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Effect of *Rhizobium* Inoculation and Different Levels of Phosphorus and Sulphur on Growth and Yield of Green Gram (*Vigna radiata L.*) in Dehradun, India.

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ABSTRACT

Nutrients like nitrogen, phosphorus and sulphur plays a very important role in the cultivation of Moong crop. The response of green gram to varying levels of Rhizobium, phosphorous, and sulphur was analysed in the present research. The study was conducted at Crop Research Farm, Institute of Agriculture Training in Dehradun, Uttarakhand, India. The experiment followed a Factorial Randomized Block Design (RBD) with 12 treatments each with three replicates. The treatments included Rhizobium inoculation (inoculated and uninoculated) phosphorous (50, 60,70 kg/ha), and Sulphur (5,10 kg/ha) doses in a plot size of 2m×2m. The results demonstrated the significant role of these nutrients in enhancing green gram productivity offering valuable insights into sustainable crop management practices. Data analysis revealed that the most effective treatment for improving the quality characters and yield is Rhizobium inoculation with 5kg/ha sulphur + 60kg/ha phosphorous under the agro-ecological conditions of Dehradun.

Introduction

Green gram, locally called as Moong or mung [*Vigna radiata* (L.)] belongs to the family, Leguminaceae. It is a significant pulse crops of India accounting for 65% of its global acreage and 54% of the total production. The cultivation area has increased from 1.99 million ha in 1964-65 to 3.54 million ha in 2018-2019. While production has risen from 0.60 million tonnes to 1.81 million tonnes during the same period. Green gram plays a vital role in soil fertility improvement as it can symbiotically fix atmospheric N_2 (20-25 $kgha^{-1}$) through root nodules.

In India it contributes 14% in total pulse area and 7% in total pulse production in India. Pulses are reowned for their high protein content (220-250 g/kg) second only to fish (dry) with (335 g protein/kg) and easy digestibility provide an answer in persisting problem of malnutrition. As all the pulses crops belongs to leguminaceae family, inoculation with efficient *Rhizobium* strain and fertility management are essential important place aspect of their production technology of these crops. The present study aims to assess any interaction effect of phosphorus and sulphur with and without *Rhizobium* inoculation, on growth and yield of green gram.

Materials and Methods

Study area

The present field experiment was conducted at Crop Research Farm, Institute of Agriculture Training in Premnagar, Dehradun, Uttarakhand, India in *Zaid* season of 2023. The city is located at 25.28° N latitude and 81.54° E longitude, 410 m above mean sea

level. Various parameters were considered and data was recorded for plant height, leaf area index (LAI), number of leaves, dry matter etc. and yield components such as, grain yield and 1000-grain weight at different intervals of the growing season.

Experimental Design

The experiment was laid out in the month of April, 2023.The field was prepared to the fine tilth. Thinning and gapping was done on 37th day after sowing. Insecticide and Herbicide application was done at intervals. The harvesting was done in the month of July. Randomized block design (factorial) was laid with 12 treatment combinations each replicated thrice which resulted in a total replication of 36 plots. The treatments combines specifications of the layout, etc., are given below.

Details of Treatment

A) **Levels of *Rhizobium***

Rh_0 :uninoculated
Rh_1 :inoculated

B) **Levels of Phosphorous**

P_1:50 $kgha^{-1}$
P_2:60 $kgha^{-1}$
P_3:70 $kgha^{-1}$

C) **Levels of Sulphur**

S_1:5 $kgha^{-1}$
S_2:10 $kgha^{-1}$

The experiment design allows for the comprehensive evaluation of the impact of Rhizobium inoculation, phosphorous levels, and sulphur levels on the growth and yield of green gram under local condition in Dehradun, India.

Table 1: Treatment combinations

Treatment No.	Treatment combination	Treatment Description
T_1	Rh_0 P_1 S_1	Rh_0 = non treated P_1=50 × S_1=5
T_2	Rh_0 P_1 S_2	Rh_0 = non treated P_1=50 × S_2=10
T_3	Rh_0 P_2 S_1	Rh_0 = non treated P_2=60 × S_1=5
T_4	Rh_0 P_2 S_2	Rh_0 = non treated P_2=60 × S_2=10
T_5	Rh_0 P_3 S_1	Rh_0 = non treated P_3=70 × S_1=5
T_6	Rh_0 P_3 S_2	Rh_0 = non treated P_3=70 × S_2=10
T_7	Rh_1 P_1 S_1	Rh_1 = treated P_1=50 × S_1=5
T_8	Rh_1 P_1 S_2	Rh_1 = treated P_1=50 × S_2=10
T_9	Rh_1 P_2 S_1	Rh_1 = treated P_2=60 × S_1=5
T_{10}	Rh_1 P_2 S_2	Rh_1 = treated P_2=60 × S_2=10
T_{11}	Rh_1 P_3 S_1	Rh_1 = treated P_3=70 × S_1=5
T_{12}	Rh_1 P_3 S_2	Rh_1 = treated P_3=70 × S_2=10

Agronomic practices adopted

To ensure optimal conditions for sowing, and crop growth following agronomical practices were adopted. The experimental field was thoroughly ploughed and harrowed to create a fine, tilth, providing a suitable seed bed for sowing. Seed treatment was carried out using *Rhizobium* at the rate of 25 g per kg of seed.This treatment to increase nodulation, growth and ultimately yield of crop. The seeds were inoculated with *Rhizobium* by preparing slurry with jagerry (gur) solution. 120 gm of (gur) *i.e.*jagerry was dissolved in 1 liter of water and boiled for half an hour and then cooled. After cooling, *Rhizobium* was added at the rate of 25 gm/kg seed and then kept for shade drying of the inoculated seeds.

Vigna radiate L. CV. SML 668 variety was selected for sowing which takes around 60-65 days to mature. Seeds were sown in line manually on 28 h of April 2023. Seeds were covered with soil immediately after sowing the seeds. The spacing adopted was (plant to plant 10 cm and row to row 30 cm) was according to the treatment details and the seeds were drilled at 3-4 cm depth.

Fertilizers were applied as side placement, for which 4-5 cm deep furrows were made along the seed rows with a *hand hoe*. The nutrient sources were, diammonium phosphate (DAP) and to fulfill the requirement of P_2O_5 and S/ha. The recommended dose of 20 kg N per ha was applied. Whole of nitrogen, phosphorus and sulphur was applied as basal at the time of sowing. Picking was done only when pods were found turning blackish brown or black in colour. This colour started appearing at 64 DAS onwards

consecutively up to 70 DAS and so the pickings were done in three slots, 1st at 64 DAS, and 2nd at 66 DAS and finally 3rd at 68 DAS.

Results

Plant height (cm)

The highest plant height was observed in the highest treatment $R_1P_2S_1$ (*Rhizobium* + phosphorus @ 60 kg/ha+ Sulphur @ 5 kg/ha). The maximum plant height recorded by *Rhizobium* application was 62.11cm; S_1 (5 kg Sulphur ha^{-1}) was 59.17 cm and in case of phosphorus treatments significant highest plant height was recorded by treatment P_2 (60 kg phosphorus ha^{-1}) was 57.25 cm.

Leaf area index (%)

The leaf area index was found highest with treatment $R_1P_2S_1$ (*Rhizobium* + phosphorus @ 60 kg/ ha+ Sulphur @ 5 kg/ha). Maximum leaf area index was recorded by S_1 (5 kg Sulphur ha^{-1}). In case of phosphorus treatments significant highest leaf area index was recorded by treatment P_2 (60 kg phosphorus ha^{-1}).

Plant dry weight (g)

The dry weight $plant^{-1}$ was found highest with treatment $R_1P_2S_1$ (*Rhizobium* + phosphorus @ 60 kg/ ha+ Sulphur @ 5 kg/ha). Maximum dry weight $plant^{-1}$was recorded by S_1 (5 kg Sulphur ha^{-1}). In case of phosphorus treatments significant highest dry weight $plant^{-1}$was recorded by treatment P_2 (60 kg phosphorus ha^{-1}).

Grain yield (q ha^{-1})

Data on harvest stages of crop plant were collected in term of grain yield are presented below.

The grain yield was found highest with treatment $R_1P_2S_1$ (*Rhizobium* + phosphorus @ 60 kg/ ha+ Sulphur @ 5 kg/ha). Maximum grain yield was recorded by S_1 (5 kg Sulphur ha^{-1}). In case of phosphorus treatments significant grain yield was recorded by treatment P_2 (60 kg phosphorus ha^{-1}).

Table 2. Effect of different treatments on growth components

Treatments		20 DAS			40 DAS			60 DAS		
		Plant height	Leaf Area Index	Dry Weight	Plant height	Leaf Area Index	Dry Weight	Plant height	Leaf Area Index	Dry Weight
***Rhizobium* (R)**										
R_0	Uninoculated	25.79	1.23	3.67	50.53	2.96	8.87	54.80	4.93	15.28
R_1	Inoculated	30.67	1.28	4.75	57.06	3.08	11.09	62.11	5.13	22.33
F – test		S	NS	NS	S	S	S	S	S	S
S. Ed. (±)		0.05	-	-	0.11	0.05	0.01	0.07	0.04	0.07
CD(P=0.05)		0.09	-	-	0.23	0.09	0.03	0.13	0.08	0.14
Phosphorus (P)										
P_1	50 kg ha^{-1}	26.20	1.27	3.71	50.94	3.04	9.29	55.79	5.06	15.83
P_2	60 kg ha^{-1}	30.27	1.27	4.71	57.25	3.05	10.78	60.97	5.08	21.75
P_3	70 kg ha^{-1}	28.22	1.24	4.21	53.20	2.97	9.87	58.62	4.94	18.83
F – test		S	NS	NS	S	S	S	S	S	S
S. Ed. (±)		0.06	-	-	0.14	0.06	0.02	0.08	0.05	0.08
CD(P=0.05)		0.11	-	-	0.29	0.11	0.03	0.17	0.10	0.17
Sulphur (S)										
S_1	5 kg ha^{-1}	28.94	1.24	4.39	54.27	2.99	10.16	59.17	4.98	19.40
S_2	10 kg ha^{-1}	27.51	1.27	4.03	53.32	3.05	9.80	57.74	5.08	18.21
F – test		S	NS	NS	S	S	S	S	S	S
S. Ed. (±)		0.05	-	-	0.11	0.05	0.01	0.07	0.04	0.07
CD(P=0.05)		0.09	-	-	0.23	0.09	0.03	0.13	0.08	0.14
Interaction (R x P)	F – test	S	NS	NS	S	S	S	S	S	S
	S. Ed. (±)	0.08	-	-	0.20	0.08	0.02	0.11	0.07	0.11
	CD(P=0.05)	0.16	-	-	0.40	0.16	0.05	0.23	0.14	0.24
Interaction (P x S)	F – test	S	NS	NS	S	S	S	S	S	S
	S. Ed. (±)	0.08	-	-	0.20	0.08	0.02	0.11	0.07	0.11
	CD(P=0.05)	0.16	-	-	0.40	0.16	0.05	0.23	0.14	0.24
Interaction (R x S)	F – test	S	NS	NS	S	S	S	S	NS	S
	S. Ed. (±)	0.06	-	-	0.16	0.06	0.02	0.09	-	0.09
	CD(P=0.05)	0.13	-	-	0.33	0.13	0.04	0.19	-	0.19

Table 3. Effect of different treatments on yield components

Treatment			Grain yield (q ha^{-1})	Test weight (g)
***Rhizobium* (R)**				
R_0		Uninoculated	8.61	47.23
R_1		Inoculated	11.08	49.96
	F – test		S	S
	S. Ed. (±)		0.03	0.04
	CD (P=0.05)		0.05	0.08
Phosphorus (P)				
P_1		50 kg ha^{-1}	8.98	47.87
P_2		60 kg ha^{-1}	10.74	49.43
P_3		70 kg ha^{-1}	9.82	48.49
	F – test		S	S
	S. Ed. (±)		0.03	0.05
	CD (P=0.05)		0.07	0.10
Sulphur (S)				
S_1		5 kg ha^{-1}	10.13	48.78
S_2		10 kg ha^{-1}	9.57	48.41
	F – test		S	S
	S. Ed. (±)		0.03	0.04
	CD (P=0.05)		0.05	0.08
Interaction (R x P)		F – test	S	S
		S. Ed. (±)	0.05	0.07
		CD (P=0.05)	0.09	0.14
Interaction (P x S)		F – test	S	S
		S. Ed. (±)	0.05	0.07
		CD (P=0.05)	0.09	0.14
Interaction		F – test	S	NS

Discussion

A steady increase in plant height was observed and significantly higher plant height was observed in treatment T_9 $R_1P_2S_1$ (*Rhizobium* treated + phosphorous @60 kg/ha + sulphur @ 5 kg/ha). The data showed that there was a steady increase in number of branches/plant and number of leaves/plant up to 60 DAS. Highest number of branches/plant was observed in treatment T_9, T_{10} and T_{11} with (*Rhizobium* inoculation + phosphorus @ 60 kg/ha, 60 kg/ha and 70 kg/ha and S @ 5, 10 and 5 kg/ha respectively) while highest number of branches/plant was observed in treatment T_9, (*Rhizobium* inoculation + phosphorus @ 60 kg/ha and sulphur @ 5 kg/ha).

Maximum dry weight/plant was observed in treatment T_9 (*Rhizobium* inoculation + P @ 60 kg/ha and sulphur @ 5 kg/ha) and none of the treatment was found significant. CGR was observed with major growth in almost all the treatments and highest CGR was observed in treatment T_9 $R_1P_2S_1$ (*Rhizobium* treated + phosphorous @ 60 kg/ha + sulphur @ 5 kg/ha).A steady increase in RGR was observed during the successive growth intervals at 40 and 60 DAS but decreased at 60 DAS. At 40 and 60 DAS intervals significantly higher RGR was observed in treatment T_{10} $R_1P_2S_2$ (*Rhizobium* treated + phosphorous @ 60 kg/ha + sulphur @ 10 kg/ha).

Rhizobium inoculation, phosphorous and sulphur had non-significant influence on number of pods/plant of green gram. Highest number of number of pods/plant (14.00) was observed in treatment T_{12} (*Rhizobium* treated + phosphorous @ 70 kg/ha + sulphur @ 10 kg/ha) in comparison to other treatments. *Rhizobium* inoculation, phosphorous and sulphur had significant influence on number of grains/pod of green gram. Treatment T_9 $R_1P_2S_1$ (*Rhizobium* treated + phosphorous @ 60 kg/ha + sulphur @ 5 kg/ha), recorded maximum number of grains/pod (12.56).

Rhizobium inoculation, phosphorous and sulphur had significant influence on test weight of green gram, regardless of the sources used. Treatment T_9 $Rh_1P_2S_1$ (*Rhizobium*treated + phosphorous @ 60 kg/ha + Sulphur @ 5 kg/ha), recorded maximum value (51.03 g) of test weight. *Rhizobium* inoculation, phosphorous and sulphur had significant influence on grain yield (q/ha) of green gram. Treatment T_9 $R_1P_2S_1$ (*Rhizobium* treated + phosphorous @ 60 kg/ha + sulphur @ 5 kg/ha) recorded maximum value (12.39 q/ha) of grain yield. *Rhizobium* inoculation, phosphorous and sulphur had significant influence on straw yield of green gram. Treatment T_9 $R_1P_2S_1$ (*Rhizobium* treated + phosphorous @ 60 kg/ha + sulphur @ 5 kg/ha) recorded maximum value (28.26 q/ha) of straw yield.

Rhizobium inoculation, phosphorous and sulphur had significant influence on the harvest index of green gram. Treatment T_9 $Rh_1P_2S_1$ (*Rhizobium* treated + phosphorous @ 60 kg/ha + sulphur @ 5 kg/ha), recorded maximum value (30.48 %) of harvest index. Highest gross return, net return and Benefit Cost Ratio were observed in treatmentT_9 $R_1P_2S_1$ (*Rhizobium* treated + phosphorous @ 60 kg/ha + sulphur @ 5 kg/ha) compared with other treatment combinations.

Conclusions

The use of *Rhizobium* inoculation was found to be beneficial for green gram cultivation. This suggests that the presence of Rhizobium

bacteria which can fix atmospheric N_2into a form that the plant can use, positively impacted the growth and yield of green gram. Then applying phosphorous at the rate of 60kg/ha was identified as an optimal practice for obtaining a higher grain yield. Phosphorous is an essential nutrient for plant growth and the specific application rate in this study proved to be effective. Similarly, applying sulphur at a rate of 5kg/ha was found to be beneficial for green gram cultivation. Sulphur is another essential nutrient that can impact plant growth and yield. The benefit cost ratio (BCR) in green gram cultivation was found to be significant with the highest value being 2.22. This indicates that the investment in the recommend practices (Rhizobium inoculation, phosphorous application and sulphur application) yielded a favorable return in term of crop yield and economic benefits. It is important to note that these findings are based on a one year experiment.

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