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Effect of different levels of sulphur and rhizobium inoculation on soybean (*Glycine max* L. Merril) cv.JS 75-46 in inceptisols

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Abstract: An investigation was conducted on soybean (*Glycine max* L. Merril) during *Kharif* season 2001 at Allahabad to study the performance of crop to *Rhizobium* inoculation and at different levels of sulphur. The dry matter accumulation increased significantly due to the *Rhizobium* and sulphur. The pod numbers per plant, grain yield and stover yield were maximum due to *Rhizobium* inoculation coupled with 30 kg S/ha. The treatment *Rhizobium* inoculation coupled with 45 kg S/ha was found at par with the former. The nodulation and oil content was maximum due to inoculation of *Rhizobium* as well as application of 45 kg S/ha. The treatment *Rhizobium* inoculation + 30 kg S/ha was found at par with above treatment. The *Rhizobium* inoculation significantly affected CGR at 40 DAS and RGR at 40, 60 and 100 DAS. The levels of sulphur were found to affect significantly CGR at 20, 40, 60 and 80 DAS and RGR at 60 and 80 DAS. The interaction between *Rhizobium* and sulphur was found significant in respect of pods/plant, grain yield, stover yield and oil content. The treatment *Rhizobium* inoculation + 30 kg S/ha gave the maximum B:C ratio.

Key words : Soybean, Rhizobium, Sulphur, Oil content, Yield.

Introduction

The area under soybean has been expanding since its introduction in India during mid-sixties. At present it is cultivated in about 5 m ha, occupying the 3rd position among oilseed crops in terms of area and production (Halvanker *et al.* 1999). Soybean is a leguminous crop, which has *Rhizobium* bacteria in their roots for efficient biological fixation of atmospheric nitrogen. It is essential that soybean seeds should be inoculated with suitable strains of *Rhizobium japonicum*. Soybean fixes about 49-130 kg N/ ha (Lee and Wani, 1989). Among biofertilizers, *Rhizobium* inoculants are of the greatest importance. Their importance is generally seen with reference to pulses and leguminous oilseeds.

Sulphur is the fourth major plant nutrient and is as important as nitrogen, phosphorus and potassium (Ram *et al.* 1996). Sulphur is involved in the formation of chlorophyll and thereby encourages vegetative growth. It promotes the nodule formation on the roots of leguminous plants and is essential for the synthesis of certain amino acids and oils. It is also called as 'Master Nutrient' for oilseed production Therefore, the present investigation was aimed to find out the response of soybean to *Rhizobium* inoculation at different levels of sulphur.

Material and Methods

A field experiment was conducted during *Kharif* season of 2001 at Allahabad Agricultural Institute- Deemed University, Allahabad. The treatment combinations comprised of two levels of *Rhizobium* (seed uninoculated and seed inoculated) and four levels of sulphur, (0,15,30 and 45 kg/ha). Biofertilizer was applied as seed treatment and were evaluated in (2x2) Factorial Randomized Block Design (FRBD) with three replications. The soil of the experimental field was sandy loam having pH 7.6 and low in organic carbon (0.21%). The available N_2, P_2O_2 and K_2O were 180, 59 and 377 kg/ha, respectively. The fertilizer rate applied was 70:60:40 kg/ha NPK. Half the dose of N and full doses of P and K were applied as basal. Rest half of the N was applied at flowering and pod formation stages in two equal splits. Data pertaining to dry matter accumulation, crop growth rate (CGR), relative growth rate (RGR), yield attributes, yield and quality parameters were subjected to statistical analysis and were interpreted accordingly.

Table 1. Effect of Rhizobium and different levels of sulphur on growth parameters of soybean

Treatment	Dry weight (g/m^2) Days after sowing					Crop growth rate ($g/day/m^2$) Days after sowing					Relative growth rate ($g/g/day/m^2$) Days after sowing				
	20	40	60	80	100	20	40	60	80	100	20	40	60	80	100
Rhizobium															
Uninoculated	12.25	267.50	638.0	718.0	883.50	0.61	12.53	17.70	6.52	7.32	0.11	0.15	0.83	0.18	0.18
Inoculated	11.25	428.75	783.50	875.75	953.50	0.57	20.86	17.73	6.79	4.32	0.11	0.18	0.48	0.17	0.11
CD (P=0.05)	NS	19.77	53.50	NS	NS	NS	1.01	NS	NS	NS	NS	0.008	0.12	NS	0.06
Levels of Sulphur															
0 kg/ha	10.0	328.50	711.50	716	877.50	0.51	15.92	19.14	3.65	5.75	0.11	0.17	0.80	0.10	0.14
15 kg/ha	14.75	358.75	636.25	710.0	851.50	0.73	17.19	13.12	5.77	7.71	0.12	0.16	0.55	0.17	0.18
30 kg/ha	10.0	373.0	825.0	1000.0	1040.75	0.50	18.14	23.81	8.89	4.31	0.11	0.18	0.71	0.20	0.07
45 kg/ha	12.50	332.25	670.50	761.75	903.0	0.62	15.55	14.81	8.30	5.52	0.12	0.16	0.57	0.22	0.13
CD (P=0.05)	NS	27.97	76.0	NS	NS	0.18	1.44	3.85	3.38	NS	NS	NS	0.17	0.07	NS

The crop growth rate (CGR) was calculated as follows:

$$\text{Mean CGR} = \frac{w_2 - w_1}{t_2 - t_1} \ g/g/day/m^2$$

where w_2 and w_1 are the total dry weight of crop plant in g/m^2 at t_2 and t_1 days respectively.

The relative growth rate (RGR) was calculated as follows:

$$\text{Mean RGR} = \frac{l_n w_2 - l_n w_1}{t_2 - t_1} \ g/g/day/m^2$$

where $l_n w_2$ and $l_n w_1$ are the logs of total dry weight of soybean plants in g/m^2 at t_2 and t_1 days, respectively.

Results and Discussion

Dry matter accumulation

Rhizobium inoculation significantly influenced the dry matter accumulation (g/m^2) at 40 and 60 DAS. The maximum dry matter (953.50 g/m^2) was accumulated by Rhizobium inoculated treatment, which was about 7.92 per cent more than uninoculated at 100 DAS. Among sulphur levels, the maximum dry matter was associated with treatment 30 kg S/ha, whereas the minimum was with the control (0 kg S/ha). The treatment 30 kg S/ha recorded 13.54 and 15.95 per cent more dry matter accumulation than control (no sulphur) at 40 and 60 DAS. Hemantrajan and Trivedi (1997) and Jat *et al.* (1998) also reported significant increase in dry matter production with S-application in soybean.

Crop growth rate

The CGR was recorded at 20,40,60,80 and 100 days after sowing. The *Rhizobium* inoculation significantly effected the crop growth rate of soybean only at 40 DAS. The *Rhizobium* inoculated at 40 DAS recorded 66.48 per cent more CGR than uninoculated. Sulphur had a significant effect on CGR at 40, 60 and 80 DAS. The maximum

Table 2. Effect of Rhizobium and different levels of sulphur on yield attributes, quality parameters of soybean

Treatments	No. of pods/ plant	No. of seeds/ pods	No. of total grains/ plant	1000 seeds weight (g)	Grain yield (q/ha)	Stover yield (q/ha)	Oil content
Rhizobium							
Uninoculated	86.41	2.17	188.98	97.64	21.39	47.50	17.83
Inoculated	113.33	2.23	252.69	98.60	29.35	54.70	19.34
CD (P=0.05)	4.49	0.04	11.95	NS	0.85	6.06	0.44
Levels of Sulphur							
0 kg/ha	83.83	2.13	178.44	98.23	22.47	50.03	16.04
15 kg/ha	100.49	2.23	224.36	98.16	24.27	43.58	17.95
30 kg/ha	110.33	2.27	252.38	98.53	27.81	56.36	19.78
45 kg/ha	104.83	2.18	228.18	97.57	26.83	54.44	20.05
CD (P=0.05)	6.35	0.06	16.90	NS	1.20	8.58	0.63

CD - Critical Difference

Table 3. Effect of different combinations of Rhizobium (uninoculated and inoculated) along with levels of sulphur on yield attributes, quality parameters and economic of soybean

Treatments	No. of pods/ plant	No. of seeds/ pods	Grain yield (q/ha)	Oil content (%)	Net return (Rs/ha)	B:C ratio
Uninoculated + 0 kg S/ha	80.0	2.02	19.43	15.66	7209	1.59
Uninoculated + 15 kg S/ha	84.33	2.25	21.52	17.67	9115	1.73
Uninoculated + 30 kg S/ha	91.66	2.22	22.59	18.33	9996	1.79
Uninoculated + 45 kg S/ha	89.60	2.22	22.03	19.66	9253	1.72
Rhizobium Inoculated + 0 kg S/ha	87.66	2.25	25.51	16.43	13220	2.07
Rhizobium Inoculated + 15 kg S/ha	116.66	2.21	27.02	18.24	14546	2.16
Rhizobium Inoculated + 30 kg S/ha	129.0	2.33	33.03	21.23	20367	2.31
Rhizobium Inoculated + 45 kg S/ha	120.0	2.14	31.84	21.49	18993	2.48
CD (P=0.05)	8.99	0.08	1.70	0.89	-	-

crop growth rate (23.81 g/day/m²) was achieved with 30 kg S/ha at 60 DAS, which was 24.39 per cent more than the minimum value recorded with control (0 kg S/ha).

Relative growth rate

The RGR of soybean was significantly affected by *Rhizobium* inoculation at 40, 60 and 100 DAS and the inoculated treatments showed 20 per cent more RGR than uninoculated at 40 DAS. The different levels of sulphur had a significant effect on RGR of soybean. The treatment 30 kg S/ha recorded 5.88 per cent more RGR over control (no sulphur) at 40 DAS whereas it was maximum (0.22 g/ g/day/m²) with treatment 45 kg S/ha at 80 DAS.

Effect of Rhizobium

The inoculation of *Rhizobium* (Table 1) increased the yield attributes like number of pods/plant, total grains/plant and number of seeds/pod which were 31.15, 33.71 and 2.76 per cent more than uninoculated. The inoculation of *Rhizobium* recorded significantly higher grain and stover yield along with quality parameter (*i.e.* oil content) of soybean over uninoculated. This positive influence of *Rhizobium* inoculation may be attributed to its ability of enhancing nodulation, more nitrogen fixation and nutrient uptake. Kulhare *et al.* (1996), Dubey (1997) and Kim *et al.* (1998) also reported similar results.

Effect of sulphur levels

Application of 30 kg S/ha recorded the maximum values for all yield attributing parameters like number of pods/plant, total grains/plant, number of grains/pod and test weight along with grain and stover yield (Table 1). The treatment 30 kg S/ha recorded 31.61, 6.57, 23.76, 12.5 and 23.31 per cent increase over control (0 kg S/ha), for the parameters *viz.* number of pods/plant, number of seeds/pod, grain and stover yield and oil content of soybean, respectively. The values obtained with 30 kg S/ha were statistically at par with those obtained with that of 45 kg S/ha. It may be attributed to the well-known fact that sulphur promotes nodule formation on the roots of leguminous plants (Das, 1993), leading to enhanced crop performance. Vishwakarma *et al.* (1998) reported that root system development and nodulation increased with increasing S-rate. Mandal and Sikder (1999) also found similar response.

Interaction effect

Interaction between *Rhizobium* and sulphur levels was significant in respect of number of pods/plant, number of grains/pod, grain yield (q/ha) and oil content (%) of seed (Table 3). The maximum values of these attributes were obtained with treatment combination of Rhizobium inoculation + 30 kg S/ha, except for oil content of seed, for which the maximum values was obtained with Rhizobium inoculation + 45 kg S/ha. However, the values with 30 kg S/ha were at par with that of 45 kg S/ha. The maximum values obtained with the above attributes were 61.25, 15.34, 69.99 and 37.22 per cent more than control (uninoculated + 0 kg S/ ha) that recorded the minimum values. Hoque *et al.* (1999) reported that *Rhizobium* inoculation either alone or in combination with sulphur-increased chlorophyll and seed yield significantly as compared to controls (uninoculated and unfertilized). Jat and Rathore (1994) also revealed similar findings.

Economics

All the treatments gave appreciable net return and B:C ratio. However the maximum net return and B:C ration was registered by the treatment Rhizobium inoculation + 30 kg S/ha (*i.e.* Rs.20367 and 2.61), followed by Rs.18993 and 2.48 in case of Rhizobium inoculation + 45 kg S/ha. The least net return and B:C ratio (*i.e.* Rs. 7209 and 1.59) was recorded with control (uninoculated and no sulphur). The treatment *Rhizobium* inoculation coupled with 30 kg S/ha accrued 182 and 64.15 per cent more net return and B:C ratio, respectively than the minimum value obtained with the control.

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