulating plant development. Priming seeds with hormones mitigates the adverse effects of various environmental stressors, facilitating accelerated germination and improved seedling establishment. Consequently, such primed seeds exhibit increased resilience to soil-borne pests and diseases (Movaghatian et al. 2013).

## MATERIAL AND METHODS

The impact of zinc and boron foliar treatment on the growth-primed Mung bean (salicylic acid gibberellin) was studied at the farm of the Department of Agronomy, Lovely Professional University, Phagwara, Kapurthala district. A study trial was conducted in the Zaid season of 2022 in that area, which has a sub-tropical environment in the middle plains of Punjab. The study used a randomized block design (RBD) and was duplicated three times for each therapy. The crop was harvested on May 17th, 2022, after it was sown on March 9th, 2022. Each plot's dimensions were set at 5m x 3m. The farm, 252 meters above mean sea level and 20 km from Jalandhar, Punjab, is between 31.24 North latitude and 75.6909 East latitude. The soil in the region is sandy loamy to clay-textured, with a pH range of 7.8 to 8.5. The existing location is classified as part of the Trans-Gangetic Agro-climatic Zone. It receives 527.1 mm of rain per year on average.

### Plant Genetic Material

Summer mung bean cultivar SML 1827 features an upright and determinate plant type with medium size. It bears pods in clusters and matures synchronously (in approximately 62 days). Each pod contains roughly ten seeds. It is resistant to yellow mosaic disease. Grains are bright green and medium in size, with good culinary characteristics. It produces 5.0 quintals per acre on average.

### Experimental Treatments

The study comprised six hours of seed priming before planting with salicylic acid at 150 $mg.L^{-1}.kg^{-1}$ seed and gibberellin at 50 $mg.L^{-1}.kg^{-1}$ seed as a plant growth regulator. Zinc and boron foliar applications were administered 15 and 45 days after seeding. T0 is the control, T1 is the GA (50 $mg.L^{-1}$), T2 is the SA (150 $mg.L^{-1}$), T3 is the $ZnSO_4$ (0.5%), T4 is the B (1%), T5 is the GA (50 $mg.L^{-1}$) + $ZnSO_4$ (0.5%), T6 is the GA (50 $mg.L^{-1}$) + B (1%), T7 is the SA (150 $mg.L^{-1}$) + $ZnSO_4$ (0.5%), T8: SA (150 $mg.L^{-1}$) + B (1%), T9: GA (50 $mg.L^{-1}$) + $ZnSO_4$ (0.5%) + B (1%), T10: SA (150 $mg.L^{-1}$) + $ZnSO_4$ (0.5%) + B (1%). The observations were made at 30, 60, and at harvest following seeding, as well as at harvesting.

### Fertilizers

In the current study, the suggested fertilizer dose for summer moong was 5 kilograms N (11 kg urea) and 16 kg $P_2O_5$ (100 kg single superphosphate) per acre. Nitrogen is applied when planting, and a single superphosphate is utilized as a potassium supplement during sowing.

Plant height, fresh weight, dry weight, number of branches, nodule count, Chl a, Chl b, total soluble sugar, and grain yield were recorded on time.

### Data Collection

**Plant height:** In each plot, the final plant height was measured using a measuring scale, the height of three randomly selected plants was estimated at 30DAS, 60DAS, and at harvest, and observations were gathered. The mean of these three plants was calculated and analyzed using the OPSTAT and SPSS software packages.

**Number of branches:** The number of branches was counted at 30 and 60 DAS from three randomly selected plants in each plot and averaged.

**Number of nodules:** Three plants were randomly removed from the observation plot using a fork without injuring the roots at the Mung bean flowering and harvesting stages. The roots were gently cleansed to eliminate any dirt that had adhered to them, and nodules were counted.

**Fresh and dry weight:** Four Mung bean plants were picked from each batch independently for fresh and dry weight calculations. Following fresh weight measurement, the tissues were placed in a hot air oven at 50°C for two days, followed by three days at 60°C, and dried plant weight was recorded at 30 DAS, 60 DAS, and at harvest (Zhang et al. 2016).

**Chl a and Chl b:** The chlorophyll content in the leaf of mung bean was estimated by the method of Arnon DI. (1949) at 30 and 60DAS. The absorbance was measured at 645 nm and 663 nm. The amount of chlorophyll was calculated using the absorbance coefficient.

$$\text{Chlorophyll 'a' (mg/g Fresh Weight)} = 12.25(A663)-2.79(A645) \times \frac{V}{1000 \times W}$$

$$\text{Chlorophyll 'b' (mg/g Fresh Weight)} = 21.50(A645)-5.10(A663) \times \frac{V}{1000 \times W}$$

where V = Final volume of the extract

W = Fresh weight of the leaves

A = absorbance at a specific wavelength.

**Total soluble sugar:** The method developed by Sadasuvam & Manickam (1992) was followed. Total soluble sugar was estimated in the leaf of mung bean at 30 and 60DAS. Absorbance was measured at 620 nm with the help of a spectrophotometer.

**Grain yield:** After harvesting weight of grains was measured by weighing balance.

**Statistical analysis**: The statistical analysis of the data variance was performed using R software with Duncan 's multiple range test (DMRT) with a probability $p<0.05$. The means of all treatments were compared.

Table 1: Effect of foliar application of zinc and boron on primed mung bean Plant height and Fresh Weight during Summer 2022.

| Treatments | Plant Height | | | Fresh Weight | | |
|---|---|---|---|---|---|---|
| | 30DAS | 60DAS | At Harvest | 30DAS | 60DAS | At Harvest |
| T0 Control | 11.00$^{h}$± 0.50 | 54.83$^{g}$± 2.25 | 54.83$^{h}$± 3.00 | 10.80$^{f}$± 1.51 | 63.16$^{g}$± 2.69 | 86.60$^{i}$± 3.65 |
| T1 GA (50 mg.L$^{-1}$) | 11.17$^{h}$± 0.76 | 57.67$^{ef}$± 2.25 | 58.00$^{g}$± 1.89 | 12.89$^{de}$± 1.58 | 68.63$^{f}$± 12.23 | 94.06$^{h}$± 3.80 |
| T2 SA [150 mg.L$^{-1}$] | 11.50$^{gh}$± 0.50 | 57.00$^{f}$± 2.00 | 60.83$^{ef}$± 2.75 | 11.98$^{ef}$1.77± | 65.96$^{fg}$± 3.55 | 88.16$^{i}$± 3.15 |
| T3 $ZnSO_4$ [0.5%] | 12.83$^{ef}$±0.76 | 58.33$^{def}$± 2.51 | 60.33$^{f}$± 4.50 | 14.07$^{cd}$± 1.17 | 81.40$^{e}$± 3.15 | 105.00$^{g}$± 4.05 |
| T4 B [1%] | 12.17$^{fgh}$±.076 | 57.00$^{f}$± 2.00 | 62.67$^{de}$± 3.25 | 12.66$^{de}$± 0.41 | 78.50$^{e}$± 3.05 | 103.30$^{g}$± 4.03 |
| T5 GA [50 mg.L$^{-1}$] + $ZnSO_4$ [0.5%], | 14.83$^{bc}$± 1.04 | 61.00$^{c}$± 2.50 | 61.67$^{def}$± 2.25 | 18.63$^{a}$± 2.25 | 111.40$^{b}$± 3.61 | 127.93$^{c}$± 5.44 |
| T6 GA [50 mg.L$^{-1}$] + B [1%] | 13.50$^{de}$± 1.32 | 59.17$^{cde}$± 2.02 | 66.83$^{b}$± 3.01 | 13.03$^{de}$± 0.30 | 104.66$^{c}$± 4.31 | 115.76$^{e}$± 4.10 |
| T7 SA [150 mg.L$^{-1}$] + $ZnSO_4$ [0.5%] | 14.50$^{cd}$± 1.32 | 60.17$^{cd}$± 1.75 | 65.17$^{bc}$± 2.50 | 14.86$^{c}$± 0.35 | 90.00$^{d}$± 3.60 | 122.00$^{d}$± 4.51 |
| T8 SA [150 mg.L$^{-1}$] + B (1%) | 12.50$^{efg}$± 0.50 | 58.33$^{def}$± 2.51 | 66.00$^{b}$± 1.72 | 14.21$^{cd}$± 1.85 | 81.10$^{e}$± 3.70 | 110.16$^{f}$± 3.81 |
| T9 GA [50 mg.L$^{-1}$] + $ZnSO_4$ [0.5%] + B [1%] | 16.50$^{a}$± 0.86 | 65.17$^{a}$± 2.25 | 63.23$^{cd}$± 0.76 | 17.38$^{ab}$± 2.59 | 119.93$^{a}$± 4.85 | 136.86$^{a}$± 6.15 |
| T10 SA [150 mg.L$^{-1}$] + $ZnSO_4$ [0.5%] + B [1%] | 15.83$^{ab}$± 0.76 | 63.00$^{b}$± 1.73 | 70.17$^{a}$± 1.50 | 16.47$^{b}$± 0.33 | 112.66$^{b}$± 3.75 | 131.93$^{b}$± 5.61 |
| CD | 1.30 | 3.50 | 3.98 | 2.48 | 8.12 | 7.83 |

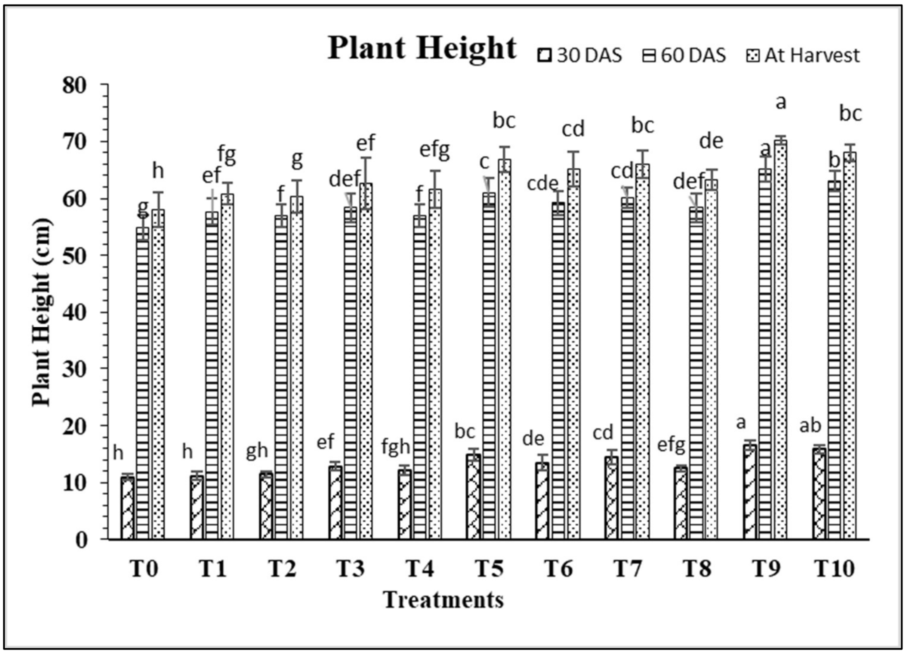


Fig. 1: Effect of foliar application of zinc and boron on primed mung bean plant height at 30, 60DAS and at harvest.

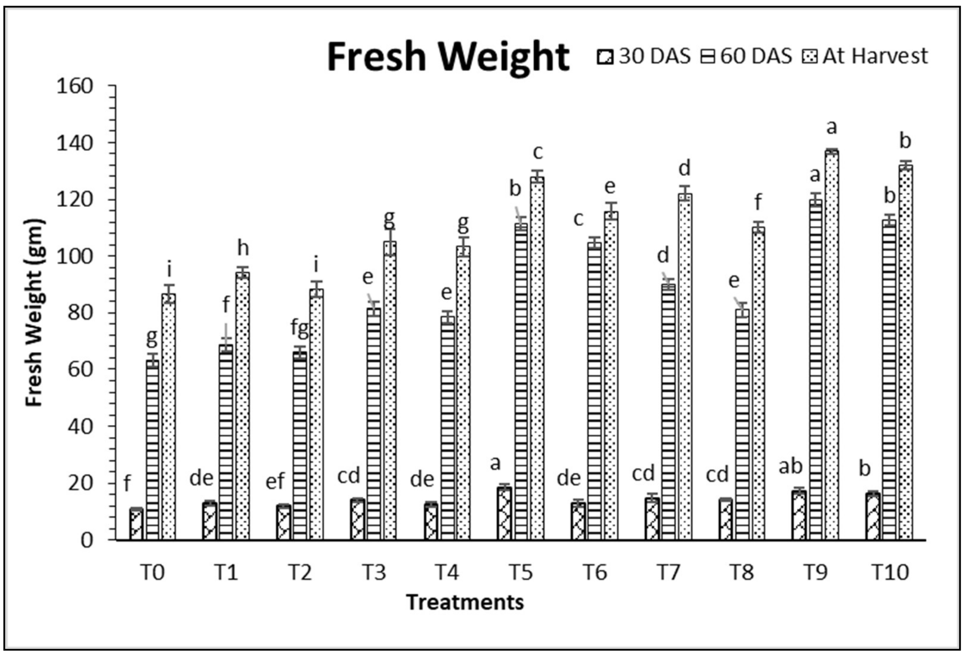


Fig. 2: Effect of foliar application of zinc and boron on primed mung bean fresh weight at 30, 60DAS and harvest.

## RESULTS AND DISCUSSION

This study investigated the impact of varying foliar spray treatments on the height of primed mung bean plants at different stages. At 30 days after sowing (30DAS), the tallest and shortest plants, measuring 16.5 cm and 11 cm, were observed in the T9 treatment (comprising GA (50 mg.L$^{-1}$), $ZnSO_4$ (0.5%), and B (1%)) and the control treatment (T0), respectively. Subsequently, at 60 days after sowing (60DAS), the tallest plant height was recorded in T9 (65.1 cm) and the control (T1) at 54.8cm shown in Table 1. At harvest, the

Table 2: Effect of foliar application of zinc and boron on primed mung bean Dry weight (gm $plant^{-1}$) and Number of Branches during Summer 2022.

| Treatments | Dry Weight | | | Number of Branches | |
|---|---|---|---|---|---|
| | 30DAS | 60DAS | At Harvest | 30DAS | 60DAS |
| T0 Control | $3.56^{d} \pm 0.20$ | $19.74^{f} \pm 0.84$ | $27.93^{h} \pm 1.18$ | $2.00^{c} \pm 0$ | $4.66^{d} \pm 0.58$ |
| T1 GA [50 $mg.L^{-1}$] | $3.96^{cd} \pm 0.15$ | $21.44^{f} \pm 3.82$ | $30.34^{g} \pm 1.22$ | $2.67^{bc} \pm 0.58$ | $5.33^{cd} \pm 0.58$ |
| T2 SA [150 $mg.L^{-1}$] | $3.93^{cd} \pm 0.15$ | $20.61^{f} \pm 1.11$ | $28.44^{h} \pm 1.01$ | $2.67^{bc} \pm 0.58$ | $5.00^{d} \pm 0$ |
| T3 $ZnSO_4$ [0.5%] | $4.40^{bc} \pm 0.29$ | $25.43^{e} \pm 0.98$ | $33.87^{f} \pm 1.30$ | $3.00^{ab} \pm 0$ | $5.66^{bcd} \pm 0.58$ |
| T4 B [1%] | $4.36^{bcd} \pm 0.30$ | $24.53^{e} \pm 0.95$ | $33.32^{f} \pm 1.30$ | $2.67^{bc} \pm 0.58$ | $5.33^{cd} \pm 0.58$ |
| T5 GA [50 $mg.L^{-1}$] + $ZnSO_4$ [0.5%], | $5.10^{ab} \pm 0.20$ | $34.81^{b} \pm 1.13$ | $41.26^{b} \pm 1.75$ | $3.33^{ab} \pm 0.58$ | $6.33^{abc} \pm 0.58$ |
| T6 GA [50 $mg.L^{-1}$] + B [1%] | $4.03^{cd} \pm 0.15$ | $32.70^{c} \pm 1.34$ | $37.34^{d} \pm 1.32$ | $3.33^{ab} \pm 0.58$ | $6.33^{abc} \pm 0.58$ |
| T7 SA [150 $mg.L^{-1}$] + $ZnSO_4$ [0.5%] | $4.43^{bc} \pm 0.35$ | $28.12^{d} \pm 1.12$ | $39.35^{c} \pm 1.45$ | $3.33^{ab} \pm 0.58$ | $6.33^{abc} \pm 0.58$ |
| T8 SA [150 $mg.L^{-1}$]+ B [1%] | $4.39^{bc} \pm 0.59$ | $25.34^{e} \pm 1.15$ | $35.53^{e} \pm 1.22$ | $3.00^{ab} \pm 0$ | $5.66^{bcd} \pm 0.58$ |
| T9 GA [50 $mg.L^{-1}$] + $ZnSO_4$ [0.5%] + B [1%] | $5.37^{a} \pm 0.55$ | $37.47^{a} \pm 1.51$ | $44.15^{a} \pm 1.98$ | $3.67^{a} \pm 0.58$ | $7.00^{a} \pm 0$ |
| T10 SA (150 $mg.L^{-1}$] + $ZnSO_4$ [0.5%] + B [1%] | $5.26^{a} \pm 0.30$ | $35.20^{b} \pm 1.17$ | $42.55^{b} \pm 1.81$ | $3.67^{a} \pm 0.58$ | $6.66^{ab} \pm 0.58$ |
| CD | 0.49 | 2.52 | 2.53 | 0.63 | 0.92 |

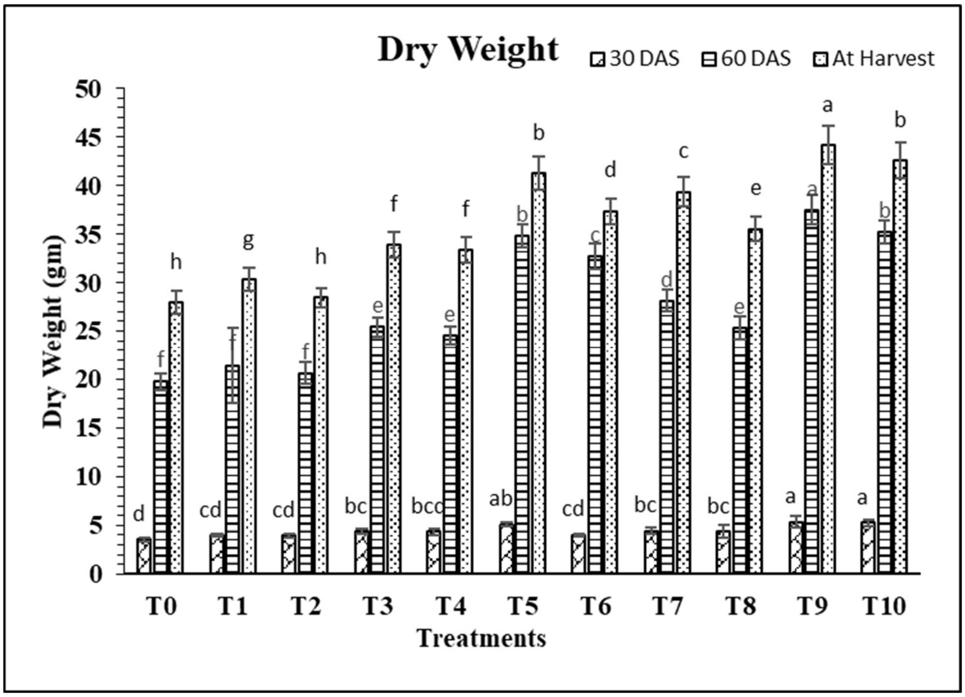


Fig. 3: Effect of foliar application of zinc and boron on primed mung bean dry weight at 30 and 60 DAS.

most significant plant height was achieved in T9 (70.1cm), followed by T10 (SA(150 $mg.L^{-1}$)+ $ZnSO_4$ (0.5%)+B (1%)) at 68cm, while T0 (control) had a height of 58 cm (Table 1 and Fig. 1). It is noteworthy that GA3 priming primarily influences the elongation of tissues with rapid growth, such as stems, petioles, and flower inflorescences (Ayala-Silva et al. 2005). Ross et al. (2003) reported that GA3 promotes stem elongation, contributing to improved plant height. Increased plant height corresponds to heightened vegetative growth, conversely. Boron plays a role in metabolism and increases photosynthetic rates, often resulting in greater mature plant height (Kaisher et al. 2010). In contrast, zinc supplementation significantly enhanced the growth and height of Mung bean plants (Gobarah et al. 2006).

In treatment T9 (comprising GA(50 $mg.L^{-1}$), $ZnSO_4$ (0.5%), and B (1%)) and the control group (T0), we observed

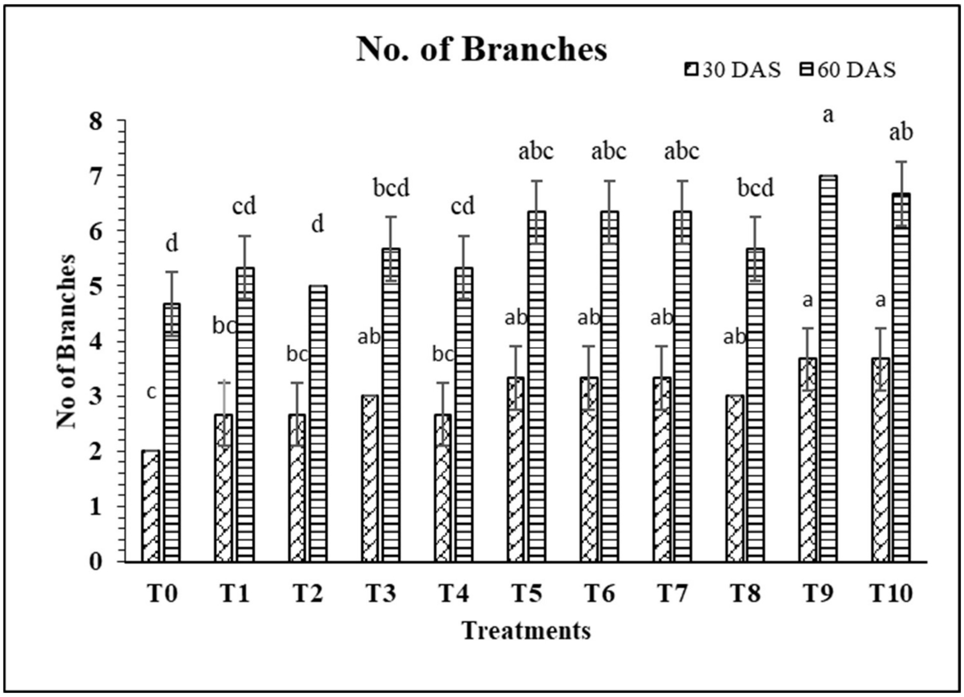


Fig. 4: Effect of foliar application of zinc and boron on primed mung bean branches at 30 and 60 DAS.

variations in the fresh weight of mung bean plants. The highest fresh weight recorded was 17.38g in T9, while the lowest was 10.8 g in the control (T0) 30 days after sowing (30DAS). At 60 days after sowing (60DAS), the maximum fresh weight reached 119.9 g in T9 and 63.1 g in T0 shown in Table 1. At harvest, the highest fresh weight was 136.8 g in T9, followed by 131.9 g in T10 (SA(150 mg.$L^{-1}$) + $ZnSO_4$ (0.5%) + B (1%)), with the lowest at 86.6g in the control (T0) (Table 1 and Fig. 2). Plant growth parameters, including stem and overall fresh weight, exhibited variability due to different foliar applications and treatment types. Rahman et al. (2018) reported that foliar application of GA3 significantly enhanced plant growth. They observed an increase in leaf area and fresh weight in *Vigna radiata*, concluding that GA3, combined with zinc or boron as foliar applications, provided substantial benefits for achieving greater leaf area, ultimately enhancing plant fresh weight.

Regarding dry weight, T9 (GA(50 mg.$L^{-1}$) + $ZnSO_4$ (0.5%)+ B (1%)) had the highest dry weight at 5.37 g, while T1 (control) had the lowest at 3.56 g, as depicted in Table 2 and Fig. 3. The maximum dry weight at harvest was 44.15 g in T9, followed by 42.52 g in T10 [SA (150 mg.$L^{-1}$) + $ZnSO_4$ (0.5%) + B (1%)] (Table 2 and Fig. 3). Salam et al. (2005) reported that micronutrients, particularly zinc and boron, significantly influenced the accumulation of dry matter, resulting in increased plant biomass, pod and seed production, and other growth-related parameters.

At 30 days after sowing (30DAS), the highest and lowest number of branches per plant were observed in T9 (GA (50 mg.$L^{-1}$) + $ZnSO_4$ (0.5%)+ B (1%)) and the control group (T0), with 3.6 and 2 branches, respectively. At 60 days after sowing (60DAS), the maximum number of branches was 7 in T9, followed by 6.6 in T10 (SA(150 mg.$L^{-1}$) + $ZnSO_4$ (0.5%)+B (1%)), and the control (T0) had 4.6 branches (Table 2 and Fig. 4). Zinc treatments have been known to enhance growth characteristics in various crops, as reported by Jain & Dahama (2007), Sharma & Abraham (2010), Dubey et al. (2013), and Khalil & Prakash (2014). In *Phaseolus vulgaris*, soil and foliar applications of zinc substantially increased plant height, branch count, radiation use efficiency, and extinction coefficient, according to studies by Necat et al. (2004) and Nasri et al. (2011).

At 30 days after sowing (30DAS), the highest and lowest numbers of nodules in mung bean roots were observed in T9 (GA(50 mg.$L^{-1}$) + $ZnSO_4$ (0.5%)+ B (1%)) and the control group (T0), with 21.3 and 13 nodules, respectively. At 60 days after sowing (60DAS), the maximum number of nodules was recorded in T9, followed by 35.6 in T10 (SA(150 mg.$L^{-1}$)+ $ZnSO_4$ (0.5%)+B (1%)), and the control (T0) had 22 nodules (Table 3 and Fig. 5). Das et al. (2012) found that combining various micronutrients resulted in increased nodulation. Inversely proportional to nitrogen fixation: as nodule number increases, nitrogen fixation decreases. There is an evident correlation between N-fixation and

Table 3: Effect of foliar application of zinc and boron on primed mung bean number of nodules and Chl a, b ($mg.g^{-1}$ FW) during Summer 2022.

| Treatments | Number of Nodules | | Chlorophyll "a" | | Chlorophyll "b" | |
|---|---|---|---|---|---|---|
| | 30DAS | 60DAS | 30DAS | 60DAS | 30DAS | 60DAS |
| T0 Control | $13^{f}$± 1.00 | $22^{g}$± 3.00 | $4.43^{e}$± 0.70 | $8.58^{f}$± 0.10 | $1.33^{c}$± 0.24 | $2.11^{d}$± 0.17 |
| T1 GA [50 $mg.L^{-1}$] | $15^{de}$± 1.00 | $24.66^{fg}$± 3.51 | $5.46^{de}$± 0.85 | $9.28^{def}$± 0.29 | $1.62^{bc}$± 0.26 | $2.43^{bcd}$± 0.59 |
| T2 SA [150 $mg.L^{-1}$] | $14^{ef}$± 2.00 | $25.66^{ef}$± 3.51 | $4.73^{de}$± 0.08 | $8.99^{ef}$± 0.37 | $1.55^{bc}$± 0.39 | $2.31^{cd}$± 0.58 |
| T3 $ZnSO_4$ [0.5%] | $17.66^{bc}$2.51± | $27.33^{de}$± 3.51 | $5.28^{de}$± 1.73 | $9.49^{cdef}$± 0.28 | $1.94^{bc}$± 0.16 | $2.77^{abcd}$± 0.25 |
| T4 B [1%] | $16.66^{cd}$± 2.08 | $26.33^{def}$± 3.51 | $5.18^{de}$± 1.11 | $9.33^{def}$± 0.20 | $1.79^{bc}$± 0.06 | $2.79^{abcd}$± 0.52 |
| T5 GA [50 $mg.L^{-1}$] + $ZnSO_4$ [0.5%], | $17.66^{bc}$± 1.52 | $33.66^{b}$± 3.05 | $7^{bc}$± 1.82 | $10.71^{ab}$± 0.28 | $2.33^{b}$± 0.51 | $3.15^{abc}$± 0.58 |
| T6 GA [50 $mg.L^{-1}$] + B [1%] | $16.33^{cd}$± 2.51 | $30.66^{c}$± 3.05 | $5.85^{cde}$± 0.25 | $10.3^{abcd}$± 0.17 | $2.41^{b}$± 0.35 | $2.63^{bcd}$± 0.35 |
| T7 SA [150 $mg.L^{-1}$] + $ZnSO_4$ [0.5%] | $17.66^{bc}$± 2.08 | $30.33^{c}$± 3.51 | $6.1^{bcd}$± 0.21 | $10.44^{abc}$± 0.44 | $2.42^{b}$± 0.35 | $3.16^{abc}$± 0.40 |
| T8 SA [150 $mg.L^{-1}$] + B (1%) | $17^{c}$± 2.00 | $28.66^{cd}$± 2.51 | $5.59^{cde}$± 0.84 | $9.94^{bcde}$± 0.49 | $1.96^{bc}$± 0.71 | $2.97^{abcd}$± 0.35 |
| T9 GA [50 $mg.L^{-1}$] + $ZnSO_4$ [0.5%] + B [1%] | $21.33^{a}$± 2.51 | $37.66^{a}$± 3.51 | $8.76^{a}$± 1.12 | $11.15^{a}$± 0.99 | $3.28^{a}$± 0.13 | $3.72^{a}$± 0.54 |
| T10 SA [150 $mg.L^{-1}$] + $ZnSO_4$ [0.5%] + B [1%] | $19.33^{b}$± 3.05 | $35.66^{ab}$± 3.05 | $7.39^{b}$± 0.42 | $10.93^{ab}$± 1.28 | $2.3^{b}$± 0.68 | $3.41^{ab}$± 0.87 |
| CD | 2.91 | 5.72 | 1.76 | 0.93 | 0.69 | 0.78 |

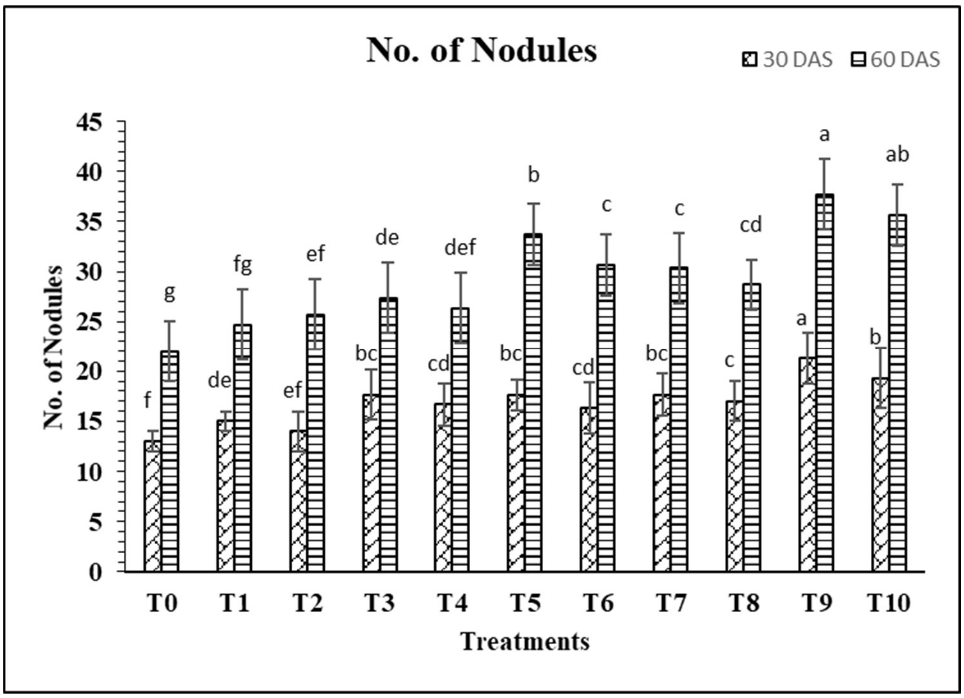


Fig. 5: Effect of foliar application of zinc and boron on primed mung bean nodules number at 30 and 60 DAS.

protein synthesis in mung bean plants. Combining B and Zn increased the rate of root nodulation and, consequently, the protein content of cereals by a substantial margin, according to the findings. Increased nodule counts and desiccated weight were observed as a consequence of micronutrient treatment (Tripathi et al. 2012).

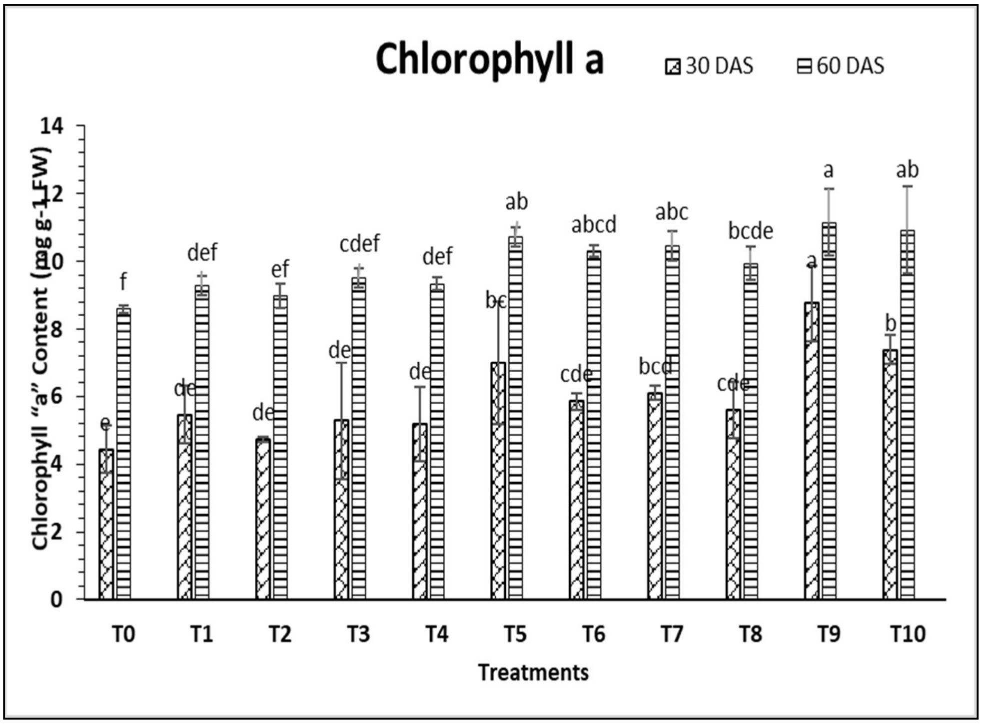


Fig. 6: Effect of foliar application of zinc and boron on primed mung bean Chlorophyll "a" mg.g$^{-1}$ FW at 30 and 60 DAS.

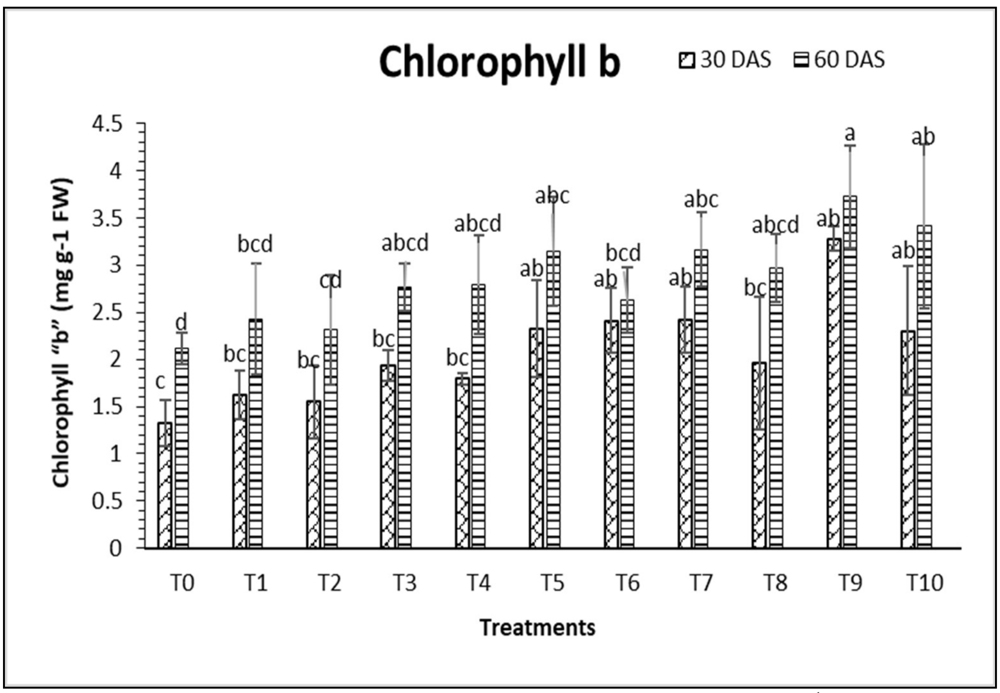


Fig. 7: Effect of foliar application of zinc and boron on primed mung bean Chlorophyll "b" mg.g$^{-1}$ FW at 30 and 60 DAS.

In the plant leaves, the content of chlorophyll a raised when the foliar application of $ZnSO_4$ (0.5%) and B (1%) in a primed seed with gibberellic acid (T9) done, then the content of chlorophyll "a" was raised by 8.7, and 11.14 mg.g$^{-1}$ FW at 30 and 60DAS in respect to controlled treatment (T0) (Table 3 and Fig. 6). At 30 days after sowing (30DAS),

Table 4: Effect of foliar application of zinc and boron on primed mung bean Total Soluble Sugar (mg.g$^{-1}$ FW) and Grain Yield (g.m$^{-2}$) during Summer 2023.

| Treatments | Total Soluble Sugar | | Grain Yield (g.m$^{-2}$) |
|---|---|---|---|
| | 30DAS | 60DAS | Harvest |
| T0 Control | $0.47^{b}\pm 0.06$ | $0.82^{e}\pm 0.08$ | $89.93^{f}\pm 4.12$ |
| T1 GA [50 mg.L$^{-1}$] | $0.53^{b}\pm 0.03$ | $1^{cde}\pm 0.17$ | $92.67^{f}\pm 3.72$ |
| T2 SA [150 mg.L$^{-1}$] | $0.52^{b}\pm 0.04$ | $0.96^{de}\pm 0.06$ | $90.8^{f}\pm 8.95$ |
| T3 $ZnSO_4$ [0.5%] | $0.59^{b}\pm 0.15$ | $1.24^{bcde}\pm 0.06$ | $96.13^{de}\pm 3.61$ |
| T4 B [1%] | $0.59^{b}\pm 0.05$ | $1.14^{cde}\pm 0.07$ | $93.07^{ef}\pm 6.44$ |
| T5 GA [50 mg.L$^{-1}$] + $ZnSO_4$ [0.5%], | $0.85^{ab}\pm 0.09$ | $1.63^{abc}\pm 0.15$ | $103.73^{bc}\pm 4.84$ |
| T6 GA [50 mg.L$^{-1}$] + B (1%) | $0.73^{ab}\pm 0.06$ | $1.38^{abcde}\pm 0.13$ | $101.2^{c}\pm 6.44$ |
| T7 SA [150 mg.L$^{-1}$] + $ZnSO_4$ [0.5%] | $0.82^{ab}\pm 0.09$ | $1.52^{abcd}\pm 0.21$ | $101.73^{c}\pm 4.77$ |
| T8 SA [150 mg.L$^{-1}$] + B (1%) | $0.69^{ab}\pm 0.11$ | $1.31^{bcde}\pm 0.07$ | $97.47^{d}\pm 6.63$ |
| T9 GA [50 mg.L$^{-1}$] + $ZnSO_4$ [0.5%] + B [1%] | $1.05^{a}\pm 0.02$ | $1.95^{a}\pm 0.24$ | $112.93^{a}\pm 5.28$ |
| T10 SA [150 mg.L$^{-1}$] + $ZnSO_4$ [0.5%] + B (1%) | $0.87^{ab}\pm 0.06$ | $1.78^{ab}\pm 0.47$ | $105.73^{b}\pm 6.82$ |
| CD | 0.13 | 0.31 | 10.09 |

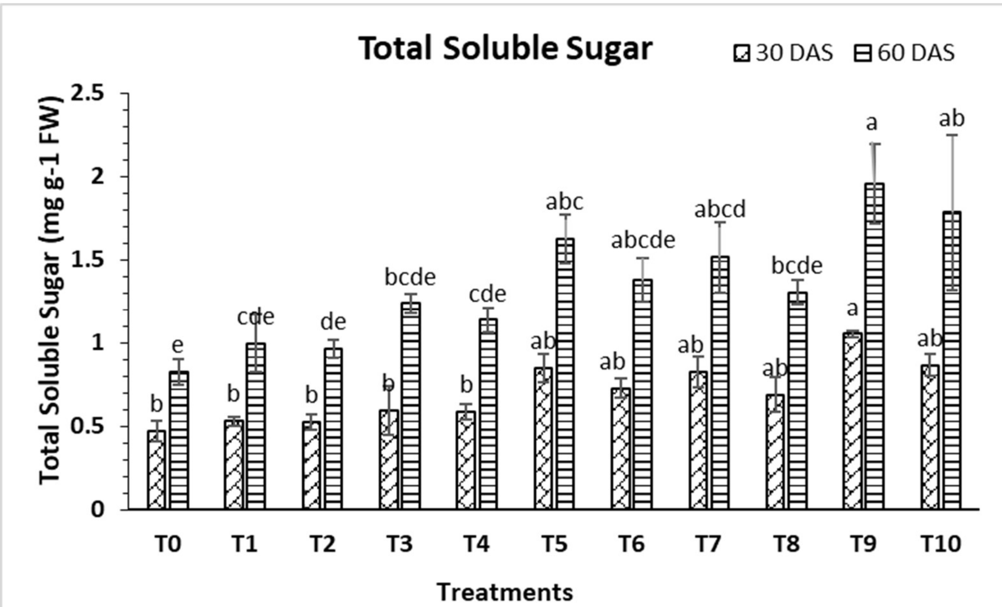


Fig. 8: Effect of foliar application of zinc and boron on primed mung bean total soluble sugar mg.g$^{-1}$ FW at 30 and 60 DAS.

The maximum content of chlorophyll "b" was observed in treatment T9, followed by 2.3 in T10 (SA(150 mg.L$^{-1}$)+ $ZnSO_4$ (0.5%)+B (1%)). The control (T0) had 1.3 mg.g$^{-1}$ (FW) (Table 3 and Fig. 7). At 60DAS highest content of chlorophyll "a" was 7 mg.g$^{-1}$ fresh leaf of mung bean plant observed in treatment T9 (GA(50 mg.L$^{-1}$)+ $ZnSO_4$ (0.5%)+ B (1%)) as compared to control treatment T0 4.67. Enhanced chlorophyll formation and plant cell division may contribute to an increase in leaf chlorophyll content. This finding is supported by Shah et al. (2012) and Khan et al. (2009). In contrast, Soheil et al. (2011) reported that zinc supplementation increased the levels of chlorophyll a, chlorophyll b, carotenoids, and protein in soybeans.

At 30 days after sowing (30DAS), the maximum total soluble sugar in mung bean plant leaves was observed in T9 (GA(50 mg.L$^{-1}$)+ $ZnSO_4$ (0.5%)+ B (1%)) and the control group (T0), with 1.05 and 0.47 mg.g$^{-1}$ FW (fresh weight) shown in Table 4, respectively. At 60 days after sowing (60DAS), the maximum total soluble sugar was 1.95 in T9, followed by 1.78 in T10 (SA(150 mg.L$^{-1}$)+ $ZnSO_4$ (0.5%)+B (1%), and the control (T0) had 0.82 mg.g$^{-1}$ FW (fresh weight) (Table 4 and Fig. 8). The result supported by Islam et al. (2021), Ahmad et al. (2021), Kaur et al. (2023). The promotion of seed germination and early

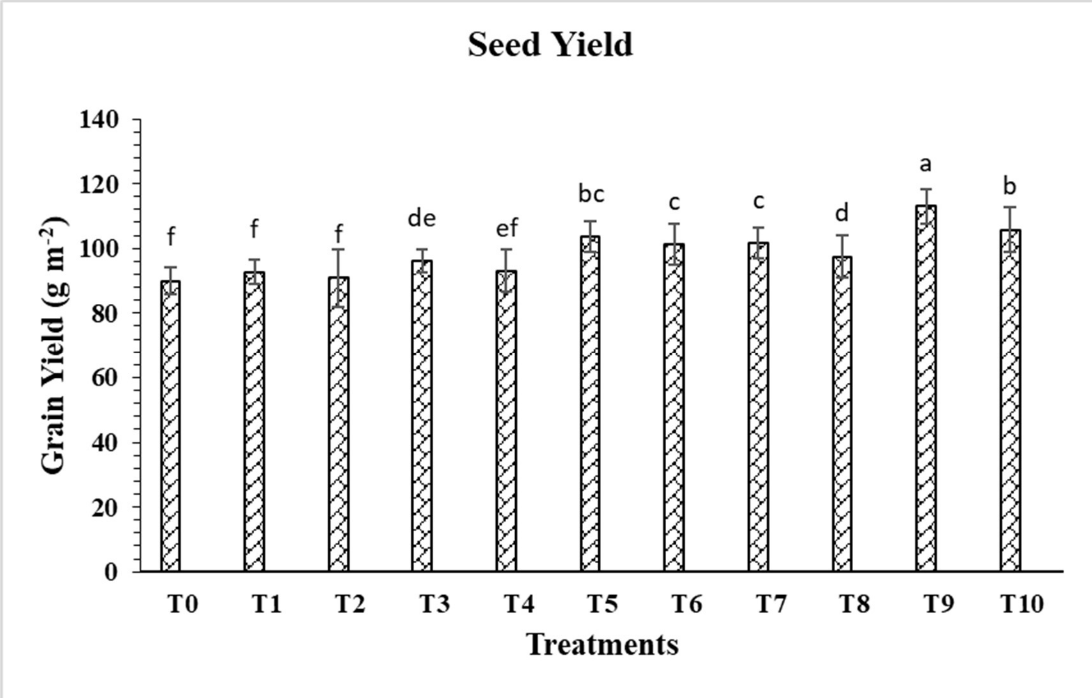


Fig. 9: Effect of foliar application of zinc and boron on primed mung bean Grain Yield (g.m$^{-2}$) at 30 and 60 DAS.

seedling development by GA priming may have contributed to an increase in photosynthetic activity. Additionally, it could potentially enhance the overall well-being of plants and safeguard the pathways involved in sucrose synthesis. Micronutrients zinc and boron, when applied foliarly, can exert a direct influence on enzymes that are implicated in the process of sucrose metabolism.

After the mung bean harvest, the most significant grain yield was achieved in T9 112 g.m$^{-2}$, followed by T10 [SA (150 mg.L$^{-1}$) + $ZnSO_4$ (0.5%) + B (1%)] at 105.7 g.m$^{-2}$, while T0 (control) had a grain yield of 89.9 g.m$^{-2}$ (Table 4 and Fig. 9). The result supported by Chen et al. (2017) the combined foliar application of Zn, B, and seed priming with gibberellic acid maximize the net photosynthetic rate in leaves and better translocation of metabolites and photosynthates. The concentration of Zn in grains increases due to an increase in source Zn concentration through the soil and foliar application of Zn. Usman et al. (2014) reported that Zn-fertilization increases biological yield and grains, enhancing the number of grains per pod in mung bean.

## CONCLUSION

In conclusion, our experimental findings underscore the significant positive impact of foliar micronutrient application and the priming of mung bean seeds using Gibberellic acid (GA) and salicylic acid (SA) on various growth and yield parameters. The treatment combining GA-primed seeds with foliar applications of zinc and boron [GA (50 mg.L$^{-1}$) + $ZnSO_4$ (0.5%) + B (1%)] produced remarkable improvements in mung bean development and yield. Notably, GA (50 mg.L$^{-1}$) + $ZnSO_4$ (0.5%) + B (1%) emerged as the most effective treatment, underscoring the preference for Gibberellic acid priming at 50 mg.L$^{-1}$.kg$^{-1}$ seed in conjunction with varying intervals of micronutrient foliar spraying. Additionally, treatment T10 [SA (150 mg.L$^{-1}$) + $ZnSO_4$ (0.5%) + B (1%)] yielded results comparable to those of T9 [GA (50 mg.L$^{-1}$) + $ZnSO_4$ (0.5%) + B (1%)] in terms of plant height, the number of branches, and fresh weight. Treatment T5 [GA(50 mg.L$^{-1}$) + $ZnSO_4$ (0.5%)] showed similar outcomes to T10 [SA(150 mg.L$^{-1}$) + $ZnSO_4$ (0.5%) + B (1%)] concerning nodule number and dry weight. The Seed priming with gibberellic acid and combined application of boron or Zn-fertilization increases biological yield and grains, enhancing the number of grains per pod in mung bean. The most significant grain yield was achieved in T9 112 g.m$^{-2}$, followed by T10 [SA(150 mg.L$^{-1}$)+ $ZnSO_4$ (0.5%)+B (1%)] at 105.7 g.m$^{-2}$. Conversely, the absolute control treatment (T0), devoid of growth regulators or micronutrients, demonstrated the lowest treatment efficacy. These findings underscore the efficacy of these treatments in optimizing mung bean growth and yield, providing valuable insights for agricultural practices and future research in this domain.

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