Effect of Boron, Zinc and Sulphur on Growth, Yield and Mineral Composition of Black gram (*Vigna mungo* L.) in alluvial soil

ABSTRACT

The present study determining the effect of Boron, Zinc and Sulphur on Growth, Yield and Mineral Composition of Black gram (Vigna mungo L.) in alluvial soil. A pot experiment was conducted during kharif 2023 at Net House in Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, B.H.U, Varanasi, U.P. to study the effect of Boron, Zinc and Sulphur on growth, yield and quality of black gram (*Vigna mungo* L.). The experiment was laid-out in a Completely Randomized design (CRD) with eight treatments, each having three replications. Dry matter accumulation, Number of branches plant^{-1}, test weight, grain yield kg ha^{-1}, straw yield kg ha^{-1}, harvest index significantly affected due to various treatments. T_7 (B +Zn+ S) recorded most pronounced improvements.

Keywords: *Blackgram; sulphur; zinc; boron; test weight; quality and yield*

1. INTRODUCTION

Pulses are integral to Indian cooking due to their affordability, accessibility, and rich protein content. Farmers benefit significantly from cultivating pulse crops, which offer sustainable agricultural advantages such as minimal water needs, deep root systems that prevent soil erosion, extensive ground coverage, and their ability to enhance productivity and resilience in farming through crop rotation and intercropping [1]. Pulse crops hold a crucial role in Indian agriculture for several reasons. Firstly, they have the unique capability of biological nitrogen fixation, which enriches the soil with essential nutrients. Additionally, their deep root systems help in mobilizing insoluble soil nutrients and improving soil structure. These plants also bring about beneficial changes in the physical properties of the soil, earning them the title of 'soil fertility restorers'. Beyond their agronomic benefits, pulses are highly valued as sources of food, fodder, and animal feed. India is the world's largest producer of pulses, accounting for one-third of the global pulse acreage and a quarter of its total production. For a significant segment of the population, especially vegetarians, pulses are the main source of protein [2].

Black gram (*Vigna mungo* L.) is a significant pulse crop and a staple in tropical and subtropical regions. Also known as urad bean, urad dal, or urad, it thrives in light soils that retain moisture, though loamy and clay loam soils are also suitable. Black gram (*Vigna mungo* L.) is a significant pulse crop and a staple in tropical and subtropical regions. Also known as urad bean, urad dal, or urad, it thrives in light soils that retain moisture, though loamy and clay loam soils are also suitable. Neutral pH loam to clay loam soils is ideal for its cultivation, as it does not tolerate waterlogged conditions well. Black gram is valued for its nutritional richness, boasting high protein content (22.24%), carbohydrates (56.6-59.6%), fats (1.2-1.4%), minerals (3.2%), and significant amounts of phosphorous (385 mg/100g), calcium, and iron [1]. Unlike other pulses, it stands out for its somewhat mucilaginous texture, which adds density due to its long polysaccharide carbohydrate chains. It provides affordable protein, it is often referred to as the "poor man's meat" [4].

Boron is an essential element for healthy plant growth and development. It is essential to the fertilization and blooming processes, which raise crop yield and quality [5]. Since its deficiency has been documented in 132 crops, it is acknowledged as one of the most often deficient micronutrients in soils. Zinc is a crucial nutrient for plants that is involved in several metabolic, regulatory, and developmental processes [5]. Additionally, it has been demonstrated to play a role in defense against the harmful effects of reactive oxygen species [8]. Concern over zinc nutrition in plants is growing as zinc deficiency is common in the world's arid and semi-arid regions [9]. Sulphur (S) is a vital plant nutrient necessary for the manufacture of protein, vitamins, enzymes, and amino acids such as cystine, cysteine, and methionine. It also plays a major role in maintaining increased output of pulse crops and participates in several metabolic and enzymatic processes, including respiration, photosynthesis, and the nitrogen fixation symbiotic relationship between legumes and rhizobium [10].

2. MATERIALS AND METHODS

2.1 Experimental site

A pot experiment on black gram was conducted on July 30th, 2023 in the Net House of the Department of Soil Science and Agricultural Chemistry at the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, situated at an altitude of 80.71 meters above mean sea level, lies between 25°18' North latitude and 80°36' East longitude. "The region has a humid subtropical climate, with an average annual rainfall of approximately 1100 mm and a potential evapotranspiration of around 1525 mm" [14].

Table 1. Treatment details of the experiment in black gram

Treatment details	**Abbreviations**
Control	T_0
RDF+Boron @ 1.5 kg ha^{-1}	T_1
RDF+Zinc @ 5 kg ha^{-1}	T_2
RDF+Sulphur @ 20 kg ha^{-1}	T_3
RDF+Boron@1.5 kg ha^{-1} + Zinc(@5 kg ha^{-1}	T_4

RDF+Boron@ 1.5 kg ha^{-1} + Sulphur(@ 20 kg ha^{-1}	T_5
RDF+Zinc@ 5 kg ha^{-1} + Sulphur(@ 20 kg ha^{-1}	T_6
RDF+Boron@1.5 kg ha^{-1}+Zinc @ 5 kg ha^{-1}+Sulphur(@ 20 kg ha^{-1}	T_7

Where: Recommended dose of fertilizer N, P and K, seed treatment with Rhizobium + PSB was given for each treatment, Recommended dose of fertilizer N: P_2O_5: K_2O, 20: 40: 20 kg ha^{-1}[17].

2.2 Experimental Setup

Initially, the soil had a sandy clay loam texture. It was slightly alkaline (pH 7.41), had normal salt content (EC 0.17 dS m^{-1}), low organic carbon content (0.48%), low available nitrogen (155.36 kg ha^{-1}), high available phosphorus (23.46 kg ha^{-1}), and medium available potassium (190 kg ha^{-1}) and Available Sulphur (17.80 kg ha^{-1}). The soil also had DTPA-extractable micronutrients with concentrations of Zn at 1.20 mg kg^{-1} and Available boron 0.51 mg kg^{-1}. During August-September 2023, a pot experiment was conducted using Black gram (variety T-9) as the test crop. The soil for the experiment was collected from the Agro farm at BHU, air-dried, ground, sieved through a 2-mm mesh, and placed in polythene-lined pots. The experiment was laid-out in a Completely Randomized design (CRD) with eight treatments, each having three replications. Uniform basal application was made with 20 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1}, 20 kg K_2O ha^{-1} through urea, DAP (Diammonium phosphate) and MOP (Murate of Potash), respectively. Sulphur, Zn and B were applied @ 20, 5 and 1.5 kg ha^{-1} from Bentonite-S, Zinc sulphate and Di-sodium tetra-borate pentahydrate, respectively. The pots were kept at field capacity throughout the study period.

2.3 Growth and Yield Attributes

Growth attributing characters of blackgram mainly plant height at 20, 40 and 60 days after sowing (DAS), number of branches per plant, dry matter accumulation were recorded. At maturity grain yield, straw yield, test weight (g) was recorded and harvest index were calculated.

$$\text{Harvest index} = \frac{\text{Economical yield}}{\text{Total biological yield}} \times 100$$

2.4 Statistical Analysis

"The research data were analyzed using statistical software SPSS 16.0 for ANOVA (complete randomized design). Duncan multiple range test (DMRT) at $p \leq 0.05$ levels of significance was used to evaluate the significant differences among mean values" [11].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

The analysis of variance for the data on plant height shows non-significant difference was found on growth stages .T_7 (Boron + Zinc + Sulphur) exhibited the highest plant height (17.31,39,45.69 cm) which was statistically at par with T_5 (Boron + Sulphur) that is (17.05,39.11,44.18 cm).This was followed by treatment T_6 (Zinc + Sulphur), T_4 (Boron + Zinc), and T_3 (Sulphur @20 kg ha^{-1}), with harvest plant heights of 43.8 cm, 43.34 cm, and 42.58 cm, respectively. In contrast, the control group recorded the lowest harvest plant height of 40.75 cm T_7 was statistically at par with T_5 and T_6.More availability of B, Zn and S might have encouraged growth promoting hormones and protein synthesis means more chlorophyll content leading to higher photosynthesis. These resulted into rapid cell elongation and enlargement and ultimately plant height [12] [13] and [14]. Number of branches count plant^{-1} was statistically significant due to various treatments (Table 2).

The analyzed data relating to the dry matter accumulation at harvest of black gram is shown in Table 1. T_7, which involved the application of boron, zinc, and sulphur, resulted in the highest dry matter accumulation at 4.95 grams per plant. This was followed closely by treatment T_5, which involved the application of boron and sulphur, with 4.78 grams per plant. Treatments T_6 (zinc and sulphur) and T_4 (boron and zinc) recorded 4.56 grams per plant and 4.50 grams per plant, respectively. In contrast, the lowest dry matter accumulation of 3.98 grams per plant was observed in treatment T_2, which involved zinc application at 5 kg ha^{-1}. T7 was statistically at par with all the treatments except the control. The data revealed a significant difference among the various treatments. These findings align with previous research by [15], which found that the sulphur rate significantly affects soybean dry matter.

The highest of branches plant^{-1} was observed with application of B + Zn + S, which was statistically superior from all the treatments except T_5 (B + S). The lowest number of branches plant^{-1} was observed with control T_0 [16] and [17].

3.2 Yield Component

The data of grain yield were analyzed and summarized in Table 3. Different treatments exhibited significant variation in grain yield of urad bean. Treatment T_7, involving the application of boron, zinc, and Sulphur, resulted in the highest seed output at 1.95 t ha^{-1} followed by T_5 (1.68 t ha^{-1}) and T_6 (1.62 t ha^{-1}). In contrast, the control treatment (T_0) exhibited the lowest grain production at 0.66 t ha^{-1}. T_7 demonstrated the highest haulm yield of 3.71 t ha^{-1}, surpassing the control (2.61 t ha^{-1}) and treatments T_5 (3.63 t ha^{-1}), and T_6 (3.5 t ha^{-1}). T_7 was statistically at par with T_4, T_5, T_6. However, three other treatments with application of B + S, Zn + S and B + Zn were also found effective to enhance yield over control as well as those treatments where applied alone nutrients i.e. B, Zn and S. The lowest grain and straw yield were found in control. The Harvest Index of black gram demonstrates significant variation ranging from 20.21% to 34.40%. T_7, exhibited the highest Harvest

Index at 34.45 %, while the control treatment (T_0) showed the lowest Harvest Index at 20.21% [17]. Treatments exerted significant impacts on variations in test weight (1000-seed weight). T_7 (Boron + Zinc + Sulphur) emerged as the most effective, producing the highest test weight of 40.20 grams followed by T_5 and T_6. Conversely, the control group (T_0) exhibited the lowest test weight at 33.20 grams. Noteworthy improvements in test weight were observed with alternative treatments.

3.3 Nutrient content

Table 4 shows Nitrogen content ranged from 1.80% to 3.80% in seeds and 1.40% to 2.80% in haulm across the treatments. Analysis of the data revealed that nitrogen content increased in both seed and haulm compared to the control when treated with boron, Zinc and Sulphur.T_0 had the lowest content of phosphorus (0.51 and 0.21), in seed and haulm while the T_7 with combine application of Boron, Zinc and Sulphur had the highest content of Phosphorus (1.17 and 0.45), followed by the T_5, T_6 and T_4.The T_0 produced the lowest value (0.20 % and 0.41%) in seed and haulm, respectively, whereas the combine application of Boron, Zinc and Sulphur (T_7) had the highest potassium content in both seed and haulm (1.04% and 0.89%).

3.4 Available nutrients in post-harvest soil of black gram

Table 5 shows the lowest amount of nitrogen, at 160 kilograms per hectare, was observed in the control (T_0), while the soil in T_7 exhibited the significantly highest nitrogen content at 296.00 kg per hectare. T_7 resulted in the largest amount of accessible phosphorus (50.90 kg ha^{-1}). The available phosphorus value was lowest (23.06 kg ha^{-1}) in the control, or T_0. The data in Table 5 shows information on available potassium in soil post the harvest of Black gram and it varied from 201.15 to 312.20 kg ha^{-1} indicating that soil was categorized under medium to high in available potassium.

Table 2: Effect of different treatments on plant height, dry matter accumulation and number of branches per plant at harvest of black gram

Treatments	Plant height (cm)			Dry matter accumulation (g plant^{-1})	Number of branches per plant at harvest
	at 20 DAS	at 40DAS	at 40DAS		
Control	13.51	34.01	40.75	3.98	6.23
T_0	16.10	36.35	42.06	4.35	7.16
T_1	15.76	36.06	41.85	4.20	6.67
T_2	16.03	36.65	42.58	4.38	7.42
T_3	16.10	37.02	43.34	4.50	7.48
T_4	17.05	39.11	44.18	4.78	7.82

T_5	16.83	38.78	43.80	4.56	7.64
T_6	17.31	39.00	45.69	4.95	8.23
T_7	0.67	1.211	1.89	0.15	0.21
CD (5%)	1.33	1.94	1.80	0.54	0.41

Table 3: Effect of different treatments on seed yield, haulm yield, harvest index and test weight of black gram.

Treatments	**Seed yield** **(t ha^{-1})**	**Haulm Yield** **(t ha^{-1})**	**Harvest index** **(%)**	**Test weight** **(gm)**
T_0	0.66	2.61	20.2	33.20
T_1	1.03	3.06	25.06	34.20
T_2	0.82	2.8	22.73	32.80
T_3	1.35	3.17	29.9	34.70
T_4	1.56	3.41	31.32	37.20
T_5	1.68	3.63	32.72	38.75
T_6	1.62	3.55	31.65	38.21
T_7	1.95	3.71	34.45	40.20
SEm±	0.03	0.139	0.763	0.78
CD (0.05)	0.1	0.42	4.48	2.24

Table 4. Effect of different treatments on nutrient contents in seed and haulm of black gram.

Treatments	N Content (%)		P Content (%)		K Content (%)	
	Seed	Haulm	Seed	Haulm	Seed	Haulm
T_0	1.80	1.40	0.51	0.21	0.20	0.41
T_1	2.68	1.91	0.81	0.24	0.39	0.57
T_2	2.15	1.60	0.69	0.23	0.37	0.53
T_3	2.98	1.94	0.98	0.34	0.42	0.64
T_4	3.12	1.98	1.05	0.37	0.51	0.69
T_5	3.80	2.60	1.11	0.41	0.80	0.84
T_6	3.64	2.27	1.08	0.38	0.74	0.77
T_7	3.90	2.80	1.17	0.45	1.04	0.89
SEm±	0.059	0.021	0.073	0.005	0.012	0.371
CD (0.05)	0.19	0.05	0.053	0.014	0.042	1.14

Table 5. Effect of different treatments on available N, P, K, S (kg ha^{-1}) and B (mg kg^{-1}) in post-harvest soil of black gram

Treatments	**Available Nitrogen (kg ha^{-1})**	**Available Phosphorus (kg ha^{-1})**	**Available potassium (kg ha^{-1})**	**Available Sulphur (kg ha^{-1})**
T_0	167.00	23.06	201.15	21.45
T_1	225.20	27.89	235.48	23.45
T_2	215.34	25.64	224.45	25.65
T_3	260.50	31.15	250.54	30.86
T_4	277.28	32.46	262.34	29.45
T_5	283.20	42.67	290.89	31.45
T_6	281.06	36.78	276.60	32.86
T_7	296.00	50.90	312.20	35.68
SEM±	2.17	1.04	2.74	0.79
CD 5%	6.54	3.20	8.28	2.45

Where: T_0=Control, T_1=RDF+B @1.5 kg ha^{-1}, T_2=RDF+Zn @5kg ha^{-1}, T_3= RDF+S@20 kg ha^{-1}, T_4=RDF+B+Zn, T_5=RDF+B+S, T_6=RDF+Zn+S, T_7=RDF+B+Zn+SRDF=Recommended dose of fertilizer

Conclusion

Increased plant height, accumulation of dry matter, and more branches were observed upon application of (B@ 1.5 kg ha^{-1}, Zn (@ 5 kg ha^{-1}, S 20 kg ha^{-1}). When T_7 (B+Zn+ S) was applied in combination, the maximum grain yield, straw yield, harvest index, and test weight were also recorded which was significantly superior over T_0 (control), T_1 (B), T_3 (S), T_4 (B + Zn), and T_2 (Zn) and at par with T_5 (B + S) and T_6 (Zn + S). Though all treatments showed positive effect in increasing growth parameter and yield. This suggests that the application of these nutrients enhances the nutritional quality of the seeds, making them more valuable in terms of human and animal nutrition. Additionally, the study highlights improvements in soil properties resulting from the application of boron, zinc and sulphur. The treatment leads to enhancements in soil fertility, indicated by higher levels of organic carbon and nitrogen content in the soil. This suggests that the combination of these nutrients not only benefits the crop but also contributes to long-term soil health and sustainability.

DISCLAIMER(Artificial intelligence)

Author(s) hereby declare that no generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of manuscripts.

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