PERFORMANCE OF BORON ON MUNG BEAN (*Vigna radiata* L.) PRODUCTIVITY

Gani, M. N.*, F. Khanm[1], M. Hasan[2], S. M. I. Huq[1] and S. A. Ahmad[3]

Agronomy Division, Bangladesh Jute Research Institute, Dhaka-1207, Bangladesh; [1]Department of Soil, Water and Environment, University of Dhaka, Dhaka-1000, Bangladesh; [2]Department of Soil, Water and Environmental Sciences, Noakhali Science and Technology University, Noakhali-3814, Bangladesh; [3]Soil Science Division, Bangladesh Jute Research Institute, Dhaka-1207, Bangladesh

*Corresponding author: ganisoilbjri@gmail.com

Abstract

The present investigation was performed to estimate the effect of different levels of boron on the growth and yield of mung bean (*Vigna radiata* L.) under AEZ-8, Manikganj district of Bangladesh. Six treatments such as T_1: Control, T_2: B@ 1 kgha^{-1} + RDF, T_3: B@ 3 kgha^{-1} + RDF, T_4: B@ 4 kgha^{-1} + RDF, T_5: B@ 4 kgha^{-1} + RDF and T_6: RDF (N_{20} P_{45} K_{30} S_{15} kgha^{-1}) were designed to assess the impact. The experiment was laid out in a randomized complete block design maintaining three replications. Increasing the levels of boron significantly influences the growth, yield and yield attributes of mung bean, in the company of recommended fertilizer dose. The principal outcome of boron indicated that 3.0 kgha^{-1} B was superior to other doses concerning mung bean yield and yield traits. In addition, the highest grain yield increment (48.43%) over control was also achieved from 3 kg B ha^{-1}. The tallest plant (54.55 cm), maximum no. of branches (2.68), number of pods (20), pod length (8.89 cm) and yield of stover (2.80 tha-^{1}), 1000 seed (42.30 tha-^{1}) and grain (1.90 tha-^{1}) of mung bean were found with T_3: B@ 3 kgha^{-1} and minimum in control (T_1). The highest number of seeds per pod was recorded (13) in T_4: B@ 4 kgha^{-1} + RDF. The overdose of B@ 4 and 5 kgha^{-1} reduces the yield of stover, 1000 seeds and grain of mung bean compared to 3 kg B ha^{-1} in T_3. The study indicated that the integrated addition of B along with NPKS enriched the post-harvest soil by a good percentage. On the basis of the production skill, of grain yield, the treatments can be arranged in the order of $T_3 > T_4 > T_5 > T_6 > T_2 > T_1$. The application of boron @ 3 kgha^{-1} along with N_{20} P_{45} K_{30} S_{15} kgha^{-1} could be found suitable for boosting mung bean yield in AEZ-8 soils of Bangladesh.

Key words: Mung bean; Boron; Growth and yield.

INTRODUCTION

An important legume crop in Bangladesh is the mung bean (*Vigna radiata* L.) belonging to the Fabaceae family known as green gram, cultivated during the spring and autumn seasons (Quddus *et al*. 2022, Sadaf and Tahir 2017). People in the most parts of Asia, largely depend on cereals and pulses to meet the protein demand through their daily dishes (Rifhat *et al*. 2023). South Asian countries are the world's largest producers and consumers of pulse crops such as chickpeas, pigeon peas and mung beans. Mung Bean is a short-duration crop, predominantly cultivated in the country for human consumption of the edible seeds which are characterized by good digestibility, strong flavor, high protein, iron and fiber content and nonappearance of any flatulence properties (Ahmed *et al.* 2001). It is a good substitute for meat in most Asian diets, and a significant component of various cropping systems (Rudy *et al*. 2006). In Bangladesh, on average only 8-10% of protein intake comes from animal sources, and the remaining portion is met by plant sources through the consumption of pulses (Uddin *et al*. 2009). Mung bean seeds contain about 24% protein, 58% carbohydrate and 36% minerals (Nadeem *et al*. 2004) which is higher than other pulse crops. As a legume crop, mung bean can fix atmospheric nitrogen making it available for plant uptake. So, it is less dependent on nitrogenous fertilizer. However, the application of nitrogenous fertilizer as a starter or initial dose becomes helpful in increasing the growth and yield of legume crops (Achakzai *et al*. 2012). Nitrogen deficiency reduces the number of branches plant^{-1}, plant height, stem diameter, pod length and number of nodes (Rupa *et al*. 2014). This versatile crop is worth high market value, a protein and nutrient supplier for the human body, an enhancer of soil fertility, and a reducer of several non-communicable diseases. Its stover is used for animal feed and as an alternate source of organic materials (Hou *et al.* 2019).

Amena (2017) reported a shortage of pulses in Bangladesh and per capita intake is much lower (10.92 g/day) than the FAO (2013) recommendation (80 g/day). At this stage, pulse production has to be increased even more than threefold to ensure the FAO-prescribed consumption. Mung bean is cultivated in the country on 261.4 thousand hectares of land yielding a grain production of 134.4 thousand tons and an approximate yield of 482.63 kg/ha (Anonymous 2003). The average seed yield of mung bean in Bangladesh is much lower (about 867 kgha^{-1}) compared to the potential yield (BBS 2016). Bangladesh imported almost 291 thousand metric tons of pulses in the 2006-2007 fiscal year due to a deficit in production (BBS 2010). Despite its ability to grow well in any area with varying climatic and environmental conditions in Bangladesh, the nation is predicted to experience a severe shortage of mung bean/pulse crops due to the increasing demand for staple food by the rapid population expansion of the country (Rashid and Matin 2018). Bokhtiar *et al*. (2023) reported that the demand for pulses will increase and the supply will decrease significantly, by 2050. Considering these circumstances, more investigation is required to optimize strategies for maximizing its production per unit of land.

Earlier workers (Uddin *et al*. 2009, Quddus *et al*. 2022) suggested a new approach for improving mung bean seed yield through the cultivation of modern high-yielding varieties with judicial application of macro and micronutrients, particularly boron. Utilizing boron increases the yield and growth of plants by increasing the leaf area expansion, 1000 seed weight, nodule formation, seed yield and biological yield (El-Hamdaoui *et al.* 2003). Boron stands third among the micronutrients and plays a chief role in plant cell wall and membrane stability (Bassil *et al.* 2004). The application of boron while growing pulse crops is important for protein synthesis, improved protein content and also yield (Kaisher *et al.* 2010). The farmers of Bangladesh generally grow mung bean with almost no fertilizers. So, there is plenty of scope in maximizing the yield of mung bean per unit area, by using NPK and S balanced fertilizer along with boron. Keeping these facts in view an experiment was conducted with the following objectives: a) To find out the optimum dose of B on the growth and yield of mung bean; and b) To determine the post-harvest soil characteristics due to the addition of different levels of B.

MATERIAL AND METHODS

Experimental site

The site of the peasant's field is located in the Kalampur agricultural region of Manikganj district (23°55'6.27" N, 90°9'17.04" E) under AEZ-8. The study area is situated at 8.8 meters above the sea level. The crops that are cultivated in this locality are vegetables, mustard, rice, wheat, and jute. The jute-based cropping patterns are the dominant culture in this area.

Collection of soil samples

The soil sample was collected from within 15 cm depth from the surface of different points of the field using a steel auger. Collected samples were taken in a bucket and mixed thoroughly to make a representative sample and were kept in a polythene bag. Two paper tags with the required information, such as date, sampling depth and name, were put inside and outside the bag. Then the bag was sealed and transported to the laboratory. The samples were taken twice, viz. before setting the experiment to observe the initial nutrient status and after harvest for analyzing post-harvest soil conditions. The soil samples were air-dried on clean brown papers. Roots and debris were removed from the soil sample. After air drying, aggregates were broken with a wooden hammer. Samples were passed through a 0.5 mm sieve and preserved in labeled plastic bottles properly for further analysis of physicochemical properties. The physicochemical properties of the initial soil are shown in Table 1.

Table 1. Physicochemical properties of the soil used.

Properties	Values
% Silt	17
% Clay	15
% Sand	68
Textural class	Sandy loam
Soil reaction (pH)	6.5
% Organic carbon (OC)	0.56
% Organic matter (OM)	0.96
% Total N	0.058
C:N	9.65
Available P (ppm)	5.10
Exchangeable K (meq/100 g)	0.12
Available S (ppm)	1.70
Boron (ppm)	0.01 (Trace)

Field layout and experimental design

The field was laid out in RCBD having 3 replications. Six treatment combinations were designed for 18 plots with each plot size of 3 m × 2 m. A spacing of about 1.0 m and 0.5 m respectively was maintained in setting the blocks and unit plots. The six treatments are T_1: Control; T_2: B@ 1 kgha^{-1} + RDF; T_3: B@ 3 kgha^{-1} + RDF; T_4: B@ 4 kgha^{-1} + RDF; T_5: B @ 5 kgha^{-1}; and T_6: RDF (Recommended Dose of inorganic Fertilizer) N_{20} P_{45} K_{30} S_{15} kg/ha.

Land preparation

Tillage operation was done with a mini power tiller in the late weeks of March 2023. The soil was well-ploughed and smooth, laddering was done twice. Soil lumps, weed materials, and wastage were taken off and the field was leveled to make it suitable for sowing mung bean.

Fertilizer addition

The NPKS fertilizers and B were incorporated into the soil as per the experimental design. Inorganic fertilizers: NPKS and B were applied from urea, TSP, MOP, gypsum and boric acid, respectively in the plots during final land preparation.

Collection of seeds and sowing

The mung bean seeds of BARI Mung-6 were supplied by the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. These seeds were sown in the study plots on the 8th of April, 2023 maintaining the recommended line-to-line distance of 30 cm apart, and plant-to-plant distance of 10 cm.

Intercultural operations

The weeding, thinning, irrigation and application of pesticides and insecticides were done according to necessity.

Plant harvesting

The crop was harvested at maturity on 17 June 2023 by hand-picking. The mung bean plants reached maturity upon maximum pods. The 80% pods were matured on the 60th day and continued up to 65th day after sowing. The second harvest was completed after a week of the first one. Finally, all plants were harvested plot-wise by uprooting on the same days of second pod picking and were bundled separately. Grain and stover yields were recorded treatment-wise and the yields were expressed in tha^{-1}.

Soil physical properties

The percentage of sand, silt and clay was estimated with the process described by Bouyoucos (1962). The textural class of the soil sample was determined by the USDA soil texture triangle.

Soil chemical properties

A glass electrode pH meter was used to determine the pH of the soil. The ratio of soil to water in the suspension was maintained at 1:2.5. Organic carbon in soil was determined by the Wet Oxidation method as described by Walkley and Black (1934). Organic matter was calculated by multiplying the organic carbon with the Van Bemmelen factor, 1.724 as described by Piper (1966). Nitrogen was determined by the micro-Kjeldahl method as described by Jackson (1973). Available phosphorus was extracted from the soil by shaking with 0.5 *M* $NaHCO_3$ solution of pH 8.5. Exchangeable potassium was determined by using 1*N* NH_4OAc (pH 7.0) as the extract and measured the intensity with the help of a Flame Photometer. Available sulfur in the soil was determined by extracting the soil samples with 0.15% $CaCl_2$ solution. Zinc, iron and manganese contents were determined by atomic absorption and spectrophotometer.

Statistical analysis

Analysis of variance (ANOVA), Fisher's Least Significant Difference (LSD) test, Fisher's Pairwise Comparison and Pearson's Correlation analysis were carried out with the results obtained. All the statistical analyses were done using Minitab V21.10 and MS Excel 2021.

RESULTS AND DISCUSSION

In assessing the impact of boron on the productivity of mung bean plants, five morphological and three agronomical descriptors were recorded and analyzed according to the classification presented by Canci and Toker (2014).

Effects of boron on plant morphological descriptors

The plant morphological features, such as Pod length, No. of seed per pod, No. of pod per plant, No. of branch and Plant height are presented in Table 2 and the statistical groups identified by Fisher's Pairwise Comparison are illustrated in Fig. 1. All these components of morphological studies showed significant treatment differences.

Pod length

The pod length of mung bean plants varied significantly ($p \leq 0.05$) among the treatment groups. All the groups receiving boron resulted in longer pods (Table 2) than the control. The highest pod length of 8.89 cm was observed in T_3: 3 $kgha^{-1}$ boron. The lowest pod length (5 cm) in control (T_1). In a study by Zafar *et al.* (2023), the longest pod was achieved at 8.5 cm with only 1.1 $kgha^{-1}$ of boron application than sole RDF. These findings are similar to previous research by Whahida and Rahman (2008) who reported that the pod length of mung beans enhanced significantly due to different boron treatments.

Table 2. The effects of boron on plant height, no. of branch, no. of pod and pod length of BARI mung-6.

Treatments	Pod length (cm)	No. of seed pod^{-1}	No. of pod $plant^{-1}$	No. of branch	Plant height (cm)
Control	5.00	10.00	15.00	1.49	40.27
B@ 1 kg ha^{-1} + RDF	6.92	10.30	15.30	2.50	48.70
B@ 3 kg ha^{-1} + RDF	8.89	12.00	20.00	2.68	54.55
B@ 4 kg ha^{-1} + RDF	7.98	13.00	19.70	2.55	54.00
B@ 5 Kg ha^{-1} + RDF	7.90	12.30	18.00	2.40	52.89
RDF (N_{20} P_{45} K_{30} S_{15} kg/ha)	7.91	12.25	17.90	2.35	52.10
LSD at 5%	1.28	NS	2.18	0.47	0.92

(RDF = Recommended Dose of inorganic Fertilizer)

No. of seed pod^{-1}

The number of seeds contained in each pod is the direct indicator of the yield of legume plants. The highest number of seeds per pod was recorded in T_4: B@ 4 $kgha^{-1}$ + RDF with a mean of 11.64 ± 1.2. The control group produced on average only 10 seeds in each pod of mung bean plants, which is the lowest among all other treatment groups (Table 2). Results showed that no. of seeds pod^{-1} were not statistically different from the other boron treatments at lower than 4 $kgha^{-1}$ but produced higher than the control. Quddus *et al.* (2022) reported that mung beans cultivated in calcareous soils produced a maximum of 10.6 seeds per pod with 1.5 $kgha^{-1}$ boron. In addition, a significant correlation ($r = 0.72$) was found in the present study between the number of seeds in each pod and the level of boron in post-harvest soil. Chowdhury *et al.* (2010) also proved that no. of seeds per pod enhanced with the exogenous application of boron. This achievement is in close conformity with the findings of Noor *et al.* (1997).

No. of pod $plant^{-1}$

All the treatments varied significantly ($p \leq 0.05$) in terms of the number of pods per plant. The application of boron@ 3 $kgha^{-1}$ (T_3) showed the largest number (20) of pods in a mung bean plant, which is a great variation compared to the control (Table 2). In addition, the findings noticed that boron at a higher level than 4 $kgha^{-1}$ decreased the number of pods $plant^{-1}$. This result is comparable to the findings of Kaisher *et al.* (2010). They reported boron had a significant impact on the number of pods enhancement in each mung bean plant. Quddus *et al*. (2011) also observed a higher number of pods plant^{-1} with a graded dose of boron.

No. of branch

All the treatments of boron showed significant differences in producing the number of branches (Table 2). The number of branches was statistically similar in T_2 and T_1 (Fig. 1). The highest number of branches (2.68) was obtained from the application of boron at 3 kgha^{-1} and the lowest (1.49) in control (T_1). This agrees with the findings of Alam and Islam (2016). They cultivated mung bean plants in acidic northern and eastern hills soil (AEZ-29), and the number of branches was found to be highest with boron level 3 kgha^{-1} with NPK.

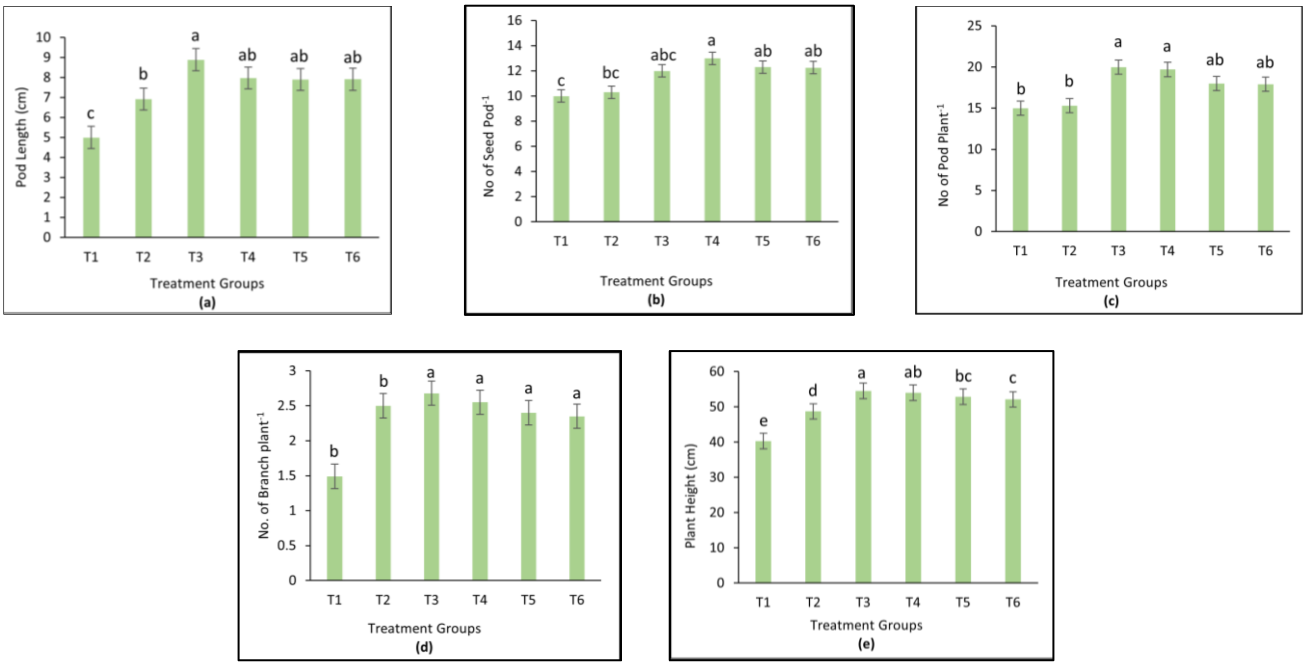

Fig. 1. Effects of boron on plant morphological descriptors (a, b, c, d, e being the indicators of the individual statistical group differing from each other at 5% confidence level).

Plant height

According to Canci and Toker (2014), plant height is a significant morphological feature of mung bean legume plants as it is strongly associated with branches and pods per plant. The mung bean plants exhibited a wide variation in height ($p \leq 0.05$). Results in Table 2 demonstrate that the tallest plant (54.55 cm) attained in T_3: boron@ 3 kgha^{-1} and the shortest plant (40.27 cm) with control group (T_1). Interestingly, the plants receiving the sole recommended dose of inorganic fertilizers showed 52.10 cm plant height, which is statistically different from the height found in T_3 (Fig. 1). It is clear in this study that boron played a positive impact on the growth and yield of mung bean. Moreover, plant height was found to be strongly related to the boron level of post-harvest soil (correlation coefficient r = 0.76). Dixit and Elamathi (2007) reported that boron application (2%) significantly improved the plant height of red lentils. Kachare *et al*. (2022) reported that the plant height of green gram was significantly enlarged by the application of B, Zn, and Mo. Roshid (2021) found the maximum plant height of field peas from 3.0 kg B ha^{-1}.

Effect of boron on plant agronomical descriptors

The results of agronomical studies, viz. yield of stover, grain and weight of 1000 seeds are shown in Table 3 and the statistical groups identified by Fisher's Pairwise Comparison are illustrated in Fig. 2. The yield of different agronomic plant characters varied significantly due to the levels of boron.

Yield of stover

The highest yield of stover (2.80 tha^{-1}) was obtained from T_3 (boron 3 $kgha^{-1}$). However, stover yield declined beyond 3 $kgha^{-1}$ of boron application, which implies that other factors might be contributing to this yield component. Shamsuddoha *et al.* (2011) noticed significant variation in stover yield and found higher stover yield with graded doses of boron. A similar trend was reported by Malik *et al.* (2015) that different levels of potassium and boron fertilizer showed significant variation in terms of stover yield of other varieties of mung bean.

1000 seed weight

1000 seed weight is a parameter used to indicate seed health and thus is important for yield assessment. The study revealed that there was a remarkable increase in 1000 seed weight after boron application. The highest value (42.3 g) was obtained from T_3: boron@ 3 $kgha^{-1}$ and the lowest (30 g) in control (T_1). Besides, a significant variation ($p \leq 0.05$) was noticed across all treatment groups. Maqbool *et al*. (2018) reported the maximum value of 1000 seed weight to be 47.63 g with an application of 4 $kgha^{-1}$ boron. Moreover, there was a strong positive relationship between the 1000 seed weight values and the boron level in post-harvest soil (correlation coefficient, $r = 0.77$). Kant *et al.* (2008) found such strong correlation between the 1000 seed weight of linseed and boron. Similar results were also reported by Mathew and George (2013) in the production of sesame due to boron addition.

Grain yield

Significant variation ($p \leq 0.05$) was observed across all the treatments regarding grain yield, which is the most important factor yield attribute in legume plants (Table 3). All the boron-treated plots produced a higher rate of grain yield over the control (T_1) and sole application of RDF (T_6). The maximum grain yield (1.90 tha^{-1}) was obtained in T_3: boron@ 3 $kgha^{-1}$ and minimum (0.98 tha^{-1}) with control (T_1). The higher level of boron application of 4 $kgha^{-1}$ in T_4 and supreme dose 5 $kgha^{-1}$ in T_5 exhibited lower performance in producing grain yield, compared to boron in T_3: 3 $kgha^{-1}$. It indicates higher dose of boron over 3 $kgha^{-1}$ decreases the seed yield. Study also showed (Fig. 2) the statistically similar grain yield with T_4, T_5 and T_6 (sole RDF application and receiving no boron). These findings are in agreement with Shakti *et al*. (2020) who reported basal application of boron before sowing with recommended fertilizer was found to enhance yield and yield attributes of urd bean (*Vigna mungo* L.) significantly over other treatments. The results also correlate with the study of Singh *et al*. (2014). They found the grain yield of mung bean significantly higher with boron from an experiment in the field of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, India. On the basis of production skill of grain yield, the treatments can be arranged in the order of $T_3 > T_4 > T_5 > T_6 > T_2 > T_1$. All the above results are supported by Chowdhury *et al.* (2010) who proved that plant height, number of pods per plant, number of seeds per pod, 1000 seed weight and seed yield were enhanced with exogenous application of boron.

Table 3. Effect of levels of boron on yield attributes and yield of BARI mung-6.

Treatments	Yield of stover (tha^{-1})	Grain yield (tha^{-1})	1000 seed wt. (g)
Control	1.98	0.98	38.00
B@ 1 $kgha^{-1}$ + RDF	2.15	1.38	40.10
B@ 3 $kgha^{-1}$ + RDF	2.80	1.90	42.30
B@ 4 $kgha^{-1}$ + RDF	2.73	1.70	42.10
B@ 5 $kgha^{-1}$ + RDF	2.71	1.60	42.09
RDF (N_{20} P_{45} K_{30} S_{15} kg/ha)	2.78	1.59	41.80
LSD at 5%	NS	0.28	1.23

(RDF= Recommended Dose of inorganic Fertilizer)

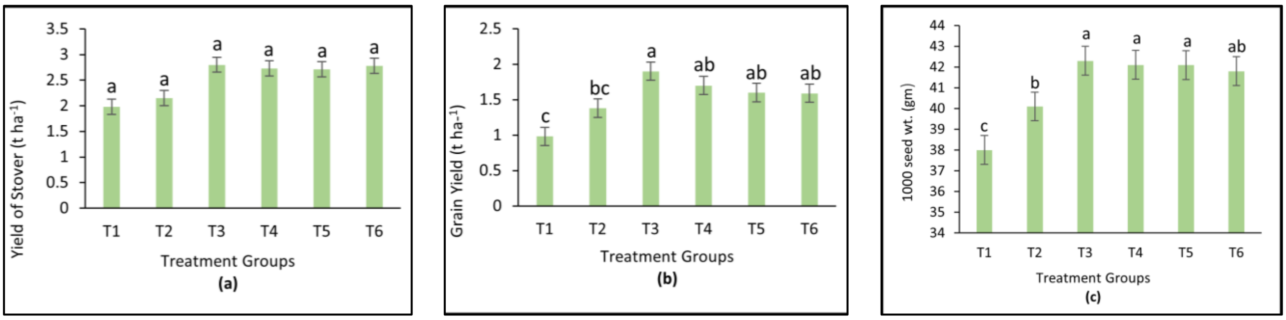

Fig. 2. Effects of boron on plant agronomical descriptors (a, b, c being the indicators of the individual statistical group differing from each other at 5% confidence level).

All the treatment groups showed an increase in all the yield attributes to various extents over the control group. While T_3: B@ 3 $kgha^{-1}$ + RDF had the largest impact percentage-wise in terms of stover yield and 1000 seed weight (41.41 and 11.3%) among all groups, T_4: B@ 4 $kgha^{-1}$ + RDF was the most responsive regarding grain yield and the number of seed per pod (73.47 and 30%, respectively) (Table 4). In addition, the plants grown using the recommended dose of inorganic fertilizers only also exhibited better yield compared to the control. However, this impact was more remarkable in the groups receiving boron in addition to the RDF, which implies a significant impact of boron on the yield of mung bean plants. Begum *et al*. (2015) obtained the onion yield increased by 02-99% due to the effect of Zn and B application. A similar trend was stated by Anjali *et al*. (2023) where a 27.6% higher grain yield of wheat was achieved with boron (sprays of 0.2% borax).

Table 4. Per cent increase in yield attributes over control.

Treatments	Stover yield	Grain yield	1000 seed wt.	No. of seed pod^{-1}
B@ 1 $kgha^{-1}$ + RDF	8.59	40.82	5.53	3
B@ 3 $kgha^{-1}$ + RDF	41.41	20.41	11.3	20
B@ 4 $kgha^{-1}$ + RDF	37.88	73.47	10.78	30
B@ 5 $kgha^{-1}$ + RDF	36.87	63.26	10.76	23
RDF (N_{20} P_{45} K_{30} S_{15} kg/ha)	40.4	62.24	9.99	22.5

* Yield obtained over control = (Yield with treatments - yield with control)/yield with control

Soil fertility status of post-harvest soil

Results (Table 5) exhibited that soil nutrient status increased with all the treated plots over control. Gani *et al*. (2001) reported similar trends of results in the enhancement of soil fertility with the macro and micronutrient-bearing city waste compost. Findings (Table 5) showed that amongst the applied differential levels of boron, the application of 5 kg Bha^{-1} (T_5) was realized as the most prominent boron dose responsible for increasing the maximum content of soil nutrient status in the soil while the control plots recorded the lowest. This research correlates with Ingudam *et al*. (2021). Das *et al*. (2023) reported liming and application of boron and molybdenum micronutrients improves soil properties and productivity of the groundnut-rapeseed cropping system in an acidic Inceptisol of India's eastern Himalayas. Ingudam *et al.* (2021) also reported such type of result, they found boron had the capability to improve the soil chemical properties, nutrient status in soil, and yield of crops under cauliflower-cowpea-okra cropping sequence. Table 5 presents the changes in soil physicochemical properties after the cultivation of mung bean plants under various treatment combinations. It reveals that in most cases soil becomes slightly acidic after cultivation. This trend can be explained by the increase in organic matter across all treatment groups. Similar findings are reported by Quddus *et al.* (2020). However, Arvind and Rai (2018) found a significant variation in soil properties across groups treated with different levels of boron after harvesting sesame.

Table 5. Nutrient status of post-harvest soil due to addition of boron.

Treatments	pH	% OC	% OM	% Total N	P (ppm)	K (meq/100g)	B (ppm)
Control	6.57	0.54	0.93	0.59	7.50	0.128	0.05
B@ 1 $kgha^{-1}$ + RDF	6.55	0.57	0.98	0.61	7.51	0.131	0.11
B@ 3 $kgha^{-1}$ + RDF	6.58	0.58	1.00	0.64	8.10	0.165	0.10
B@ 4 $kgha^{-1}$ + RDF	7.10	0.59	1.01	0.65	7.79	0.158	0.14
B@ 5 $kgha^{-1}$ + RDF	7.15	0.65	1.12	0.67	7.82	0.157	0.17
RDF (N_{20} P_{45} K_{30} S_{15} kg/ha)	6.54	0.57	0.98	0.61	7.51	0.157	0.11
LSD at 5%	NS	NS	NS	NS	NS	NS	0.03

*(RDF = Recommended Dose of inorganic Fertilizer)

It can be concluded from the above results that the inclusion of boron with the recommended dose of fertilizer significantly enhanced the yield and yield contributing characters. Findings also showed that a much higher dose of boron was unable to produce a standard yield. Maximum grain yield of mung bean recorded in T_3: boron@ 3 $kgha^{-1}$. On the basis of the production skill of grain yield, the treatments can be arranged in the order of $T_3 > T_4 > T_5 > T_6 > T_2 > T_1$. The study also revealed that boron@ 3 $kgha^{-1}$ may be recommended for boosting the mung bean yield. Research also has proved that the addition of boron upgraded soil fertility.

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