Effect of Sulphur and bio- inoculants on growth and yield of soybean (*Glycine Max* L).

Abstract: An experiment entitled, "Effect of sulphur and bio-inoculants on growth and yield of soybean (*Glycine Max* L.)" was conducted during *kharif*, 2023 at new experimental cum demonstration field, SVIAg, SVVV, Indore. The field experiment was carried out in randomized block design with nine treatments. The treatments were T_1- RDF (20:40:20), T_2- RDF + 20 kg S ha^{-1}, T_3- RDF + 20 kg S ha^{-1} + *Rhizobium*, T_4- RDF + 20 kg S ha^{-1}+ PSB, T_5- RDF + 20 kg S ha^{-1}+ *Thiobacillus*, T_6- RDF + 20 kg S ha^{-1} + *Rhizobium* + PSB, T_7- RDF + 20 kg S ha^{-1} + *Rhizobium* + *Thiobacillus*, T_8- RDF + 20 kg S ha^{-1} + *Thiobacillus* + PSB and T_9- RDF + 20 kg S ha^{-1} + *Rhizobium* + *Thiobacillus* + PSB. The growth and yield attributes such as plant height, no. of leaves $plant^{-1}$at 60 DAS, no. of branches $plant^{-1}$, leaf area $plant^{-1}$ at 60 DAS, dry matter $plant^{-1}$, number of pods $plant^{-1}$, pod yield $plant^{-1}$, seed yield $plant^{-1}$, seed yield (ha^{-1}), straw yield (ha^{-1}) and biological yield (ha^{-1}) were recorded and found to be highest with the application of RDF + 20 kg S ha^{-1} + *Rhizobium* + *Thiobacillus* + PSB as compared to rest of the treatments.

Keywords: Sulphur, Bio-inoculants, *Rhizobium*, *Thiobacillus* and PSB.

Introduction

The soybean (*Glycine max*) is a species of legume native to East Asia and belongs to the Fabaceae or bean family. Soybean is an annual plant that may vary in growth, habit, and height. It grows prostrate, not growing higher than 20 cm (7.8 inches), or even stiffly erect up to 2 meters (6.5 feet) in height. The pods, stems and leaves are covered with fine brown or gray pubescence. The leaves are trifoliate, having 3 leaflets per leaf and the leaflets are 6-15 cm (2-6 inches) long and 2-7 cm (1-3 inches) broad. The leaves fall before the seeds mature. The small, inconspicuous, self-fertile flowers are borne in the axil of the leaf and are white, pink or purple. The fruit is a hairy pod that grows in clusters of 3-5 with each pod 3-8 cm (1-3 inches) long and usually containing 2-4 (rarely more), seeds 5-11 mm in diameter. Like other legumes, the plant adds nitrogen to the soil through nitrogen-fixing bacteria and historically has been an important soil-enriching crop, though this practice is not common in most industrial agriculture systems.

As per world soybean production, United States was the leading global producer of soybeans with a production volume of 120.52 million metric tons in 2018-19. As of 2019, Brazil overtook the United States as the leading soybean-producing country with a production volume of some 162 million metric tons in 2022-23 followed by United States of America, Argentina, China and India accounting for 40 per cent of world production. In India, the area, production and productivity of soybean during 2022-23 was 12.07 m ha, 13.98 Mt and 1158 kg ha^{-1} respectively as against 12.18 m ha area, 13.12 Mt production and 1077 kg ha^{-1} productivity during 2021-22. Among the states, Madhya Pradesh stood first with 50.18 lakh ha followed by Maharashtra, Rajasthan, Karnataka, Gujarat and Telangana. (Anonymous 2023).

Microorganisms in the soil play a crucial role in soil biodiversity and coordinated nutrient management. Recent years have seen the use of chemical fertilizers in agriculture, making the nation more self-sufficient in food production, but at the expense of the ecosystem and the well-being of all living things, creating negative impacts on soil fertility. To satisfy our agricultural requirements, beneficial microorganisms are better alternatives to conventional farming methods. Bioinoculants do not show any detrimental impact on the soil, plant and animal life as they are eco-friendly and highly efficient. Nitrogen-fixing bacteria, such as *Rhizobium*, form intimate alliances with soybean roots, establishing nodules where they convert atmospheric nitrogen into a plant-usable form. This biological nitrogen fixation not only reduces the need for synthetic fertilizers but also enhances soil fertility, enriching the nutrient bank through enhancing nutrient availability and uptake for present and subsequent crops and promoting sustainable soil management practices, the key drivers of soybean growth and yield. Phosphorus-solubilizing bacteria (PSB) unlock phosphorus in the soil, making it accessible to soybean roots and fuelling critical metabolic processes. Thiobacillus, a genus of sulphur-oxidizing bacteria, plays a significant role in the sulphur cycle in soil environments. These bacteria facilitate the conversion of sulphur and sulphide compounds into forms that plants can readily absorb i.e. sulphate. The activity of Thiobacillus can enhance soil fertility by increasing a steady supply of sulphate thus, leading to better crop growth and higher yields (Shahwar *et al*., 2023).

Materials and Methods

The present experiment entitled "Effect of sulphur and bio-inoculants on soybean production (*Glycine max* L.)" was carried out at New experimental cum demonstration field, Shri Vaishnav Institute of Agriculture, Shri Vaishnav Vidyapeeth Vishwavidyalaya, Indore during *rabi* 2023-24. The soil at the experimental site was clayey in texture, low in available nitrogen (206.18 kg ha^{-1}), medium in phosphorus (13.98 kg ha^{-1}), and high in available potassium (448.25 kg ha^{-1}). The field experiment was carried out in randomized block design with nine treatments and three replications. The treatments were T_1- RDF (20:40:20), T_2- RDF + 20 kg S ha^{-1}, T_3- RDF + 20 kg S ha^{-1} + *Rhizobium*, T_4- RDF + 20 kg S ha^{-1}+ PSB, T_5- RDF + 20 kg S ha^{-1} + *Thiobacillus*, T_6- RDF + 20 kg S ha^{-1} + *Rhizobium* + PSB, T_7- RDF + 20 kg S ha^{-1} + *Rhizobium* + *Thiobacillus*, T_8- RDF + 20 kg S ha^{-1} + *Thiobacillus* + PSB and T_9- RDF + 20 kg S ha^{-1} + *Rhizobium* + *Thiobacillus* + PSB. The field was divided into 27 plots with gross plot size of 3.00 m x 4.50 m each.

Recommended dose of fertilizers (20:40:20 NPK kg ha^{-1}) and sulphur was applied as basal dose and seed treatment with different bio-fertilizers (*Rhizobium*, Thiobacillus and PSB) was given as per treatments. The nutrients were applied through Urea, Single super phosphate (SSP), Muriate of potash (MOP) and Bensulph (Elemental Sulphur).

To record biometric observations, five plants were chosen at random from each net plot. Seedlings emerged six days after sowing, and the total number of plants was counted 15 days later. The final plant stand was recorded at the time of harvesting. Height of plant were measured from ground level to the base of last fully opened leaf and average height was work out. The total number of trifoliate leaves were counted and recorded. Number of branches plant^{-1} grown on stem were counted and recorded. Leaf area were calculated by using formula. A single plant was randomly sampled from each plot for dry matter production. Numbers of pods were counted from 5 randomly selected plants from net plots and then the average was worked out. Total numbers of pods from five selected sample plants were harvested and per plant seed yield was recorded. Thousand seeds were counted from each net plot seed yield and its weight was recorded. The plants from each net plot were harvested and seeds were separated by threshing. After sun drying seed yield obtained in each net plot were weighed in kg and presented as kg ha^{-1}. Straw yield was obtained by deducting the seed yield from the weight of total dry produce (biological yield) of respective net plot in kg and given as kg ha^{-1}. The figures of biological yield were calculated by summing of seed yield and straw yield of net plots. Finally, it was converted on hectare basis. The harvest index was calculated by using formula seed yield (kg ha^{-1}) ÷ biological yield (kg ha^{-1}) X 100.

Results and Discussion

Growth attributes.

The growth parameters such as plant height increased at every step of crop development till maturity. The number of branches increased up to 60 days and remained constant thereafter. The number of nodules increased positively up to flowering and decreased thereafter due to shrinkage of nodules. The number of leaves and leaf area increased up to 60 days and decreased thereafter towards maturity due to leaf senescence. Total dry matter increased at every growth stage from 30 DAS up to harvest. The development of pods started after flowering and increases continuously up to harvest. Highest values of plant height (42.53 cm) at harvest, no. of leaves $plant^{-1}$ (32.87) at 60 DAS, no. of branches $plant^{-1}$ (12.13) at harvest, leaf area $plant^{-1}$ (13.40) at 60 DAS and dry matter $plant^{-1}$ (23.53 g) at harvest was recorded in treatment with application of RDF + 20 kg S ha^{-1} + *Rhizobium* + Thiobacillus + PSB (T_9) inoculants throughout the entire crop growth period. The lowest values of all these parameters were recorded by the application of RDF alone (T_1). The increase in growth attributes may be due to better uptake and translocation of plant nutrients to growing plants. The findings were supported by Jaga and Sharma (2015), Farhad *et al.,* (2010), Akter (2013), Kawde *et al.,* (2016) and Sharma (2011).

Table no. 1: Effect of sulphur and bio inoculants on growth attributes of soybean.

Treatments	Plant height (at harvest)	No. of leaves $plant^{-1}$ (60 DAS)	No. of branches $plant^{-1}$ (at harvest)	Leaf area $plant^{-1}$ (60 DAS)	Dry matter $plant^{-1}$ (at harvest)
T_1	33.70	24.33	7.12	7.33	12.22
T_2	33.88	26.33	8.53	7.48	17.68
T_3	35.87	27.41	9.82	9.59	19.50
T_4	34.07	27.03	9.56	8.79	18.20
T_5	36.56	27.47	9.92	10.37	20.02
T_6	39.37	29.47	10.99	12.19	21.95
T_7	40.53	30.20	11.82	12.28	22.31
T_8	38.85	28.93	10.63	11.60	21.26
T_9	42.53	32.87	12.13	13.40	23.53
S.Em. (±)	1.78	0.85	0.59	0.51	1.02
CD at 5%	5.35	2.56	1.77	1.53	3.06
General mean	37.26	28.23	10.06	10.34	19.63

Yield attributes and yield.

Yield attributing characters *viz*., maximum no. of pods plant^{-1} (31.90), pod yield plant^{-1} (22.67 g), seed yield plant^{-1} (11.33 g) at harvest was recorded in treatment with the application of RDF + 20 kg S ha^{-1} + *Rhizobium* + Thiobacillus + PSB (T_9). Whereas the minimum values were recorded from the treatment with the application of RDF alone (T_1).

The seed, straw and biological yield of maize was significantly influenced by different treatments. Application of RDF + 20 kg S ha^{-1} + *Rhizobium* + Thiobacillus + PSB (T9) recorded maximum seed yield (16.41 q ha^{-1}), straw yield (28.52 q ha^{-1}) and biological yield (44.93 q ha^{-1}) which was found to be at par with RDF + 20 kg S ha^{-1} + *Rhizobium* + PSB (T6), RDF + 20 kg S ha^{-1} + *Rhizobium* + Thiobacillus (T7) and RDF + 20 kg S ha^{-1} + Thiobacillus + PSB (T8). The increase in all the growth parameters with application of RDF + 20 kg S ha^{-1} + *Rhizobium* + Thiobacillus + PSB (T_9) must have resulted in increase in final yield of soybean. These findings are supported by Bonde and Gawande (2017) and Patel *et al.*, (2013)

Table no. 2: Effect of sulphur and bio inoculants on yield attributes of soybean.

Treatments	No. of pods plant^{-1}	Pod yield (g) plant^{-1}	Grain yield (g) plant^{-1}	Seed yield q ha^{-1}	Straw yield q ha^{-1}	Biological yield q ha^{-1}
T_1	21.03	13.17	7.67	8.11	13.99	22.09
T_2	21.57	15.23	7.83	10.27	17.22	27.49
T_3	24.20	18.20	8.40	12.11	21.58	33.69
T_4	22.73	17.00	7.97	11.76	20.28	32.04
T_5	26.87	19.43	9.17	13.21	24.45	37.66
T_6	30.00	21.07	10.10	15.08	27.10	42.18
T_7	30.47	21.43	10.67	15.92	27.87	43.80
T_8	29.13	20.07	9.87	14.21	25.94	40.15
T_9	31.90	22.67	11.33	16.41	28.52	44.93
S.Em. (±)	0.93	0.88	0.56	1.06	0.92	1.48
CD at 5%	2.79	2.65	1.68	3.18	2.76	4.44
General mean	**26.43**	**18.70**	**9.22**	**13.01**	**22.99**	**36.00**

Conclusion.

It may conclude that; the highest values of growth attributes, yield attributes and yield can be obtained with the application of RDF + 20 kg S ha^{-1} + *Rhizobium* + Thiobacillus + PSB (T9) whose values are at par with the treatment containing any one of the bio-inoculant.

Application of RDF along with sulphur (20 kg ha^{-1}) and seed treated with all bio-inoculants (*Rhizobium*, PSB and Thiobacillus) or at least one of the available bio-inoculant helps to increase soybean growth and yield of soybean.

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