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GROWTH AND YIELD OF MUNGBEAN (*VIGNA RADIATA* L.) IN RESPONSE TO THE APPLICATION OF SULPHUR AND BORON UNDER RAINFED CONDITIONS

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ABSTRACT

A field experiment was conducted during the kharif season of 2013–14 to study the effect of sulphur (S) and boron (S) on growth and yield of mungbean (*Vigna radiata* L.). The treatment combinations comprised four levels of sulphur (0, 10, 20 and 30 kg ha^{-1}) and three levels of boron (0, 100 and 200 ppm) in randomized block design with three replications. The maximum plant height (68.90 cm) and maximum number of leaves (35.75) were recorded significantly higher over control at 60 DAS with sulphur application at the rate of 30kg ha^{-1}. Likewise, the maximum plant height (67.57 cm) and maximum number of leaves (34.51) were recorded significantly higher over control at 60 DAS with boron application at the rate of 200 ppm. However, data regarding number of branches was found non significant with different levels of sulphur and boron. Moreover, both seed and stover yield of mungbean was significantly higher and peak values were 502.7, 490.6 and 1504.5, 1437.1 kg ha^{-1}, respectively at sulphur level of 30kg ha^{-1} and boron level of 200 ppm. Similar trend was observed in case of number of root nodules. Hence, sulphur and boron are important nutrients for better production and productivity of mungbean.

INTRODUCTION

Pulses are the most favoured crops in semi-arid tropics on account of their less input requirement, intrinsic capacity of biological nitrogen fixation, less water requirement deep rooting-system and high temperature tolerance (Kanwar, 1986). The current productivity of rainfed agriculture is 1 to 1.5 tonnes ha^{-1} only, nevertheless, it has a potential for two to four times the present productivity (Wani *et al.* 2012). In India, pulses are the prominent source of protein in vegetarian diet. Mungbean (*Vigna radiata* L.) is an important pulse crop of India belonging to family Leguminaceae. The nutrient management of mungbean is one of the key factors to scale up the production and quality. Our soils are in the grip of multinutrient deficiency. Therefore, the yields of pulses are held back due to deficiencies of sulphur (S). The demand of sulphur for mungbean like other pulses is higher than cereals because of their high protein content. Heavy sulphur mining through crop removal and extensive use of high analysis fertilizers of nitrogen, phosphorous and potassium (NPK) free of sulphur with concomitant leaching losses are some of the factors responsible for its impoverishment in Indian soils. Sulphur plays pivotal role in synthesis of sulphur containing aminoacids like cysteine, cystine and methionine, besides glutathione (Kokani *et al.*, 2014). Thus, judicious and balanced use of sulphur is of paramount importance in increasing pulse production and to combat protein calorie malnutrition of populace.

Besides sulphur, boron (B) is another essential element for all vascular plants, whose deficiency or excess cause impairment in various metabolic and physiological processes including cell wall structure and function. Boron has critical role in growing tissues and any imbalance may inhibit the vegetative and reproductive growth in plants. Its deficiency might lead to inappropriate adsorption of NPK and S in different field crops including mungbean. Legumes require higher amounts of boron than non-legume crops. Thus, addition of boron is essential for optimum yield of mungbean. The per capita availability of pulses in the country is decreasing due to extreme population pressure and shrinking agricultural land which is a matter of serious concern (Prajapati *et al.*, 2013). To avert this problem it is necessary to promote pulse production in the country which can be achieved by the balanced fertilization. Therefore, for plant nutrition a balanced fertilization program with micro- and macro-nutrients is very crucial for high yield and high quality products (Sawan *et al.*, 2001). Taking into consideration the vital roles of sulphur and boron in terms of growth, yield and quality of mungbean, balanced nutrition of crop with appropriate amounts of S and B is of relevance. In order to ascertain the aforementioned facts the study entitled growth and yield of mungbean (*Vigna radiata L.*) in response to the application of sulphur and boron under rainfed conditions was undertaken.

MATERIALS AND METHODS

The experiment was conducted during the kharif season of 2013-14 at the Rajola Farm of the Faculty of Agricultural Sciences, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot - Satna (Madhya Pradesh) located at 24°31′N latitude and 81°15′E longitude at an altitude of 306 m above mean sea level. The climate of the region is semi-arid and sub-tropical having cold winter and hot summer. The temperature drops below 2°C in winter while in the summer the temperature reaches above 45°C; hot dessicating winds (Loo) are regular feature during summers whereas they may be occasional spell of frost during the winters. The average rainfall in the area is approximately 90-100 cm, with maximum downpour during the monsoon *i.e.* July-November with a few occasional showers during the rainy months. The meteorological data of the study area in terms of temperature, rainfall and humidity is presented in figure 1. The soil of the study area was sandy loam in texture having pH (7.78), EC (0.26 dSm^{-1}), organic carbon (0.33%), available N (202.36 kg ha^{-1}), available P (16.12 kg ha^{-1}), available K (246.22 kg ha^{-1}) and available S (15.88 kg ha^{-1}) analyzed by standard methods in the laboratory (Table 1). The experiment was laid out in randomized block design having twelve treatments with three replications and four levels of sulphur (0, 10, 20 and 30kg ha^{-1}) and three levels of boron (0,100 and 200 ppm). The field was prepared by two time harrowing, planking and removal of stubbles and weeds. The summer mungbean variety "Samrat (PDM-139)" was sown in rows, 30 cm apart at a seed rate of 25 kg ha^{-1}. The recommended dose of chemical fertilizers (20:40:20 kg NPK ha^{-1}) in the form of urea, diammonium phosphate and muriate of potash was applied as basal application for all treatments. The crop was thinned after complete germination to maintain a plant to plant spacing of 10 cm; five plants were selected randomly from each plot to measure the growth and yield attributes. The growth characters plant height (cm), branches per plant, leaf number, and nodule number and number of branches per plant were studied and subsequent observations were recorded at 20, 40 and 60 days after sowing (DAS) and yield (kg ha^{-1}) was recorded. The harvesting of border rows in the plot was carried out just after the maturity of the crop and the produce of net plot was considered as the crop biomass of the respective treatments. The data was subjected to statistical analysis separately by using Analysis of Variance Technique. The difference among treatment means was compared by using least significant difference test at 5% probability levels (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth Parameters

The parameters plant height, number of branches per plant, leaf number, and nodule number were recorded at three stages, viz., 20, 40 and 60 days after sowing (DAS) except number of nodules which was recorded only at 40 DAS; a stage having maximum nodulation. The plant height was significantly influenced by sulphur. The tallest plant was found in 30 kg S ha^{-1} whereas the shortest was found in control. All the levels of sulphur resulted in significant enhancement in plant height at 20 DAS. Among the treatments of sulphur S_{10} was significantly superior to S_{20}, but S_{10} and S_{30} were statistically at par. At 40 DAS sulphur levels resulted in about three times increase in plant height regardless of different treatments on mean basis as compared to 20 DAS. The plant height at this stage varied from 47.95 cm to 53.64 cm; S_{20} gave the highest value and S_0 (control) gave the lowest. All the levels of sulphur were significantly superior to S_0. Significant differences were also found between S_{10} and S_{20} and S_{20} and S_{30}. It was observed that the plant height increased in the order of 7.88%, 10.61% and 8.08% by S_{10}, S_{20} and S_{30}, respectively over control. At 60 DAS there was a linear and significant increase in plant height from 61.95 cm in control to 68.90 cm in S_{30}. The percent increase in plant height over control were 7.17% in S_{10}, 8.88% in S_{20} and 10.09% in S_{30} (Table 2). Similar results were observed by Kaisher *et al.,* 2010 and Tahir *et al*., 2013. They reported that application of 30 kg S ha^{-1} was optimum for plant height. The reason may be attributed to the fact that sulphur is involved in the formation of chlorophyll thereby promotes vegetative growth; consequently, increases plant height (Kaisher *et al.,* 2010). The plant height varied significantly due to boron level. The tallest plant was observed with 200 ppm B level and shortest in control. In case of boron levels the plant height varied from 15.81 (in control) to 18.96 cm at 20 DAS. The increase in plant height was linear and significant for each increase in boron levels. The magnitude of increase was 11.89% in case of B_1 and 16.65% in B_2 over B_0. The main effects of boron were significant in case of plant height at 40 DAS. B_2 was significantly superior to control but B_1 was only numerically, better than control. The increase in plant height may be ascribed to the fact that boron plays a crucial role in the development and differentiation of tissue, cell division and nitrogen absorption from the soil, therefore, increase plant growth and eventually plant height (Kaisher *et al.,* 2010). It was concluded that height of the plant is influenced by sulphur and boron levels individually and by their combination. Himanshu *et al.* (2008) reported that application of sulphur at the rate of 40 kg ha^{-1} (elemental S) increased the plant height of summer mungbean.

Sulphur application significantly influenced the number of branches per plant. The maximum number (35.08) was observed in 10 kg ha^{-1} and lowest in control. It was observed that at initial stage the number of branches was very less varying between 3.84 and 4.96 in case of sulphur treatments and 4.23 to 4.74 in boron treatments. All the sulphur levels were significantly better than control but S_{10}, S_{20} and S_{30} did not differ significantly among themselves. However, S_{20} and S_{30} were statistically at par. The increase in number of branches was 14.86% in case of S_{10} and 22.70% in S_{20} and S_{30} over control. The effect of boron was not significant. At 40 DAS the number of branches nearly doubled as compared to 20 DAS. All the sulphur levels were significantly superior over control. The highest number was in S_{10} followed by S_{30} and then S_{20} in that order. At 60 DAS the number of branches increased by approximately 4 times as compared to that of 40 DAS, regardless of the treatments. S_{10} gave the highest branch number and the lowest one was recorded in control. All the sulphur levels were significantly better than control but did not vary significantly among themselves. The increase in number of branches per plant over control was 19.62%, 17.22% and

Table 1: Physicochemical properties of the soil

Soil Property	Values	Method used
Texture (sandy loam)		Hydrometer Method (Bouyoucos,1962)
Sand (%)	52	
Silt (%)	22	
Clay (%)	26	
Organic carbon (%)	0.15	Walkley and Black Wet oxidation method (Jackson, 1973)
Soil pH	8.10	Glass electrode pH meter (Jackson, 1973)
EC (dSm^{-1} at 25 ^0C)	0.15	Conductivity bridge meter (Richards, 1954)
Available nitrogen (mg kg^{-1})	54.50	Alkaline permagnate method (Subbiah and Asija, 1956)
Available potassium (kg ha^{-1})	246.22	1N neutral Ammonium acetate method (Hanway and Heidel,1952)
Available phosphorous (kg ha^{-1})	16.12	0.5M Sodium bicarbonate method (Olsen *et al*. 1954)
Available sulphur (kg ha^{-1})	15.88	Turbiditmetric procedure (Enisminger, 1954)

Table 2: Growth and yield parameters of the mungbean as influenced by different levels of sulphur and boron

Treatments	Plant height (cm) 20 DAS	40 DAS	60 DAS	Number of branches 20 DAS	40 DAS	60 DAS	Number of leaves 20 DAS	40 DAS	60 DAS	Number of root nodules	Seed yield (kg/ha)	Stover yield (kg/ha)
Sulphur levels												
S_0: 0 kg/ha (control)	15.26	47.95	61.95	3.84	7.67	28.20	11.39	23.79	21.20	5.65	448.2	1355.4
S_{10}: 10 kg/ha	19.02	52.05	66.74	4.51	10.72	35.08	14.66	31.35	34.06	7.33	470.5	1363.2
S_{20}: 20 kg/ha	17.54	53.64	67.99	4.96	9.70	34.06	13.53	32.26	34.06	7.64	487.3	1469.8
S_{30}: 30 kg/ha	18.45	52.16	68.90	4.96	10.04	34.18	17.03	33.16	35.75	8.18	502.7	1504.5
Mean	17.57	51.45	66.40	4.57	9.53	32.88	14.15	30.14	31.27	7.20	477.2	1423.2
SE.m ±	0.71	0.89	1.33	0.34	0.62	1.36	0.62	1.63	1.02	0.29	12.2	30.6
CD(p= 0.05)	1.46	1.84	2.75	0.71	1.29	2.82	1.29	3.39	2.11	0.60	25.3	63.4
Boron levels												
B_0: 0 ppm (control)	15.81	49.79	64.49	4.23	9.31	31.38	13.11	29.01	32.56	6.45	460.1	1389.3
B_1: 100 ppm	17.94	51.25	67.14	4.74	9.39	32.91	14.13	30.45	33.58	7.37	480.8	1443.4
B_2: 200 ppm	18.96	53.30	67.57	4.74	9.90	34.34	15.23	30.96	34.51	7.77	490.6	1437.1
Mean	17.57	51.45	66.40	4.57	9.53	32.88	14.16	30.14	33.55	7.20	477.2	1423.2
SE.m ±	0.61	0.77	1.15	0.30	0.54	1.18	0.54	1.41	0.88	0.25	10.5	26.5
CD(p= 0.05)	1.27	1.59	2.38	N.S.	N.S.	N.S.	1.12	N.S.	N.S.	0.52	21.9	54.9

*NS = non significant

17.49% in S_{10}, S_{20} and S_{30}, respectively. Nevertheless, variations in number of branches due to boron spray were not significant (Table 2). The increase in number of branches per plant may be attributed to the fact that sulphur is involved in chlorophyll formation, therefore, promotes vegetative growth and number of branches (Singh and Yadav, 1997). Moreover, boron and interaction of sulphur and boron were statistically non significant. The results are in line with those of Kaisher *et al.,* 2010 and Tahir *et al*., 2013.

Number of leaves per plant was significantly influenced by the application of different levels of sulphur. The highest number of leaves per plant was obtained with 30 kg S ha^{-1} whereas lowest was observed in control. The results revealed that all the levels of sulphur had significantly higher number of leaves than control at 20 DAS. S_{20} gave slightly lower value than S_{10} but the differences were not significant. However, S_{30} gave significantly higher leaves number than S_{10} and S_{20}. The results were also significant for boron sprays than control and increase was linear. Both B_1 and B_2 gave significantly higher leaf number than B_0 and B_1 and B_2 were at par. At 40 DAS, S_{10}, S_{20} and S_{30} gave significantly higher leaf number over S_0 (control) but S_{10}, S_{20} and S_{30} were at par. However, increasing trend due to boron sprays was not significant. Irrespective of different treatments leaf number increased by two times at 40 DAS as compared to 20 DAS. At 60 DAS there was no marked increase in leaf number as compared to 40 DAS. All the sulphur levels were statistically significant and superior to control. S_{10} and S_{20} were at par and S_{30} was significantly superior to S_{10} and S_{20}. Among the sulphur doses S_{30} produced the highest number of leaves at all the stages of growth. Regarding boron, B_2 gave the highest value at 60 DAS but the same was not significant statistically (Table 2). The increase in number of leaves per plant may be assigned to the fact that sulphur plays a crucial role in plant growth and development processes owing to its presence in sulphur containing amino acids. The number of leaves increased with application of boron but was statistically non significant. Since, increased sulphur supply enhances tissue differentiation. Similar results were confirmed by (Mengel and Kirkby, 1987 and Devi *et al*. 2012 in soyabean).

Root nodulation is the distinguishing feature of legumes and is important site for nitrogen fixation. Application of sulphur had profound effect on nodulation of mungbean. The number of nodules per plant was significantly influenced by application of sulphur. The highest number of nodules per plant (35.75) was found with application of sulphur at the rate of 30 kg ha^{-1} and lowest was found in control. This observation was recorded only at 40 DAS, a stage having maximum nodulation. All the levels of sulphur produced higher number of nodules over control. Among the levels S_{10} and S_{20} were at par but S_{30}

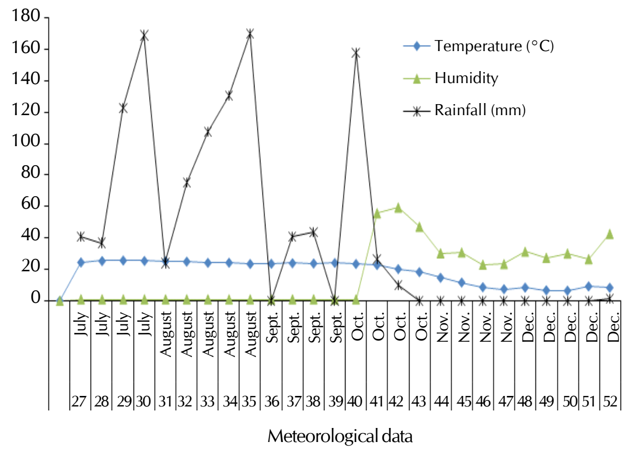

Figure 1: Meteorological data from July–Dec 2013 recorded during experiment

gave significantly higher number than S_{10} and S_{20}. The number of nodules per plant varied from 5.65(S_0) to 8.18 (S_{30}) (Table 2). The increment in nodulation with increasing levels of sulphur may be due to increase in amount of ferrodoxin. Ferrodoxins are copious in sulphur and contain Fe-S clusters that play a pivotal role in nitrogen fixation (Ali et al., 2004). Similar results were confirmed by Ganie *et al*. 2014 in French bean. Likewise, boron showed significant influence on root nodulation. B_1 and B_2 were significantly superior over B_0 (control) but B_1 and B_2 were not significantly different although B_2 was numerically higher than B_1. It was evident that S_{30} and B_2 were the best treatments in respect of nodulation (Table 2). It may be ascribed to the fact that boron enhances root nodulation. The results are in conformity with Tahir *et al*. 2013.

Sulphur application resulted in increased plant growth perhaps due to sulphur deficiency in soil (Rego *et al.,* 2007). The fact that sulphur application increased the root and shoot length have been reported by Lluch *et al*. (1983) in phaseolus crop. Similar results have been ascertained by several workers (Srinivasarao *et al.,* 2000, Patel *et al.,* 2010). Boron application increased the plant height and improved the other growth parameters (Krishna, 1995). The fact that boron application along with sulphur increased all the biometric characters including plant height has been reported by Sekhawat and Shivay (2012) in green gram.

Yield parameters

The effect of different levels of sulphur nutrition on seed and stover yield was found statistically significant. The highest seed and stover yield (502.7 and 1504.5 kg ha^{-1}, respectively) was achieved by application of 30 kg S ha^{-1} (Table 2). Boron too had significant effect on seed and stover yield of mungbean. However, maximum seed yield (490.6 kg ha^{-1}) was obtained with supply of 200 ppm boron whereas maximum stover yield (1443.4 kg ha^{-1}) with the supply of 100 ppm boron (Table 2). In both cases the minimum yield (seed and stover) was observed in control. Under rainfed conditions this yield level might be considered satisfactory. The main effects of sulphur and boron levels were significant but S x B interaction was not significant. Sulphur application resulted in a linear increase in grain yield from S_0 to S_{30}. Although, S_{10} was slightly below the significant level but S_{20} and S_{30} were significant. The increase in yield was 4.72%, 8.02% and 10.83% in S_{10}, S_{20} and S_{30}, respectively over control. Thus, S_{20} and S_{30} were highly rewarding levels. B_1 and B_2 were significantly better than B_0. The main effects of boron levels were also significant. B_1 was significantly different from B_0 and so was B_2. But B_1 and B_2 were not significantly different from each other. The magnitude of increase was of the order of 4.3% and 6.2% in B_1 and B_2 over control. The general mean yield was 477.2 kg ha^{-1}. Use of two boron sprays was better than one spray for optimum yields. Thus, S_{30} and B_2 were superior to all other treatments. Increase in the yield might be ascribed to key metabolic role of sulphur and boron in respect of growth, nodulation, pod setting, carbohydrate and protein synthesis as reported by several researchers (Anita *et al*. 2012). Based on the key metabolic roles of sulphur and boron, several authors have reported increased yield in mungbean and other pulses (Srinivasarao, 2010).

Stover yield followed the same trend of variation as described for seed yield and the theoretical reasons ascribed for seed yield are applicable to stover yield also. The results were significant for main effects of S and B but the interaction of S x B was not significant. S_{10} was not significantly different from S_0 but S_{20} and S_{30} were significant. The magnitude of yield increase was 0.57% in B_1 and 7.25% in case of B_2. The results are in conformity with those of Srinivasarao, 2010; Himanshu *et al*. 2008; Singh and Yadava, 1997.

From the above investigation, it is concluded that sulphur and boron have spectacular impact in enhancing the growth and yield of mungbean. Application of 30 kg S ha^{-1} and 200 ppm boron resulted in achievement of maximum growth and yield attributes of summer mungbean variety "Samrat (PDM-139)". Therefore, this combination of sulphur and boron is economical under rainfed conditions. Hence, sulphur and boron are important nutrients for better production and productivity of mungbean. This study will be helpful in order to create awareness within agrarian community about the importance of balanced use of fertilizers to obtain maximum production.

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