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EFFECT OF SULPHUR AND ZINC ON GROWTH AND YIELD OF SOYBEAN (*GLYCINE MAX* L.)

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ABSTRACT

A field experiment was conducted during the *kharif* season of 2024 at the College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, to study the effect of sulphur and zinc on the growth and yield of soybean (*Glycine max* L.). The study involved twelve treatment combinations comprising four levels of sulphur (0, 10, 20, and 30 kg/ha) and three levels of zinc oxide (0, 12.5, and 25 kg/ha), laid out in a Factorial Randomized Block Design (FRBD) with three replications. Results revealed that the application of 30 kg S/ha significantly improved plant height at 60 DAS and at harvest, number of pods per plant, seed yield (2530 kg/ha), stover yield (3370 kg/ha) and seed index. However, 20 kg S/ha produced statistically similar results. Among zinc oxide treatments, application of 12.5 kg ZnO/ha significantly enhanced growth and yield attributes such as plant height at 60 DAS and at harvest, number of pods per plant, seed yield (2460 kg/ha) and stover yield (3261 kg/ha), which were comparable to 25 kg ZnO/ha. No significant interaction effects between sulphur and zinc oxide were observed for any growth or yield parameter. The study concluded that the application of 30 kg S/ha and 12.5 kg ZnO/ha can effectively enhance soybean productivity under field conditions.

***Keywords*:** Soybean, sulphur, zinc oxide, growth and yield

Introduction

Soybean (*Glycine max* L.), a leguminous oilseed crop, holds considerable economic and nutritional importance in India due to its high protein (~40%) and oil (~20%) content, along with essential minerals and vitamins (Chauhan and Joshi, 2005, and Schmutz *et al.*, 2010). India ranks fifth in global soybean production and fourth in area, with Madhya Pradesh and Maharashtra contributing nearly 82% of national output (Anonymous, 2023 and Anonymous, 2022a). In Gujarat, key soybean-growing districts include Junagadh and Aravalli, accounting for around 40% of the state's soybean area (Anonymous, 2022b). Among the critical nutrients for oilseed crops, sulphur plays a vital role in protein synthesis and oil formation through its involvement in amino acids and disulphide bond formation (Gangadhara *et al.*, 1990, and Aulakh and Pasricha, 1988). The overall requirement of sulphur for oilseed crops is as high as phosphorus. However, widespread sulphur deficiency in Indian soils reported in over 60% of soils across major states of India causes limitations for enhancing productivity (Shukla *et al.*, 2021). Similarly, zinc deficiency is a persistent issue in Indian agriculture, affecting about 40% of soils and contributing to yield and quality constraints despite efforts to promote its use (Shukla *et al.*, 2012 and Kumar *et al.*, 2020). Zinc is essential for enzymatic functions, photosynthesis, and stress tolerance in plants (Fox and Guerinot, 1998, and Alloway, 2009). Thus, balanced nutrition with adequate sulphur and zinc is crucial to enhance the productivity and quality of soybean.

Materials and Methods

A field experiment was conducted during the *kharif* season of 2024 at the College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand. The experimental soil was loamy sand in texture, alkaline in reaction (pH 8.10) and had an EC of 0.35 dS/m. It was low in organic carbon (0.40%), available nitrogen (235 kg/ha) and sulphur (7.65 mg/kg). Available phosphorus (40.7 kg/ha), potassium (218 kg/ha) and DTPA-extractable zinc (0.620 mg/kg) were found in the medium range. The experiment was laid out in a Factorial Randomized Block Design (FRBD) with three replications, comprising twelve treatment combinations involving four levels of sulphur (0, 10, 20 and 30 kg/ha) and three levels of zinc oxide (0, 12.5 and 25.0 kg/ha). The recommended dose of fertilizers was applied through urea and DAP, with 50% of the nitrogen applied as a basal dose and the remaining at 30 DAS, while 100% of the phosphorus was applied at the basal stage. Sulphur was applied at the time of sowing through Bentonite sulphur. The soybean NRC 37 was sown manually in furrow with maintaining the optimum row spacing of 45 cm. However, all the other intercultural operations were done as per need of crop.

Table 1: Details of treatment

Treatment no.	Treatment details
T_1	00 kg S + 00 kg ZnO/ha
T_2	00 kg S + 12.5 kg ZnO/ha
T_3	00 kg S + 25.0 kg ZnO/ha
T_4	10 kg S + 00 kg ZnO/ha
T_5	10 kg S + 12.5 kg ZnO/ha
T_6	10 kg S + 25.0 kg ZnO/ha
T_7	20 kg S + 00 kg ZnO/ha
T_8	20 kg S + 12.5 kg ZnO/ha
T_9	20 kg S + 25.0 kg ZnO/ha
T_{10}	30 kg S + 00 kg ZnO/ha
T_{11}	30 kg S + 12.5 kg ZnO/ha
T_{12}	30 kg S + 25.0 kg ZnO/ha

Results and Discussion

Effect of sulphur:

Growth parameters: Data presented in Table 2 revealed that the effect of sulphur application on plant population at 20 DAS and at harvest as well as plant height at 30 DAS was found to be non-significant. However, plant height at 60 DAS and at harvest was significantly influenced by varying levels of sulphur application. The treatment receiving the application of 30 kg S/ha (S_3) recorded the significantly higher plant height at 60 DAS (68.0 cm) and at harvest (83.7 cm). These results were significantly superior over the control and lower levels of sulphur but remained at par with the application of 20 kg S/ha (S_2). Moreover, different levels of sulphur did not influence the number of branches per plant at 30 DAS, 60 DAS and at harvest significantly. The increase in plant height may be attributed to improved nitrogen uptake, enhanced chlorophyll synthesis and stimulation of vegetative growth. The slow-release property of bentonite sulphur likely provided a continuous supply of sulphur throughout the growing period, promoting sustained cell division and elongation, thereby contributing to increased plant height. These findings are in agreement with those reported by Meena *et al.* (2015) and Singh *et al.* (2017).

Yield attributes and yield: The number of pods per plant at harvest was significantly influenced by the different levels of sulphur application (Table 3). The application of 30 kg S/ha (S_3) recorded significantly higher number of pods per plant (85.2) than the lower sulphur levels but remained at par with the application of 20 kg S/ha (S_2). The increase in number of pods might be attributed to improved sulphur availability throughout the crop growth period, which enhanced nitrogen metabolism, protein synthesis, and photosynthetic efficiency. These physiological improvements likely facilitated better flowering, effective pod setting, and overall reproductive success, thereby resulting in a greater number of pods per plant. The number of seeds per pod at harvest was not influenced by different levels of sulphur application. However, the treatment receiving application of 30 kg S/ha (S_3) recorded a numerically higher number of seeds per pod compared to other treatments. The application of 30 kg S/ha (S_3) resulted in the significantly higher seed index (9.91 g), which was significantly superior over the lower levels of sulphur except 20 kg S/ha (S_2). This improvement in seed weight might be attributed to the crucial role of sulphur in the synthesis of essential amino acids such as cysteine and methionine, and its contribution to protein accumulation during the seed-filling stage. These findings are supported by the results of Devi *et al.* (2012), Kumari *et al.* (2018) and Lyngkhoi *et al.* (2020).

The seed and stover yields of soybean were significantly influenced by different levels of sulphur application (Table 3). The application of 30 kg S/ha (S_3) recorded significantly higher seed yield (2530 kg/ha) over the lower sulphur levels but was found to be at par with the application of 20 kg S/ha (S_2). Significantly maximum stover yield (3370 kg/ha) was also observed with the application of 30 kg S/ha (S_3) and was remained at par with the application of 20 kg S/ha (3173 kg/ha). The increase in seed and stover yields due to sulphur application may be attributed to improved root development, enhanced nutrient uptake (particularly nitrogen) and greater photosynthate production. Sulphur contributes to both vegetative and reproductive development by promoting chlorophyll synthesis, activation of photosynthetic enzymes, nodulation and biological nitrogen fixation. Moreover, it plays a critical role in several physiological and biochemical processes, such as energy transformation, enzyme activation, carbohydrate metabolism and the synthesis of essential amino acids like cysteine and methionine, all of which are essential for yield enhancement. These findings are in agreement with the results reported by Kumari *et al.* (2018), Lyngkhoi *et al.* (2020), Dheri *et al.*(2021) and Sharma *et al.* (2023).

Effect of zinc

Growth parameters: Data presented in Table 2 showed that the application of zinc oxide had a non-significant effect on plant population at both 20 DAS and at the time of harvest. Similarly, the effect of zinc oxide on plant height was non-significant at 30 DAS. But, a significant response was observed at 60 DAS and at harvest. The application of 12.5 kg ZnO/ha (Zn_1) resulted in significantly higher plant height at 60 DAS (66.9 cm) and at harvest (81.8 cm), compared to the control, but was remained at par with application of 25.0 kg ZnO/ha (Zn_2). The number of branches per plant at 30 DAS, 60 DAS, and at harvest was not significantly influenced by the different levels of zinc oxide. The improvement in plant height due to zinc oxide application could be attributed to its role in promoting auxin (IAA) synthesis, activating growth-regulating enzymes and enhancing root development. These physiological benefits facilitated improved nutrient uptake and hormonal regulation, ultimately leading to increased stem elongation and overall plant growth. These findings are in agreement with the results reported by Shinde *et al.* (2015) and Meshram *et al.* (2019).

Yield attributes and yield: The number of pods per plant at harvest was significantly influenced by different levels of zinc oxide (Table 3). The treatment receiving application of 12.5 kg ZnO/ha (Zn_1) recorded the significantly higher number of pods per plant (82.9), which was significantly superior over the control but was remained at par with the application of 25.0 kg ZnO/ha (Zn_2). The number of seeds per pod was not significantly influenced by different zinc oxide levels, and a numerically higher number of seeds per pod was observed under the application of 12.5 kg ZnO/ha (Zn_1). Similarly, the seed index of soybean did not show significant variation with zinc oxide application, although the numerically higher seed index was recorded with the application of 25.0 kg ZnO/ha (Zn_2). The increase in pod numbers might be attributed to zinc's crucial role in enzyme activation, auxin synthesis and pollen viability, all of which contribute to improved flower retention and successful fertilization. These results are consistent with the findings reported by Shinde *et al.* (2015) and Meshram *et al.* (2019).

Seed and stover yields of soybean were significantly influenced by varying levels of zinc oxide. The application of 12.5 kg ZnO/ha (Zn_1) resulted in the significantly higher seed yield (2460 kg/ha) than the control (2241 kg/ha) but was remained at par with the application of 25.0 kg ZnO/ha (Zn_2). Similarly, significantly higher stover yield (3261 kg/ha) was recorded with the application of 12.5 kg ZnO/ha (Zn_1) than the control (2877 kg/ha) but was remained at par with the application of 25.0 kg ZnO/ha (Zn_2). The improvement in seed and stover yield can be attributed to the critical role of zinc in enhancing reproductive growth through better flower retention, pollen viability, fertilization efficiency, and seed set. In addition, zinc promotes auxin synthesis and supports carbohydrate metabolism, contributing to overall plant vigor, pod development and biomass accumulation. Similar results were reported by Kakad *et al.* (2008), Singh *et al.* (2017) and Meshram *et al.* (2019).

Conclusion

An experimental result clearly indicated that the application of 30 kg S/ha and 12.5 kg ZnO/ha found effective in increasing the growth and yield of soybean. Therefore, it is suggested to apply 30 kg S/ha and 12.5 kg ZnO/ha for optimizing the production of soybean under middle Gujarat condition.

Table 2 : Effect of sulphur and zinc oxide on plant population, plant height and number of branches per soybean plant

Treatments	Plant population (per meter row length)		Plant height (cm)			No. of branches per plant
	At 20 DAS	At harvest	At 30 DAS	At 60 DAS	At harvest	At harvest
Sulphur (S)						
S_0: 0 kg S/ha	9.54	9.22	32.6	60.9	74.1	4.03
S_1: 10 kg S/ha	9.77	9.43	32.0	62.7	75.4	4.16
S_2: 20 kg S/ha	9.65	9.27	33.2	65.6	79.6	4.37
S_3: 30 kg S/ha	9.94	9.48	32.7	68.0	83.7	4.20
S.Em ±	0.26	0.26	0.8	1.7	2.3	0.10
CD at 5%	NS	NS	NS	5.1	6.8	NS

Zinc (ZnO)						
Zn_0: 0 kg ZnO/ha	9.77	9.30	32.7	61.1	73.9	4.04
Zn_1: 12.5 kg ZnO/ha	9.56	9.26	32.8	66.9	81.8	4.28
Zn_2: 25.0 kg ZnO/ha	9.85	9.49	32.5	65.0	78.9	4.24
S.Em ±	0.23	0.22	0.7	1.5	2.0	0.09
CD at 5%	NS	NS	NS	4.4	5.9	NS
Interaction (S × Zn)						
S.Em ±	0.45	0.45	1.4	3.0	4.0	0.18
CD at 5%	NS	NS	NS	NS	NS	NS
CV (%)	8.09	8.30	7.41	8.03	8.85	7.31

Table 3: Effect of sulphur and zinc oxide on number of pods per plant, number of seeds per pod, seed index, seed yield and stover yield of soybean

Treatments	Number of pods per plant	Number of seeds per pod	Seed index (g)	Seed yield (kg/ha)	Stover yield (kg/ha)
Sulphur (S)					
S_0: 0 kg S/ha	72.3	2.62	9.17	2163	2797
S_1: 10 kg S/ha	79.6	2.67	9.24	2306	3004
S_2: 20 kg S/ha	81.8	2.60	9.40	2451	3173
S_3: 30 kg S/ha	85.2	2.69	9.91	2530	3370
S.Em ±	1.9	0.07	0.19	69	106
CD at 5%	5.5	NS	0.56	203	311
Zinc (ZnO)					
Zn_0: 0 kg ZnO/ha	74.8	2.63	9.42	2241	2877
Zn_1: 12.5 kg ZnO/ha	82.9	2.72	9.39	2460	3261
Zn_2: 25.0 kg ZnO/ha	81.5	2.58	9.48	2386	3121
S.Em ±	1.6	0.06	0.16	60	92
CD at 5%	4.7	NS	NS	176	269
Interaction (S × Zn)					
S.Em ±	3.2	0.12	0.33	120	184
CD at 5%	NS	NS	NS	NS	NS
CV (%)	7.02	7.67	6.02	8.79	10.31

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