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EFFECT OF DIFFERENT LEVELS OF SULPHUR AND ZINC ON YIELD ATTRIBUTES AND YIELD OF SOYBEAN IN ACID ALFISOLS

Alka Tigga[1]*, B.K. Agarwal[1], S.B. Kumar[1], C.S. Singh[2], Karishma Banra[1] and Anjali Bhagat[1]

[1]Department of Soil Science, Birsa Agricultural University, Kanke, Ranchi - 834 006, Jharkhand, India.
[2]Department of Agronomy, Birsa Agricultural University, Kanke, Ranchi - 834006, Jharkhand, India.
*Corresponding author E-mail : alkatigga28499@gmail.com

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ABSTRACT

A field experiment was conducted at research farm of department of Soil Science, Birsa Agricultural University, Ranchi during *kharif* season of 2023-24 to study the effect of different levels of sulphur and zinc on yield attributes and yield of soybean in acid Alfisols. The experiment was laid out in FRBD with twelve treatment combination replicated thrice. Treatment comprises of four levels of sulphur (0, 15, 30 and 45 kg S ha^{-1}) and three levels of Zinc (0, 5 and 10 kg Zn ha^{-1}). The results indicated that the yield attributes and yield of soybean were significantly influenced by application of varying levels of sulphur and zinc. The number of pods per plant (40.30), grain yield (22.81 q ha^{-1}) and straw yield (40.93 q ha^{-1}) significantly increased with the application of 45 kg S ha^{-1}, which was at par with 30 kg S ha^{-1} while its effects on seeds per pod and 1000-seed weight were non-significant but showed a positive trend. Results further showed that an increase in level of zinc up to 5 kg ha^{-1} significantly improved the most of the yield-determining characters of soybean over lower levels. It also recorded significantly higher grain yield (21.51 q ha^{-1}) with application of 5 kg Zn ha^{-1} over the control and 10 kg Zn ha^{-1} found at par with 5 kg Zn ha^{-1}. Application of 30 kg S ha^{-1} in conjunction with zinc at 5 kg ha^{-1} was the most effective treatment combinations for obtaining higher seed yield (23.41 q ha^{-1}) in soybean.

Key words : Soybean, Sulphur, Zinc, Yield attributes, Yield, Alfisols.

Introduction

Soybean (*Glycine max* L.) is recognized as a Golden Bean due to its high nutritional value, such as high-quality protein (40–42%), oil (18–20%) and other nutrients like calcium and iron (Devi *et al.*, 2012). In addition, soybean protein has 5% lysine which is deficient in most cereals. It is a member of the Fabaceae family, a highly impactful crop with a long history, dating back to around 1700 BC. It is a nutritionally and economically important crop that originated in Asia. It has a dual character as oilseeds and pulses but basically legume and comes under oilseed crop. It is also called the "gold of soil," as it builds up the soil fertility by fixing atmospheric nitrogen through nodules. Symbiotically, soybean fixes nitrogen and leaves about 25 percent for succeeding crops (Lal *et al.*, 2019). In India, soybean ranks fourth in area and fifth in production among the nine major oilseed crops. It is cultivated on 12.07 million ha with a production of 13.98 million tons and a productivity of 1158 kg ha^{-1} (Anonymous, 2022).

Sulphur (S) is an essential nutrient often overshadowed by nitrogen (N), phosphorus (P) and potassium (K) in agricultural practices despite its critical role in soybean nutrition. It is the fourth most important plant nutrient, as a key component of proteins, vitamins and amino acids (Tandon, 2004). Sulphur deficiency significantly hampers growth, root development and yield, potentially reducing productivity by up to 50% (Zhou *et al.*, 2024). Zinc also plays a vital role in enzyme activation, reproductive development, chlorophyll production and carbohydrate metabolism, with its deficiency causing poor growth and reduced yield. Over 30% of global agricultural soils are deficient in zinc, including India, where deficiencies affect soybean productivity (Alloway, 2008). Taking into consideration the importance of sulphur and zinc nutrition in soybean cultivation, the present investigation was undertaken with the objective to study the effect of graded levels of sulphur and zinc on yield attributes and yield of soybean in acid Alfisols.

Materials and Methods

A field experiment was conducted during 2023 in *Kharif* season in the Research Farm of the Department of Soil Science, Birsa Agricultural University, Ranchi, Jharkhand. Geographically, Ranchi is located at a latitude of 23°17' N and longitude of 85°19' E, at an altitude of 625 meter above sea level. The field was well-drained medium land and the soil type of the site is acid Alfisol with slightly acidic in reaction (pH 5.3), organic carbon (4.50 g kg^{-1}), available N (192.32 kg ha^{-1}), available P (21.68 kg ha^{-1}), available k (175.20 kg ha^{-1}), available S (6.08 mg kg^{-1}) and available Zn (0.52 mg kg^{-1}), respectively. The experiment was laid out in a factorial randomized block design (FRBD) with twelve treatment combination replicated thrice. Treatment comprised of four levels of sulphur (0, 15, 30 and 45 kg S ha^{-1}) and three levels of Zinc (0, 5 and 10 kg Zn ha^{-1}). The soybean variety Birsa Safed Soybean-2 was sown at row spacing of 45 cm with seed rate 75 kg ha^{-1}. The recommended dose of fertilizer (25:60:40 kg N, P_2O and K_2O ha^{-1}) was applied using urea, DAP and MOP, along with seed treatment with Rhizobium culture in all treatments. S and Zn were applied through bentonite sulphur and zinc sulphate monohydrate respectively as basal dose at the time of sowing. The yield attributes were recorded from five tagged plants in each plot. Grain and straw yields were measured from the net plot area and converted to kilograms per hectare. After cleaning and drying, the grain yield was recorded at 12% moisture content. The straw yield was determined by subtracting the grain yield from the total biological yield, both expressed in quintals per hectare (q ha^{-1}). Biological yield was calculated as the sum of the grain yield and straw yield, also expressed in q ha^{-1}.The harvest index was computed using the formula:

$$\text{Harvest Index (\%)} = \frac{\text{Economical yield}}{\text{Biological yield}} \times 100$$

The collected data were analyzed using the analysis of variance (ANOVA) technique for factorial randomized block design. Treatment variations were tested for significance and the standard error of the mean (SEm ±) and critical difference (CD) at the 5% probability level were calculated as per the method outlined by Gomez and Gomez (1984).

Results and Discussion

Yield attributes of soybean

Number of pods per plant

The data in Table 1 shows that sulphur application significantly increased the number of pods per plant in soybean at maturity. The highest number of pods (40.30) was recorded with 45 kg S ha^{-1}, significantly higher than 15 kg S ha^{-1} (38.32) and at par with 30 kg S ha^{-1} (39.62). The control plot (0 kg S ha^{-1}) recorded the lowest pods (37.71). This improvement can be attributed to nutrient supply and enhanced physiological processes, including improved chlorophyll formation, photosynthesis, enzyme activation and grain formation (Yadav *et al*., 2013). These findings align with those of Kumar *et al.* (2018) and Rao *et al*. (2013) reported that 45 kg S ha^{-1} significantly increased pods per plant and pod yield.

Similarly, zinc application increased pods per plant, with 10 kg Zn ha^{-1} resulting in the maximum (40.58), significantly higher than other treatments. The lowest number of pods (37.21) was in the 0 kg Zn ha^{-1} plot. No significant interaction between sulphur and zinc levels was observed. Singh and Singh (1995) reported that

Table 1 : Effect of different levels of sulphur and zinc on yield attributes of soybean.

Yield attributing characters			
Treatment	**No. of pods $plant^{-1}$**	**No. of seeds pod^{-1}**	**1000 seed weight (g)**
Sulphur levels			
S_0 - 0 kg S ha^{-1}	37.71	2.75	109.5
S_1 - 15 kg S ha^{-1}	38.32	2.90	109.9
S_2 - 30 kg S ha^{-1}	39.62	2.95	110.0
S_3 - 45 kg S ha^{-1}	40.30	3.02	110.6
SEm±	0.69	0.08	1.69
CD (P=0.05)	2.04	NS	NS
Zinc levels			
Zn_0 - 0 kg Zn ha^{-1}	37.21	2.75	109.4
Zn_1 - 5 kg Zn ha^{-1}	39.18	2.96	110.1
Zn_{2-} 10 kg Zn ha^{-1}	40.58	3.01	110.5
SEm±	0.60	0.07	1.46
CD (P=0.05)	1.76	NS	NS
Interaction (S X Zn)			
SEm±	1.20	0.14	2.92
CD (P=0.05)	NS	NS	NS
CV (%)	5.10	7.48	4.14

applying 20 kg ZnO ha^{-1} significantly increased the number of pods per plant and seeds per pod in soybean. Jat *et al.* (2021) found a positive correlation between zinc application and pod count, maximum effect observed at 6 kg Zn ha^{-1}.

Number of seeds per pod

Data on seeds per pod given in Table 1 indicated that sulphur and zinc levels had no significant effect on the number of seeds per pod in soybean. However, 45 kg S ha^{-1} recorded the highest seeds per pod (3.02), slightly higher than 30 kg S ha^{-1} (2.95), 15 kg S ha^{-1} (2.90) and the control (2.75). Similarly, 10 kg Zn ha^{-1} recorded the maximum seeds per pod (3.01), which was superior to other zinc treatments. The interaction between sulphur and zinc levels was non-significant. This aligns with findings from Parakhia *et al.* (2016), Singh *et al.* (2017) and Chavan *et al.* (2022).

1000 seed weight

Perusal of data on 1000 seed weight in Table 1 revealed sulphur and zinc application had a non-significant effect on the thousand-seed weight of soybean, though a slight numerical increase was observed with rising sulphur doses from 15 kg to 45 kg ha^{-1}. The highest seed weight (110.5 g) was recorded at 10 kg Zn ha^{-1}. Genetic potential and environmental conditions likely played a dominant role. Similar findings were reported by Meena *et al.* (2015) and Singh *et al.* (2017).The interaction between sulphur and zinc levels also had no significant effect on thousand-seed weight.

Yield

Grain yield

The data presented in Table 2 revealed that the highest grain yield (22.81 q ha^{-1}) was achieved with the application of 45 kg S ha^{-1}. A significant increase in grain yield was observed with increasing levels of sulphur upto 45 kg S ha^{-1}, which was which was at par with 30 kg S ha^{-1} (21.77 q ha^{-1}) and superior than 15 kg S ha^{-1} and 0 kg S ha^{-1}. The lowest grain yield (19.37 q ha^{-1}) was recorded in the control treatment, which was significantly lower than all other treatments. The cumulative effect of sulphur application ensures a balanced source-sink relationship, resulting in higher seed yields. Sulphur's role in forming amino acids, coenzymes and proteins supported this increase (Biswas and Tewatia, 1992; Jadhao *et al.*, 2014). Similarly, the application of 10 kg Zn ha^{-1} resulted in the highest grain yield (22.40 q ha^{-1}), significantly outperforming the control and being statistically at par with the application of 5 kg Zn ha^{-1} (21.51 q ha^{-1}). Zinc's role in carbohydrate metabolism, photosynthesis and protein synthesis contributed to this increase (Suresh *et al.*, 2013). Singh *et al.* (2017) also observed that zinc application enhanced the growth and yield of soybean, with a significant increase noted up to a level of 30 kg Zn ha^{-1}. The interaction between sulphur and zinc application significantly affected soybean grain yield (Table 3). The highest yield (23.60 q ha^{-1}) was recorded with 45 kg S

Table 2 : Effect of different levels of sulphur and zinc on grain yield, straw yield, biological yield and harvesting index of soybean.

Treatment	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
Sulphur levels				
S_0 - 0 kg S ha^{-1}	19.37	37.18	56.55	34.18
S_1 - 15 kg S ha^{-1}	20.92	38.33	59.25	35.24
S_2 - 30 kg S ha^{-1}	21.77	40.06	61.83	35.24
S_3 - 45 kg S ha^{-1}	22.81	40.93	63.74	35.78
SEm ±	0.67	0.93	1.30	0.76
CD (P=0.05)	1.97	2.74	3.82	NS
Zinc levels				
Zn_0 - 0 kg Zn ha^{-1}	19.75	37.19	56.93	34.57
Zn_1 - 5 kg Zn ha^{-1}	21.51	39.28	60.79	35.33
Zn_2 - 10 kg Zn ha^{-1}	22.40	40.91	63.31	35.43
SEm ±	0.58	0.81	1.13	0.66
CD (P=0.05)	1.70	2.37	3.31	NS
CV (%)	8.36	6.30	6.70	5.74

Table 3 : Interaction effect of different levels of sulphur and zinc on grain, straw, biological yield and harvest index of soybean.

Treatment combination	Grain yield ($q\ ha^{-1}$)	Straw yield ($q\ ha^{-1}$)	Biological yield ($q\ ha^{-1}$)	Harvest Index (%)
T_1 - S_0Zn_0	17.50	35.02	52.52	33.24
T_2 - S_1Zn_0	19.20	37.62	56.82	33.64
T_3 - S_2Zn_0	20.85	37.92	58.77	35.49
T_4 - S_3Zn_0	21.43	38.18	59.61	35.90
T_5 - S_0Zn_1	18.79	36.78	55.57	33.83
T_6 - S_1Zn_1	21.67	37.18	58.84	36.76
T_7 - S_2Zn_1	22.17	41.05	63.22	35.08
T_8 - S_3Zn_1	23.41	42.13	65.54	35.64
T_9 - S_0Zn_2	21.80	39.75	61.55	35.47
T_{10} - S_1Zn_2	21.90	40.20	62.10	35.32
T_{11} - S_2Zn_2	22.30	41.20	63.50	35.15
T_{12} - S_3Zn_2	23.60	42.48	66.08	35.79
SEm ±	1.16	1.62	2.21	1.32
CD (P=0.05)	3.41	4.75	6.72	NS
CV %	8.36	6.30	6.70	5.74

ha^{-1} and 10 kg Zn ha^{-1}, followed by 30 kg S ha^{-1} and 5 kg Zn ha^{-1} (23.41 q ha^{-1}). Similar finding was reported by Choudhary *et al.* (2014).

Straw Yield

Table 2 showed that straw yield significantly increased with sulphur application up to 45 kg S ha^{-1}, with the highest yield (40.93 q ha^{-1}) recorded at 45 kg S ha^{-1}, statistically on par with 30 kg S ha^{-1} (40.06 q ha^{-1}). Zinc levels also significantly influenced straw yield, with the lowest yield (37.19 q ha^{-1}) in the control. The highest straw yield was observed with the combined application of 45 kg S ha^{-1} and 10 kg Zn ha^{-1} (S_3Z_2), followed by S_3Z_1 and S_2Z_2 (Table 3). Improved plant growth and yield attributes led to this increase (Dheri *et al.*, 2021; Wear and Hagler, 1968 and Jat *et al.*, 2021).

Biological yield

Biological yield increased significantly with each increase in the levels of sulphur and zinc that has been presented in Table 2 and their interaction in Table 3. Biological yield was significantly influenced by the sulphur levels. The sulphur level 45 kg S ha^{-1} recorded significantly higher biological yield as compared to control and 15 kg S ha^{-1}. Biological yield was found to be at par with 30 kg S ha^{-1} and 45 kg S ha-1. Zinc application also increased the biological yield, with the highest yield recorded at 10 kg Zn ha^{-1}, which was statistically at par with 5 kg Zn ha^{-1} as mentioned by Thenua *et al.* (2014). The interaction effect of levels of sulphur and zinc was significant with reference to biological yield of soybean.

Harvest Index

The data in Tables 2 and 3 indicate that sulphur and zinc applications influenced the harvest index; however, the differences were statistically non-significant. A trend of increasing harvest index was observed with higher sulphur levels, though not significant. Similarly, zinc application at 10 kg ha^{-1} resulted in the highest harvest index (35.43%), but this increase was also non-significant. No significant interaction effects between sulphur and zinc were noted (Table 3). These results are in line with the findings of Verma *et al.* (2018) and Singh *et al.* (2017).

Conclusion

Based on the findings obtained from the experiments, it can be concluded that application of sulphur and zinc significantly improved the yield of soybean. The soil application of sulphur at 30 kg ha^{-1} combined with 5 kg zinc ha^{-1} was found the most superior treatment combination for obtaining higher grain yield (23.41q ha^{-1}) in soybean.

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