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RESEARCH PAPER

Effect of Different Levels of Sulphur with *Rhizobium* on Growth and Yield of Mungbean (BARI mung 6)

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ABSTRACT

The present investigation was carried out at the Department of Soil Science, Patuakhali Science and Technology University (PSTU), Patuakhali, Bangladesh in 2013 to evaluate the growth and yield response of mungbean to different level of sulphur with *Rhizobium*. It was designed in a randomized complete block design with three replications. In this study yield and yield contributing characters of mungbean was influenced by different levels of sulphur with *Rhizobium* viz. T_1: *Rhizobium* + Sulphur 0 kg ha^{-1}, T_2: *Rhizobium* + Sulphur 15 kg ha^{-1}, T_3: *Rhizobium* + Sulphur 30 kg ha^{-1} and T_4: *Rhizobium* + Sulphur 45 kg ha^{-1}. Results indicate that the seed inoculation with *Rhizobium* showed some good results. The maximum plant height (52.37 cm), leaf per plant (36.50), branches per plant (23.60), root length (38.92cm), leaf area (25.06 cm^2), nodule plant^{-1} (15.34), dry shoot weight (7.15 g), dry root weight (0.721 g) , total pods per plant (22.48), pod length (8.34 cm), number grains per pod (6.57),1000-seed weight (35.47g) and grain yield (2.04 t ha^{-1}), were recorded from the combined application of sulphur @ 30 kg ha^{-1} with *Rhizobium*.

Key words: Mungbean, *Rhizobium*, Sulphur, Plant parameter

Introduction

Mungbean 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 comprises 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 foliages and stems are 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). Nutrient management is one of the most important factors that greatly affect the growth, development and yield of mungbean. Sulphur has long been recognized as an essential nutrient element for plant and now a day, sulphur is considered as 4th major essential plant nutrient after nitrogen, phosphorus and potassium. It is one of the essential plant nutrients for all plants and is indispensable for the growth and metabolism and is essential for protein synthesis. 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. Sulphur deficiency induced chlorosis in young leaves and decrease seed yield by 45% (BARI, 2004). *Rhizobium* being one of the most important biofertilizer is used in modern agriculture. Rhizobium converts atmospheric nitrogen into ammonia, which is utilized by the plants, by symbiotic association. The process occurs within the root nodules, which are red or pink inside. This attributes to beneficial effects of *Rhizobium* inoculation, which has been primarily related to increase in the nitrogen uptake as a consequence of nitrogen fixation. *Rhizobium* is very much commonly used bio-fertilizer in legume crops which not only accelerates the nitrogen uptake of plants but also enhances the soil fertility. It is also seen that the crop of greengram, when inoculated with efficient *Rhizobium* strain shows favourable effect on growth attributes physiological parameters and yield components of greengram (Sarkar and Pal, 2006). The farmers of Bangladesh usually do not use bacterial biofertilizer in pulse production though they have an ample scope to increase yield by using this type of fertilizer. Biofertilizer is used in mungbean cultivation through the inoculation of effective *Rhizobium* strain can be an attractive alternative of expensive chemical fertilizer. Yield increases up to 10 to 37% by *Rhizobium* inoculation have been reported by Rao (1980). *Rhizobium* inoculation in mungbean increases number of pods and seed yield (Ashraf *et al*., 2003; Bhuian, 2004). Thakur and Panwar (1995) found an increase in yield of mungbean with *Rhizobium* seed inoculation. The farmers of Bangladesh generally grow mungbean with almost no fertilizer. It is noted that a standard level of combination (sulphur with *Rhizobium*) gives better yield of mungbean. So, there is an ample scope of increasing the yield of mungbean by using balanced fertilization including sulfur with *Rhizobium* fertilizer. Considering the above facts the present research was aimed to determine the effect of different levels of sulphur with *Rhizobium* on growth and yield of mungbean.

Materials and methods

The present research work was carried out in the experimental research farm, of the Department of Soil Science, Patuakhali Science and Technology University, Patuakhali during the period from December, 2012 to March 2013, to study the effect of different levels of sulphur with *Rhizobium* on growth and yield of mungbean. The experimental location was situated geographically at $22^0 37'$ N latitude and $89^0 10'$ E longitudes. The area is covered by Gangetic Tidal Floodplains and falls under Agroecological Zone “AEZ–13”. The area lies at 0.9 to 2.1 meter above mean sea level (Iftekhar and Islam, 2004). The experimental treatments were laid out in a randomized complete block design (RCBD) with three replications. The experimental unit was divided into 3 blocks and unit plots of 12 m^2 (4 m x 3.0 m) sizes in each plot. Four levels of sulphur with *Rhizobium* viz. T_1: *Rhizobium* + Sulphur 0 kg ha^{-1}, T_2: *Rhizobium* + Sulphur 15 kg ha^{-1}, T_3: *Rhizobium* + Sulphur 30 kg ha^{-1} and T_4: *Rhizobium* + Sulphur 45 kg ha^{-1}. 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 10, 40 and 10 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. Data on plant characters were recorded at different stages (30, 45, 60 and 75 DAS) *viz,* plant height, leaf per plant, branches per plant, root length, leaf area, dry weight of shoot, dry weight of root, while yield contributing attributes *viz.* number of pod per plant, pod length, number of seed per pod thousand seed weight and seed yield per hectare were recorded at harvest. The data obtained from experiment on various parameters were statistically analyzed in MSTAT–C computer program (Russel, 1986). The mean values for all the parameters were calculate and the analysis of variance for the characters was accomplished by Duncan’s Multiple Range Test (DMRT) and the significance of difference between pair of means was tested by the Least Significant Differences (LSD) test at 5 % levels of probability (Gomez and Gomez, 1984).

Results and discussion

The results and discussion of the investigations on effect of different levels of sulphur with *Rhizobium* on growth and yield of mungbean (BARI mung 6) are being presented under following heads.

Growth parameters

Plant height:

The plant height of mungbean as influenced by different treatments was taken at 30, 45 60 and 75 DAS. The period between 30 to 75 DAS was found to be at maximum growth of all the treatments. Table 1 shows that the plant height was found highest with treatment T_3 (*Rhizobium* + sulphur @ 30 kg/ha) at all growth stages. At 30 DAS the maximum plant height was found (12.89 cm), at 45 DAS the maximum plant height was (41.52cm), at 60DAS the maximum height (52.37cm) and at 75DAS the maximum height (61.56cm). The shortest plant height was found in T_1 (*Rhizobium*+ S_0) treatment. These results indicated that, plant height was gradually increased due to the increase in sulphur doses up to 30 kg ha^{-1}. Almost similar result was found by Kumar *et al*. (2012) and Kaisher *et al.* (2010). The result might be due to the fact that sulphur greatly increased the plant height through chlorophyll formation which enhances vegetative growth.

Number of leaves plant^{-1}

Number of leaf plant^{-1} increased significantly through the application of sulphur with *Rhizobium* on mungbean at all stages of growth. The mean data on the number of leaves plant^{-1} of mungbean for 30, 45, 60 and 75DAS are presented in the Table 1. At 30 DAS the maximum number of leaves plant^{-1} (9.02), at 45 DAS the highest number of leaves plant^{-1} (19.76), at 60 DAS the maximum number of leaf plant^{-1} (26.93) and at 75 DAS the highest number of leaves plant^{-1} (36.50) was found in treatment T_3 (*Rhizobium* + sulphur @ 30 kg/ha) which was significantly different from and superior to all other treatments and lowest number of leaves plant^{-1} was obtained in treatment T_1(*Rhizobium*+S_0). Similar trends were obtained by Kaisher *et al.* (2010).

Number of branch plant^{-1}

Significant variation was found on branch per plant production due to various treatments (Table 2). The highest number of branches plant^{-1} (9.34, 13.85, 19.06 and 23.60) at 30, 45, 60 and 75 DAS, respectively was observed in 30 kg S ha^{-1} with *Rhizobium* (T_3) which was

Table 1. Effect of sulphur with *Rhizobium* inoculation on plant height and number of leaves plant $^{-1}$

Treatment	Plant height (cm)				Number of leaves plant $^{-1}$			
	30	45	60	75	30	45	60	75
T_1: *Rhizobium* + S_0	8.43 c	23.50 d	31.33 d	41.55 d	5.96 d	12.61 d	18.63 c	24.57d
T_2: *Rhizobium* + S_{15}	10.91 b	35.45 c	45.72 c	52.61 c	7.17 c	15.10 c	24.24 b	31.01c
T_3: *Rhizobium* + S_{30}	12.89 a	41.52 a	52.37 a	61.56 a	9.01 a	19.76 a	26.93 a	36.50a
T_4: *Rhizobium* + S_{45}	11.9 4ab	39.04 b	50.48 b	56.60 b	7.58 b	17.67 b	25.17 b	34.73b
CV%	4.19	2.60	2.12	3.56	5.71	4.32	3.22	2.31
Sig. level	**	**	**	*	**	**	**	**

S_0 : 0 kg S ha^{-1}, S_{15} : 15 kg S ha^{-1}, S_{30} : 30 kg S ha^{-1}, and S_{45} : 45 kg S ha^{-1} **= significant at 1% level of probability and *= significant at 5% level of probability. The figures in a column having common letter(s) do not differ significantly at 5% level of probability

Table 2. Effect of sulphur with *Rhizobium* inoculation on number of branch plant^{-1} and leaf area of plant (cm^2).

Treatment	Number of branch plant^{-1}				Leaf area of plant (cm^2)			
	30	45	60	75	30	45	60	75
T_1: *Rhizobium* + S_0	4.93 d	8.58 d	12.25 c	14.86 d	10.04 d	13.73 d	20.71 c	23.92 d
T_2: *Rhizobium* + S_{15}	6.16 c	11.66 c	16.35 b	18.78 c	14.09 c	17.94 c	26.26 b	32.68 c
T_3: *Rhizobium* + S_{30}	9.34 a	13.85 a	19.06 a	23.60 a	17.89 a	21.84 a	32.33 a	38.92 a
T_4: *Rhizobium* + S_{45}	8.05 b	13.01 b	17.99 b	21.84 b	15.77 b	19.15 b	28.13 b	37.31 b
CV%	4.59	3.22	2.52	3.81	4.09	3.20	2.22	4.01
Sig. level	**	**	**	**	**	**	**	**

S_0: 0 kg S ha^{-1}, S_{15}: 15 kg S ha^{-1}, S_{30} : 30 kg S ha^{-1}, and S_{45} : 45 kg S ha^{-1} **= significant at 1% level of probability and *= significant at 5% level of probability. The figures in a column having common letter(s) do not differ significantly at 5% level of probability

significantly different from and superior to all other treatments and the lowest number of branches plant^{-1} (4.93, 8.58, 12.25 and 14.86), respectively was found in treatment T_1 (*Rhizobium*+S_0). Similar results were also obtained by Rahman *et al*. (2002) in 40 kg P ha^{-1} with *Rhizobium.*

Leaf area of plant
Effect of sulphur with *Rhizobium* on the leaf area of plant was found to be statistically significant (Table 2). The maximum leaf area of plant (17.89, 21.84, 32.93 and 38.92 cm^2) was found in T_3 (*Rhizobium* + 30 kg S/ha) treatment at 30, 45, 60 and 75 DAS, respectively, which was significantly different from and superior to all other treatments and lowest leaf area of plant (10.04, 13.73, 20.71 and 23.92 cm^2) was found in treatment T_1 (*Rhizobium*+S_0*).*

Root length
A significant variation was obtained in respect of root length due to the effect of different levels of sulphur with *Rhizobium* application at 30, 45, 60 and 75 DAS growth stages (Table 3). The tallest root length (6.61, 14.63, 21.30 and 25.06 cm) was found in T_3 (*Rhizobium* + 30 kg S ha^{-1}) treatment which was significantly different and superior to all other treatments and the lowest root length (3.79, 7.74, 10.59 and 12.87 cm) was found in T_1 (*Rhizobium* + S_0) treatment.

Nodule plant^{-1}
The mean data on the number of nodules plant^{-1}of mungbean for 30, 45, 60 and 75 DAS are presented in the Table 3. Nodule plant^{-1} increased significantly through the application of sulphur with *Rhizobium* on mungbean. Nodule plant^{-1} increased continuously up to 45 DAS. At 30 DAS, the maximum number of nodule plant^{-1} (7.72), at 45 DAS the maximum number of nodule plant^{-1} (15.34), at 60 DAS the maximum number of nodule plant^{-1} (9.08) and at 75 DAS the maximum number of nodule plant^{-1} (4.83) was recorded in treatment T_3 (*Rhizobium* + 30 kg S ha^{-1}). So it can be inferred from the result that inoculation with *Rhizobium* with sulphur @ 30 kg/ ha gives good result in terms of nodulation. Therefore, it is essential to go for inoculation with suitable *Rhizobium* strains application of optimum sulphur level so that highest crop yield may be obtained. Similar effect was also found by Patal *et al.* (2013) and Rahman *et al*. (2008) at 40 kg P/ha with *Rhizobium*. Chowdhury *et al.* (1998) found that 50 kg P_2O_5/ha with

Table 3. Effect of sulphur with *Rhizobium* inoculation on root length and number of nodule plant $^{-1}$

Treatment	Root length (cm)				Nodule plant^{-1}			
	30	45	60	75	30	45	60	75
T_1: *Rhizobium*+ S_0	3.79 d	7.74 d	10.59 d	12.87 d	4.65 d	7.62 d	5.61 c	2.66 d
T_2:*Rhizobium*+ S_{15}	4.750c	9.04 c	15.41 c	19.83 c	5.67 c	12.90 c	7.85 b	3.72 c
T_3: *Rhizobium* + S_{30}	6.61 a	14.61 a	21.30 a	25.06 a	7.72 a	15.34 a	9.08 a	4.83 a
T_4: *Rhizobium* + S_{45}	5.71 b	12.32 b	20.43 b	22.00 b	6.13 b	13.87 b	8.11 b	4.00 b
CV%	4.36	3.51	5.28	4.81	3.19	3.2	3.32	2.56
Sig. level	**	**	*	*	**	**	**	**

S_0: 0 kg S ha^{-1}, S_{15}: 15 kg S ha^{-1}, S_{30} : 30 kg S ha^{-1}, and S_{45} : 45 kg S ha^{-1} **= significant at 1% level of probability and *= significant at 5% level of probability. The figures in a column having common letter(s) do not differ significantly at 5% level of probability

Table 4. Effect of Sulphur with *Rhizobium* inoculation on dry shoot and root weight

Treatment	Dry shoot weight (g)				Dry root weight (g)			
	15	30	45	60	15	30	45	60
T_1: *Rhizobium*+ S_0	2.36 c	3.59 c	4.66 c	5.33 d	0.158 c	0.217 c	0.378 c	0.432 c
T_2:*Rhizobium*+ S_{15}	2.69 b	4.41 b	5.62 b	6.63 c	0.268 b	0.387 b	0.475 b	0.596 b
T_3: *Rhizobium* + S_{30}	2.99 a	4.91 a	5.98 a	7.15 a	0.326a	0.461 a	0.580 a	0.721 a
T_4: *Rhizobium* + S_{45}	2.90 a	4.79 a	5.76 b	6.88 b	0.290 ab	0.407 b	0.510 b	0.646 b
CV%	2.28	4.57	3.22	3.34	4.21	3.51	4.02	4.06
Sig. level	**	**	**	**	**	**	**	**

S_0: 0 kg S ha^{-1}, S_{15} : 15 kg S ha^{-1}, S_{30} : 30 kg S ha^{-1}, and S_{45} : 45 kg S ha^{-1} **= significant at 1% level of probability and *= significant at 5% level of probability. The figures in a column having common letter(s) do not differ significantly at 5% level of probability.

Table 5. Effect of Sulphur with *Rhizobium* inoculation on number of pod per plant, pod length, seeds per pod and 1000 seed weight and yield

Treatment	Number of pod plant^{-1}	Pod length	Number of seed pod^{-1}	1000-seed weight (g)	Grain yield (t ha-1)	Grain yield increase over control (%)
T_1: *Rhizobium*+ S_0	16.11d	6.89 c	3.85 d	28.60 d	1.14 d	-
T_2: *Rhizobium* + S_{15}	17.64 c	7.52 b	5.18 c	32.17 c	1.71 c	31.9
T_3: *Rhizobium* + S_{30}	22.48 a	8.34 a	6.57 a	35.47 a	2.04 a	44.1
T_4: *Rhizobium* + S_{45}	19.64 b	7.28 b	5.50 b	33.90 b	1.912 b	40.3
CV%	2.54	1.30	1.35	2.34	2.33	-
Sig. level	**	**	**	**	**	-

S_0: 0 kg S ha^{-1}, S_{15} : 15 kg S ha^{-1}, S_{30} : 30 kg S ha^{-1}, and S_{45} : 45 kg S ha^{-1} **= significant at 1% level of probability and *= significant at 5% level of probability. The figures in a column having common letter(s) do not differ significantly at 5% level of probability.

other fertilizers increased 245% nodule number over control. Khanam *et al.* (1993) also found the similar results with lentil.

Dry shoots weight (g):

Dry shoot weight increased significantly through the application of sulphur with *Rhizobium* on mungbean (Table 4). At 30 DAS the maximum dry shoot weight (2.99 g), at 45 DAS, the highest dry shoot weight (4.91 g), at 60 DAS, the highest dry shoot weight (5.98 g) and at 75 DAS, the highest dry shoot weight (47.15 g) was found in treatment T_3 (*Rhizobium* + 30 kg S ha^{-1}) which was significantly different from other treatments but statistically similar with that of T_4 (*Rhizobium* + 45 kg S ha^{-1}) treatment at 30 DAS and 45 DAS and the lowest dry weight of shoot was found in T_1 (*Rhizobium* + S_0) treatment. Similar reported by Khan *et al.* (2017) is more or less similar to these findings.

Dry root weight (g):

Dry root weight of mungbean influenced significantly by the application of sulphur with *Rhizobium*. The results of dry root weight at 30, 45, 60 and 75 DAS have been presented in (Table 4). The highest dry root weight (0.326, 0.461, 0.580 and 0.721 g) was found in T_3 (*Rhizobium* + 30 kg S ha^{-1}) treatment which was significantly different from and superior to all other treatments and lowest dry root weight (0.158, 0.217, 0.378 and 0.432 g) was found in T_1 (*Rhizobium*+ S_0) treatment. Similar results reported by Khan *et al.* (2017) and Erman *et al.* (2009).

Yield components:

Number of pods plant^{-1}

The number of pods $plant^{-1}$ was found statistically significant due to the application of different sulphur levels with *Rhizobium* (Table 5). The highest number of pods $plant^{-1}$ (22.48) was recorded in plants applied with 30 kg S ha^{-1} with *Rhizobium* inoculant (T_3) and the lowest number of pods $plant^{-1}$ was recorded in T_1 (*Rhizobium* + S_0). The result of the present study was similar with Pravin Kumar *et al.* (2012) and Kaisher *et al.* (2010) who reported that number of pods $plant^{-1}$ in mungbean was significantly affected by application of sulphure. The present study revealed that application of 30 kg S ha^{-1} with *Rhizobium* favors pod formation.

Pod length (cm)

The pod length was found statistically significant due to the application of different sulphur levels with *Rhizobium* (Table 5). The pod length ranged from 8.34 cm to 6.89 cm. The longest pod (8.34 cm) was produced in plants applied with 30 kg S ha^{-1} with *Rhizobium* inoculation. The lowest pod length (6.89 cm) was produced with treatment T_1 (*Rhizobium* + S_0). Kaisher *et al.* (2010) found similar results and as sulphur helps in seed formation and increases seeds per pod, which ultimately increases the pod length.

Number of seed pod^{-1}

Number of seed per pod was affected significantly by different sulphur levels with *Rhizobium* (Table 5). The seed per pod ranged from 6.57 to 3.58. The Maximum seed per pod (6.57) was produced in plants applied with 30 kg S ha^{-1} with *Rhizobium* (T_3). The lowest seed per pod (3.58) was produced with the treatment T_1 (*Rhizobium* + S_0) . The result revealed that sulphur nutrient might have given metabolic energy to the plant, which enhanced the grain pod^{-1} with increasing sulphur fertilization. It was observed that *Rhizobium* inoculant in association with S led to increase the number of seeds per pod of mungbean. Similar results were also reported by Pravin Kumar *et al.* (2012) and Kaisher *et al* (2010). Sarder (2002) found similar result with this study who reported that higher doses of chemical fertilizer were effective on mature pods $plant^{-1}$ and number of seed pod^{-1}.

1000-Seed weight

Thousand-seed weight (g) was found statistically significant due to the application of different sulphur with *Rhizobium* inoculation (Table 5). Thousand-seed weight ranged from 35.47 g to 28.60 g. The Maximum 1000-seed weight (35.47 g) was produced in plants applied with 30 kg S ha^{-1} with *Rhizobium* inoculation (T_3) which was significantly different from and superior to all other treatments. The minimum 1000-seed weight ((28.60 g) was produced with T_1 (*Rhizobium* + S_0). Similar results were also obtained by Pravin Kumar *et al* (2012) and Kaisher *et al* (2010) found similar result.

Grain yield (kg ha^{-1})

Sulphur application with *Rhizobium* significantly increased the grain yield (Table 5). The Seed yield of mungbean was significantly influenced by different levels of sulphur with *Rhizobium* inoculants (Table 5). The highest seed yield (2.04 t ha^{-1}) was found with treatment T_3 (*Rhizobium*+30 kg S ha^{-1}) which were statistically superior to all other treatment. The treatment T_3 (*Rhizobium*+30 kg S ha^{-1}) produced the highest seed yield (2.04 t ha^{-1}) which was 44.12% higher grain yield than the control The application of S significantly increased grain yield of mungbean was reported by Pravin Kumar *et al.* (2012) and Kaisher *et al*.(2010).

Conclusion

Considering the findings from the present study, it can be summarized that application of 30 kg sulphur ha-^{1} with *Rhizobium* was observed the most suitable for optimizing the yield of mungbean**.** There is enough scope to explore and exploit the production of mungbean in Bangladesh through using *Rhizobium* technology along with sulphur.

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