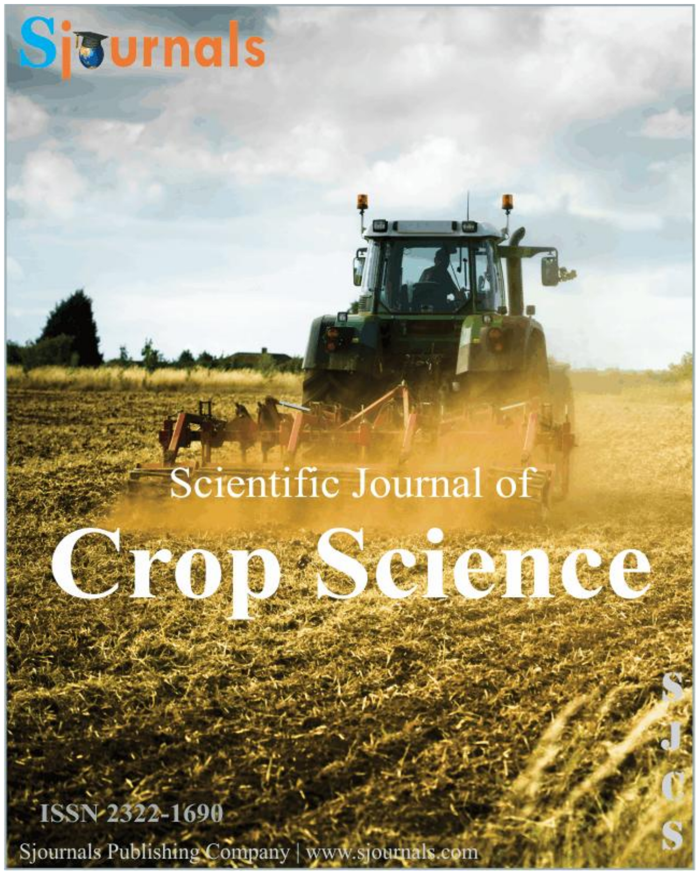
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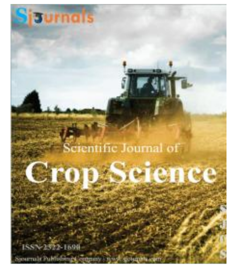

Original article

Growth and yield response of mungbean (*Vignaradiata* L.) as influenced by sulphur and boron application

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The present investigation was carried out at the Agronomy Research Field, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh in 2014 to evaluate the growth and yield response of mungbean to different sulfur and boron levels. It was designed in a randomized complete block design (factorial concept) with three replications. In this study yield traits and yield of mungbean was influenced by different levels of sulfur (S_0=0, S_1=22.22 and S_2=44.44kg ha^{-1}) and boron (B_0=0, B_1=1.0and B_2=2.0kg ha^{-1}). The maximum plant height (39.63 cm), root length (8.55 cm), total pods per plant (8.22), pod length (6.83 cm), number grains per pod (6.66), grain yield (1.60 t ha^{-1}), biological yield (2.21t ha^{-1}) and harvest index (72.25%) were recorded from the combined application of 22.22 kg ha^{-1} sulphur and 2.0 kg ha^{-1} boron. The interaction of 2.0 kg ha^{-1} boron (B_2) with 22.22 kg sulphur per hectare (S_1) produced significantly highest value of yield attributes and yields over other treatments.

1. Introduction

Mungbean (*Vignaradiata* L. Wilczek) is a major seed legume among the pulses in Asia. It ranks the second position in case of acreage and production in Bangladesh. It is a good source of protein and various important micronutrients. It contains 59.9% carbohydrate, 24.5% protein and 75 mg calcium, 8.5 mg iron, 49 mg β-carotene per 100g of split dal (Afzal et al., 2004). The foliage and stems using as fodder for livestock. It synthesizes N in symbiosis with *Rhizobia* and enriches the soil. It fixes atmospheric N that improves the fertility status of soil and can fix N in soil by 63-342 kg ha^{-1} per season (Anjum et al., 2006; Kaisher et al., 2010). The importance of pulses is very much pertinent for food and improving the farm-family income in order to ensure food security, nutritional security and economic security.

Fertilizers greatly influenced in the crop production. The recommendation of fertilizer for soils and crops is a dynamic process and the management of fertilizers is one of the important crop production factors that greatly affect the growth, development and yield of mungbean (Rafiqul Hoque et al., 2004; Singh et al., 2013). Sulphur is an important macro nutrient element, next to NPK that has a profound effect on pulse crops. In broad sense, the functions of nitrogen and sulphur are similar and they are synergistic. Sulphur plays an inseparable role for synthesis of amino-acids like cystine, cystein, methionine, hormone and vitamins. The application of sulfur increases the concentration as well as total uptake of N, P, K, Ca, S, Zn and B at different stages of crop growth (Agrawal et al., 2000). Lack of S causes retardation of terminal growth and root development. S deficiency induced chlorosis in young leaves and decrease seed yield by 45% (BARI, 2004). Intensive cultivation of high yielding varieties of rice, non-judicious chemical fertilization, higher cropping intensity without proper replenishment of nutrient elements and organic matter and very limited use of organic matter are the most probable reasons for sulphur deficiency. Boron occupies third position among the micronutrients and has a major role in plant cell wall and membrane constancy (Bassil et al., 2004). It increases the leaf area expansion, 1000- seed weight, nodule formation, seed yield and biological yield as well as the growth and yield and growth of plants. Sulphur and boron has a great importance on yield and yield components of mungbean (Halwai et al., 2016) and soybean (Jamal et al., 2010). The different levels of sulphur and boron significantly varied the plant height, total pods $plant^{-1}$, pod length, grains pod^{-1}, 1000-seed weight and yield.

The farmers of Bangladesh generally grow mungbean with almost no fertilizer. It is noted that a standard level of combination (sulphur and boron) gives better yield of mungbean. So, there is an ample scope of increasing the yield of mungbean by using balanced fertilization including sulfur and boron containing fertilizer. Considering the above facts the present research was aimed to determine the effects of sulphur and boron on the growth and yield of mungbean.

2. Materials and methods

The present experiment was carried out at the Agronomy Field Laboratory, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur, Bangladesh during February to May 2014. The experiment was laid in fairly uniform topography and well-drained soil, which had invariably poor fertility status. The soil of the experimental unit belongs to the textural class sandy loam with low drainage. It was acidic in reaction, poor in nitrogen as well as phosphorus and moderate in potash. The experimental treatments were laid out in a randomized complete block design (RCBD) with three replications. The experimental unit was divided into 3 blocks with 9 unit plots of $10m^2$ (4 m x 2.5 m) size in each plot. Three levels of sulphur viz. 0 kg, 22.22 kg, and 44.44 kg ha^{-1} and three levels of boron viz. 0 kg, 1.0 kg and 2.0 kg ha^{-1} were used as factorial experiment.

BARI Mung-6, a promising and recommended mungbean variety, was selected for the investigation. The experimental field was prepared as necessary to obtain a desirable tilth and fertilized the plots at the rate of 40, 85 and 40 kg ha^{-1} of urea, triple super phosphate and muriate of potash, respectively. One-half urea and all fertilizers were applied at the time of final land preparation and the rest urea was top-dressed at 30 days after sowing (DAS). All agronomic practices were applied as per recommendation. The height of each sample plant was measured unit plot wise from the base to the tip of main stem of the ten sample plants and then averaged. The number of pods $plant^{-1}$ were counted from the total pods of ten sample plants and then averaged. The number of seed $pods^{-1}$ were counted from the pods of each of ten randomly selected plants and then averaged. Plants from the net plot area were harvested, bundled and weighed after sun drying. Thereafter, the material was transferred to threshing floor, threshed, cleaned and recorded grain yield (kg $plot^{-1}$). The difference of the bundle weight and the grain yield gave the straw yield of crops. Yield obtained in kg $plot^{-1}$ were converted to yield in t ha^{-1} by multiplying with appropriate conversion factor. Harvest index (HI) was calculated by using the formula of Gardner et al. (1985) as shown below:

$$\text{Harvest index (\%)} = (\text{Grain yield/Biological yield}) \times 100$$

Analysis of variance" with 'R' command computer programme was used for analyzing the data".

3. Results and discussion

3.1. Plant height

Plant height of mungbean significantly influenced by different levels of sulphur. The fertilizer dose of 22.22 kg S ha^{-1} produced the tallest plant height (36.06 cm) while, the smallest plant height (30.36 cm) was observed from control treatment (Table 1). Sulphur greatly increased the plant height through chlorophyll formation which enhance vegetative growth. The findings of the study reconfirm the results of Kaisher et al. (2010). Boron had significant influenced on plant height. The maximum (35.08 cm) and minimum plant height was recorded from 2.0 kg B ha^{-1} and 2.70 kg B ha^{-1}, respectively (Table 2). It may be due to enhance the differentiation of tissue, cell division and nitrogen absorption from the soil, enhance plant growth, ultimately plant height, boron plays an important role. Singh et al. (2014) found that, addition of boron improved the seedling height. There was significant effect of sulphur and boron on the plant height. In the treatment combination of S_1B_2 (22.22 kg S ha^{-1} and 2.0 kg B ha^{-1}) produced thetallest plant (39.63 cm) while the smallest plant (29.67 cm) was recorded from 0 kg S ha^{-1} and 2.0 kg B ha^{-1} (Table 3).

3.2. Root length

The root length showed significant variation at various sulphur levels. The highest root length (7.24 cm) was recorded from 22.22 kg S ha^{-1} while the minimum (5.4 cm) was recorded from normal treatment (Table 1). This result might be due the sulphur enhanced the root elongation. Similar results were also recorded by Singh and Yadav (1997) and Verma and Yadav (2004). The application of boron exerted a significant effect on root length. The maximum root length (6.94 cm) was recorded from 2.0 kg B ha^{-1} and the minimum for control (5.79 cm) (Table 2). Application of boron improved the root length (Dutta et al., 1984). Root length was positively affected by the integrated application of sulphur and boron. The optimumroot length was observed from 22.22 kg S ha^{-1} and 2.0 kg B ha^{-1} while the minimum was recorded with control sulphur and boron (Table 3).

3.3. Total number of pods $plant^{-1}$

The number of pods per plantvaried significantly due to different levels of sulphur application. Number of pods ranged from 4.87 to 6.78. The maximumand minimum number of pods was found from 22.22 kg S ha^{-1} and 0 kg S ha^{-1}, respectively (Table 1). This result was in full agreement with the finding of Mazed et al. (2015) who recorded the similar result that is the number of pods $plant^{-1}$ increased with increasing sulphur rate. Boron exerted a positive influence on the number of pods $plant^{-1}$. The maximum number of pods $plant^{-1}$ (5.93) was achieved by application with 2.0 kg B ha^{-1} which are statistically similar with other investigations (Table 2). Boron helps to enhance the flower and pollen grain formation which improved the pod number. It was reported that number of pods $plant^{-1}$ increase with the application of boron (Dutta et al., 1984). Both application of sulphur and boron significantly influenced the number of pods/plant. The combination S_1B_2 (22.22 kg S ha^{-1} and 2.0 kg B ha^{-1}) produced the highest number of pods per plant (8.22) and S_0B_2 produced the lowest number (4.08) of pods per plant (Table 3).

3.4. Pod length

Length of pod was found to be higher response to sulphur. The maximum length of pod (6.49 cm) was achieved by application 22.22 kg S ha^{-1} while the minimum one (5.89 cm) was observed by application of 44.44 kg S ha^{-1} (Table 1). The Increase in growth and straw yield might be ascribed to cell division, enlargement and elongation resulting in overall improvement in plant organs associated with faster and uniform vegetative growth of the crop under the influence of sulphur implementations. This result reconfirms the result of Verma and Yadav (2004).

Boron application significantly influenced the length of pod. The longest length of pod (6.16 cm) was produced with 1.0 kg B ha^{-1} and which is statistically similar to the other B fertilizer doses (Table 2). Boron plays a major role in cell division which increases the pod length. Pod length of mungbean greatly influenced by differentlevels of sulphur and boron Mondal et al. (2003) found that sulphur application significantly improved number of seeds pod^{-1} in green gram. The combination S_1B_2 (22.22 kg S ha^{-1} and 2.0 kg B ha^{-1}) produced the highest length of pod (6.83 cm) which was statistically similar with the most of the treatment combination except S_0B_0 (Table 3).

3.5. Grains pod^{-1}

The different sulphur levels had a significant influence on the grains pod^{-1} in mungbean. The maximum number of grain per pods (6.47) was achieved when by application 22.22 kg S ha^{-1} while the lowest one (5.81) was produced with 44.44 kg S ha^{-1} (Table 1). The result revealed that sulphur nutrient might have given metabolic energy to the plant, which enhanced the grain pod^{-1} with increasing sulphur fertilization. Similar result was also reported by Srivastava et al. (2006) in green gram. The number of grain per pod was significantly influenced by the level of boron. The fertilizer dose of 2.0 kg B ha^{-1} produced the highest number of grain per pod (6.09) which is the statistically similar with all of the treatments (Table 2). According to Rerkasemand Jamjod (1997) application of borax increased the number of seeds pod^{-1} in green gram (*Vignaradiata*). The combined application different levels of sulphur and boron showed significant influence ongrain number/pod. The number of grains per pod greatly influenced by sulphurs and boron.

3.6. Hundred grains weight

Sulphur exerted significant effect on 100-grains weight of mungbean. The treatment combination of S_2 (44.44 kg S ha^{-1}) and S_0 (0 kg S ha^{-1}) produced the highest (5.64 g) and lowest weight of 100-grains (4.97 g), respectively. (Table 1). The highest (5.42 g) 100-grains weights was found from 2.0 kg B ha^{-1} and the lowest (5.08 g found at control (Table 2). Carbohydrate metabolism, sugar and starch formation greatly influenced by boron, which increased the size and weight of grain. Boron application increased 100-seeds weight was recorded by Zaman et al. (1996). Interaction of sulphur and boron level had significant influence in respect of 100-grains weight. The combination S_2B_1 (2.70 kg B ha^{-1} and 44.44 kg S ha^{-1}) produced the highest 100-grains weight (5.83 g) which is statistically similar with S_2B_2. The lowest 100-grains weight (4.71 g) was produced by the combination S_0B_0 (0 kg B ha^{-1} and 0 kg S ha^{-1}) (Table 3). The size and weight of grain, which increased 100-grains weight by the different levels of sulphur and boron.

3.7. Grain yield (t ha^{-1})

Sulphur application significantly increased the grain yield. (Table 1). The grain yield ranges from (0.79 -1.28 t ha^{-1}) was obtained with 22.22 kg S ha^{-1} and in control, respectively (t ha^{-1}). The application of S significantly increased grain yield of mungbean was reported by Mondal et al. (2003). Gormus and EL Sabagh, (2016) recorded that application of sulphur improved the productivity of cotton. Boron significantly influenced the grain yield of mungbean (Table 2). The more grain yield was (1.09 t ha^{-1}) observed from B_2 (2.0 kg B ha^{-1}) which was statistically identical with B_1 fertilization (Table 2). Saha et al. (1996) recorded that adding 5 kg borax gave the maximum yield of green gram. The grain yield of mungbean greatly varied due to different levels of sulphur and boron. The combination S_1B_2 (22.22 kg S ha^{-1} and 2.0 kg B ha^{-1}) and S_0B_0 (0 kg S ha^{-1} and 0 kg B ha^{-1}) produced the highest (1.60 t ha^{-1}) and lowest grain yield (0.74 t ha^{-1}), respectively (Table 3). Boron enhanced the pollination by creating the stigma receptive and sticky that helps in grain fertility. Number of grains per pod increased due to reduction of flower sterility. It was observed that 1.5 kg Zn ha-1 + 1.0 kg B ha-1 of was achieved the optimum yield and yield components of mungbean (Islam et al., 2017).

3.8. Stover yield (t ha^{-1})

Sulphur levels significantly influenced on the stover yield of mungbean. The highest stover yield (0.70 t ha^{-1}) was obtained from S_1 (22.22 kg S ha^{-1}) treatment and the lowest one (0.53 t ha^{-1}) was found from S_0 (0 kg S ha^{-1}) treatment (Table 1). There was observed that a significant influence of boron on the stover yield of mungbean. The highest stover yield (0.63 t ha^{-1}) was from 2.0 kg B ha^{-1} which is statistically similar to the stover yield of 0.58 t ha^{-1} which was obtained from 1.0 kg B ha^{-1} (Table 2). The stover yield of mungbean was significantly affected by the combined influence of sulphur and boron rate. The highest stover yield (0.88 t ha^{-1}) was obtained with 22.22 kg S × 0 kg B ha^{-1} and the lowest from control (Table 3). This result confirms the result reported by Halwai et al. (2016).

3.9. Biological yield (t ha^{-1})

Sulphur significantly influenced the biological yield of mungbean. Ferilization of S_1 (22.22 kg S ha^{-1}) and S_0 (0 kg S ha^{-1}) produced the maximum (1.98 t ha^{-1}) and minimum biological yield (1.32 t ha^{-1}), respectively (Table 1). The application of boron significantly influenced the biological yield of mungbean. Statistically the highest biological yield (1.68 t ha^{-1}) was found from B_2 (2.0 kg B ha^{-1}) which is statistically similar to the other treatments (Table 2). The biological yield of mungbean showed greater variation due to the combined influence of sulphur and boron application. The highest (2.21 t ha^{-1}) and lowest biological yield (1.24 t ha^{-1}) were obtained from the combination S_1B_2 (22.22 kg S ha^{-1} and 2.0 kg B $ha^{-1}$$S_0B_0$, respectively (Table 3). These results were in agreement with those concluded by Singh (2004).

3.10. Harvest index (%)

Sulphur application had significant influence on harvest index of mungbean. The highest harvest index (65.82%) was obtained from 0 kg S ha^{-1} which is statistically similar with the S_1 fertilization and the minimum harvest index was recorded (59.37%) with 0 kg S ha^{-1} (Table 1). Harvest index was positive influenced by boron level. More harvest index was recorded (64.76%) from 2.0 kg B ha^{-1} than the harvest index (60.27%) found from 0 kg B ha^{-1} (Table 2). Harvest index of mungbean was significantly influenced by the interaction of sulphur and boron level. The maximum harvest index (72.25%) was produced from the combination of S_1B_2 (22.22 kg Sha^{-1} and 2.0 kg B ha^{-1}) and the minimum harvest index was recorded from S_1B_0 (Table 3). Similar results were found by Ganie et al. (2014) and Halwai et al. (2016).

Table 1
Effect of sulfur on plant height (PH), root length (RL), total pods per plant (TP), pod length (PL), grains per pod (GP), hundred grains weight (HGW), grain yield (GY), stover yield (SY), biological yield (BY) and harvest index (HI).

Sulfur	PH (cm)	RL (cm)	TP	PL (cm)	GP	HGW (g)	GY tha^{-1}	SY tha^{-1}	BY tha^{-1}	HI (%)
S_0	30.46c	5.40c	4.87c	5.90b	5.96b	4.97c	0.79c	0.53b	1.32c	59.37b
S_1	36.06a	7.24a	6.78a	6.49a	6.47a	5.28b	1.28a	0.70a	1.98a	64.06a
S_2	35.34b	6.24b	5.84b	5.89b	5.81b	5.64a	1.05b	0.54b	1.59b	65.82a
LSD	0.07	0.05	0.453	0.67	0.230	0.071	0.041	0.041	0.058	3.947
CV (%)	0.21	0.90	5.94	11.00	2.91	1.03	3.04	5.35	2.75	4.79

Mean values within column with different letters are significantly ($p<0.05$) different, S_0=0 $kgSha^{-1}$, S_1= 22.22 $kgSha^{-1}$ and S_2= 44.44 $kgSha^{-1}$.

Table 2
Effect of boron on plant height (PH), root length (RL), total pods per plant (TP), pod length (PL), grains per pod (GP), hundred grains weight (HGW), grain yield (GY), stover yield (SY), biological yield (BY) and harvest index (HI).

Boron	PH (cm)	RL (cm)	TP	PL (cm)	GP	HGW (g)	GY tha^{-1}	SY tha^{-1}	BY tha^{-1}	HI (%)
B_0	33.82b	5.79c	5.60a	5.99a	6.07a	5.08b	0.95b	0.63a	1.59a	60.27b
B_1	32.97c	6.16b	5.93a	6.16a	6.09a	5.41a	1.07a	0.58a	1.66a	64.22a
B_2	35.08a	6.94a	5.96a	6.12a	6.08a	5.42a	1.09a	0.59a	1.68a	64.76a
LSD	0.07	0.06	0.37	0.67	0.210	0.045	0.056	0.097	0.121	3.775
CV (%)	0.21	0.90	6.17	11.01	3.36	0.83	5.43	16.20	7.29	5.83

Mean values within column with different letters are significantly ($p<0.05$) different, B_0=0 $kgBha^{-1}$, B_1= 1.0 $kgBha^{-1}$ and B_2= 2.0 $kgBha^{-1}$.

The combined application of 22.22 kg ha^{-1} sulphur and 2.0 kg ha^{-1} boron produced the maximum plant height (39.63 cm), root length (8.55), total pods per plant (8.81), pod length (6.83 cm), number grains per pod (7.06), grain yield (1.49 tha^{-1}), biological yield (2.10 tha^{-1}) and harvest index (70.80).

Table 3
Interaction effect of sulfur and boron levels on plant height (PH), root length(cm), total pods per plant (TP), pod length (PL), grains per pod (GP), hundred grains weight (HGW), grain yield (GY), stover yield (SY), biological yield (BY) and harvest index (HI).

Interactions	PH (cm)	RL (cm)	TP	PL (cm)	GP	HGW (g)	GY tha^{-1}	SY tha^{-1}	BY tha^{-1}	HI (%)
S_0B_0	30.08h	5.15h	5.24c	5.56b	5.51c	4.71e	0.74e	0.50b	1.24e	59.56cde
S_0B_1	31.64g	5.71f	5.30c	5.96ab	6.20b	5.09d	0.92d	0.56b	1.48d	61.65bcd
S_0B_2	29.67i	5.35g	4.08d	6.17ab	6.19b	5.13d	0.71e	0.53b	1.24e	56.89de
S_1B_0	33.48e	6.50d	5.84bc	6.26ab	6.30ab	5.21c	1.05c	0.88a	1.94b	54.22e
S_1B_1	35.08d	6.66c	6.29b	6.38ab	6.45ab	5.31b	1.19b	0.61b	1.80bc	65.69abc
S_1B_2	39.63a	8.55a	8.22a	6.83a	6.66a	5.31b	1.60a	0.61b	2.21a	72.25a
S_2B_0	37.91b	5.72f	5.74bc	6.17ab	6.40ab	5.32b	1.07c	0.53b	1.60cd	67.01ab
S_2B_1	32.19f	6.10e	6.20b	6.15ab	5.62c	5.83a	1.12bc	0.59b	1.70c	65.31abc
S_2B_2	35.94c	6.91b	5.59bc	5.35b	5.42c	5.78a	0.95d	0.50b	1.46d	65.13abc
LSD	0.13	0.09	0.65	1.16	0.364	0.079	0.097	0.168	0.21	6.553
CV (%)	0.21	0.86	6.17	11.01	3.36	0.83	5.43	16.20	7.29	5.83

Mean values within column with different letters are significantly ($p<0.05$) different, S_0= 0 $kgSha^{-1}$, S_1= 22.22 $kgSha^{-1}$ and S_2= 44.44 $kgSha^{-1}$, B_0=0 $kgBha^{-1}$, B_1= 1.0 $kgBha^{-1}$ and B_2= 2.0 $kgBha^{-1}$.

3.11. Coefficient of correlation

Correlation coefficient on the yield and yield components of mungbean are presented in the Table 4. Significant ($P<0.05$) and positive correlations were observed between the plant height and the root length. Correlation between the plant height and the total pods per plant was only highly significant. Mungbean plants having both more pods per plant and the taller plant height potentially produced higher grain yield. Pods per plant and plant height were significant correlated with seed yield, whileseed size was non-significant correlated with seed yield (Hakim, 2008). The total pods per plant exerted a positive significant correlation with yield, but non-significant correlations with pod length, hundred grains weight, stover yield, biological yield and harvest index. Sandhu et al. (1979) reported that seed size negatively correlated with number of pods per cluster and pods per plant. The pod length and hundred grains weight exerted a negative and significant effect. The negative correlations between seed yield and 100-seed weight and/or between seed yield and pod length were also recently recorded by Gul et al. (2008) and Tabasum et al. (2010). Hundred grains weight had no significant correlation with all the traits. The biological yield with stover yield and harvest index presented positive and negatively correlated. The biological yield and harvest index had no significant correlation among the traits. The significant associations between pod length with seeds per pod and 100 seed weight (Biradar, 2007).

Table 4
Estimation of correlation coefficient for various characters combination of mungbean.

	PH	RL	TP	PL	HGW	SY	BY	HI	GY
PH	1	0.779**	0.767**	-0.421	0.461	0.086	0.544	0.276	0.725*
RL		1	0.891**	-0.414	0.501	0.286	0.818	0.178	0.951
TP			1	-0.194	0.355	0.229	0.764	0.203	0.919**
PL				1	-0.653*	-0.294	-0.401	0.115	-0.325
HGW					1	0.029	0.341	0.237	0.479
SY						1	0.754**	-0.884**	0.175
BY							1	-0.364	0.778
HI								1	0.298
GY									1

PH= Plant height (CM), RL=root length (cm), TP=Total pods per plan, PL=Pod length (cm), GP= Grains per pod, HGW=Hundred grains weight (g), GY= Grain yield (tha^{-1}), SY =Stover yield (tha^{-1}), BY=Biological yield (tha^{-1}) and HI= Harvest index (%).

4. Conclusion

Considering the findings from the present study, it can be summarized that application of 22.22 kg sulphur ha^{-1} with 2.0 kg ha^{-1} boron was observed the most suitable for optimizing the yield of mungbean.

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