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RESEARCH ARTICLE

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Effect of Sulphur and Zinc Fertilization on Growth and Yield of Soybean [*Glycine max* (L.) Merrill] under Nagaland Condition

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ABSTRACT

Background: A field experiment was conducted at the Experimental Research Farm of School and Agricultural Sciences and Rural Development (SASRD), Nagaland University, during the *Kharif* season of 2017 and 2018 to study the effect of sulphur and zinc fertilization for biofortification in soybean [*Glycine max* (L.) Merrill] under Nagaland condition.

Methods: The experiment was laid out in a Factorial Randomized Block Design (RBD) with 15 treatments combinations *viz* sulphur (0 kg ha^{-1}, 20 kg ha^{-1} and 40 kg ha^{-1}), zinc (0 kg ha^{-1}, 5 kg ha^{-1}, 10 kg ha^{-1}, 15 kg ha^{-1} and 20 kg ha^{-1}) replicated thrice.

Result: The results obtained showed that the plant growth and yield attributes were significantly influenced by the treatment combination of $S_{20}Zn_{20}$. The application of 20 kg S ha^{-1} showed higher plant height, number of leaves and branches per plant, shoot dry weight, leaf area index (LAI), crop growth rate (CGR), number of nodules and was found to be quite comparable with the treatment of 40 kg S ha^{-1}. The zinc fertilization of 20 kg Zn ha^{-1} showed a greater response by the plant and showed increase in growth attributes and was at par with 15 kg Zn ha^{-1}. A higher number of pods, seed yield of and stover yield were observed in 20 kg S ha^{-1} and 20 kg Zn ha^{-1} fertilization respectively as compared to the other levels of treatments. However, the length of pods, number of seeds per pod, test weight and harvest index did not differ significantly by the treatments.

Key words: Biofortification, Fertilization, Soybean, Sulphur, Zinc.

INTRODUCTION

Soybean is one of the most valuable food crops in the global oilseed cultivation scenario today due to its unique characteristics, high productivity, profitability, adaptability to varied agro-climatic conditions and vital contribution to maintaining soil fertility. It is composed of 40 per cent protein and 20 per cent oil contributing about two-thirds of the global protein concentrates and 25% of the world's vegetable oil production. It contains essential amino acids, carbohydrates, unsaturated fatty acids, vitamins and minerals. The nutritional value of the crop is highly dependent on the presence of essential nutrients which plays a vital role in the quality and quantity of soybean crops and deficiencies of these nutrients will drastically reduce their growth and yield. With its demands for human consumption projected to be higher, there is a need for greater emphasis on these nutrient requirements of the plants for increasing the productivity of the crop.

Lately, "biofortification" defined as "the process of increasing the bio available concentrations of essential elements in edible portions of crop plants through genetic selection or agronomic intervention" (White and Broadley, 2005). It is one such approach to address these growing dietary micronutrient deficiency and also to combat food security.

Among these nutrients, sulphur and zinc are now studied and emphasized on how they influence the plant growth metabolism. Sulphur plays a significant role in seed development and is required to fix nitrogen from the soil. It is also a major nutrient for the photosynthesis process and the synthesis of tertiary structures of proteins, chlorophyll and oil content in oilseeds. Its deficiencies can lead to reduced photosynthetic activity, chlorosis and reduced plant growth. The deficiency of the sulphur-containing amino acids cysteine, cystine and methionine may limit the nutritional value of food and feed (Sexton *et al*., 1998). Zinc on the other hand is essential element used by the crop in small quantities and is a pivotal component of many enzymes' requisite for plant hormone balance and auxin activity. The crop uptake of these micronutrients is very less about one pound per acre. Despite this low requirement, critical plant functions are finite if it's deficient, causing stunted growth, reduced internodes length and young leaves that appear smaller than usual.

Recently, a widespread deficiency of sulphur in the soil of crop fields has occurred in many parts of India (Jamal *et al*., 2005). Its deficiencies have been reported in

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many areas especially in soils of coarse texture, low organic matter and good drainage (Waddoups, 2011). The increased use of sulphur free fertilizers, little or no addition of sulphur fertilizers, removal of sulphur from the soil and intensive cropping systems have led to sulphur deficiencies in the soil (Scherer, 2001). In India, soil zinc deficiency is estimated to be 50% (Sharma, 2008). The deficiencies were found to be even more severe (60%) in the acidic soils of Northeastern India. In Nagaland, the district of Dimapur recorded the most zinc deficient district (25.6% of TSA) (Bandyopadhyay *et al*., 2018). These deficiencies in the soil may be attributed to the various climatic and soil factors such as increase in rainfall, leaching, an increase of Fe and Al oxides in the soil, slower rate of decomposition of organic matters and a high critical level of nutrient availability.

Therefore, understanding the role of sulphur and zinc in pulses growth becomes pertinent as such findings have significant implications for crop production and productivity, necessitating a thorough understanding and study of the interaction between sulphur and zinc in soybean plant metabolism influencing the growth, development and yield. Taking into account all these, an effort was made to study the effect of sulphur and zinc fertilization on the growth and yield of soybean.

MATERIALS AND METHODS

The research was conducted in the Agronomy Experimental Research farm of School and Agricultural Sciences and Rural Development (SASRD), Nagaland University campus, Medziphema during the *kharif* season of 2017 and 2018. The research farm was located in the foothill of Nagaland at an altitude of 310 meters above mean sea level with a geographical location at 25°45′43″N latitude and 95°53′ 04″E longitude. The temperature during the cropping period ranged between 21.7 to 33.6°C, humidity 66.70% to 95.68% with 3.1-6.0 sunshine hours and 14.6 mm-112.7 mm rainfall. The soil of the experimental site was sandy loam in texture with pH 4.9, soil organic carbon (1.46%), available N (340.86 kg ha^{-1}), available P_2O_5 (18.25 kg ha^{-1}), available K_2O (226.82 kg ha^{-1}), available S (15.3 kg ha^{-1}) and zinc content (0.48 mg ha^{-1}). The field experiment was laid out in Factorial RBD design and replicated thrice with fifteen treatments each measuring 4 m × 3 m. A total of 45 units were made and treatments combinations *viz* sulphur (0 kg ha^{-1}, 20 kg ha^{-1}, 40 kg ha^{-1}), zinc (0 kg ha^{-1}, 5 kg ha^{-1}, 10 kg ha^{-1}, 15 kg ha^{-1} and 20 kg ha^{-1}) were allocated within the plots of a block and the well-decomposed farmyard manure, the recommended dose of nitrogen, phosphorus and potassium at 20:60:40 kg ha^{-1} through DAP (18% N and 46% P_2O_5) and MOP (60% K_2O), respectively were mixed well and uniformly incorporated to each plot. Sulphur was applied through elemental sulphur powder (90%) at 0, 20,40 kg ha^{-1} and zinc through zinc oxide (70% Zn) at 0, 5, 10, 15 and 20 kg ha^{-1}. Healthy seeds of the variety JS 97-52 @ 60 kg ha^{-1} treated with fungicide Bavistin @ 2 g/L of water and *Rhizobium japonicum* @ 20 g kg^{-1} were then sown at a depth of 1.5 cm -2 cm maintaining a row-to-row distance of 40 cm and plant to plant distance of 10 cm. The recommended agronomic practices were carried out based on the crop requirement. Harvesting was done manually from the net plot area once the seed became hard and the leaves turned yellow in colour. For taking the biometrical observations, five healthy plants were selected randomly from each plot excluding the border row plants and tagged to determine the various growths and yield attributes of the plants. The readings were recorded at 25, 50 and 75 DAS and the data of the two years recorded for each character were then analysed statistically by applying the techniques of Analysis of Variance and the significance of different sources of variation was tested by F test (Cochran and Cox, 1957).

RESULTS AND DISCUSSION

The following findings were recorded based on the research work carried out for two years. The treatments recorded significantly higher growth and yield attributes like plant height, number of leaves per plant, number of branches per plant, shoot dry weight, leaf area index, crop growth rate, number of nodules per plant, number of pods per plant, seed yield and stover yield than the control plot. However, the length of pods, number of seeds per pod, test weight and harvest index did not differ significantly by the treatments (Table 1 and 2).

Effect of sulphur on growth attributes of soybean

Based on the data of two years, the different levels of sulphur had a significant effect on the growth attributes of soybean (Table 1). The highest plant height, number of leaves and branches were recorded with the application of 20 kg S ha^{-1} which was found to be statistically at par with 40 kg S ha^{-1} but significantly higher than that of control. The increase in these growth parameters may be attributed to the favourable effects of sulphur on N-metabolism, cell division, photosynthetic process and chlorophyll formation, protein structure, vitamins and other structural components resulting in an increased growth stage and development of the plant. Similar conclusions were also reached by Farhad *et al*. (2010), Yadav *et al*. (2013), Sharma *et al*. (2014) and Gill and Sharma, (2017). A higher shoot dry weight and LAI was found in the sulphur level of 20 kg S ha^{-1} which was at par with 40 kg S ha^{-1} while the lowest was recorded in the control (Table 1). The higher shoot dry matter could possibly be due to the increased crop growth and development resulting from better absorption and utilization of sulphur nutrients from the soil leading to an increase in the plant height, number of leaves and branches (Singh *et al*., 1995; Sahebagouda *et al*., 2019). The incorporation of sulphur may have aided in increasing the meristematic activity of the plant resulting in better development of the number of leaves and size resulting in higher LAI. In the case of CGR, the data on sulphur levels showed significant influence at all the growth stages. Among the different treatments, a significant increase in the Crop Growth Rate was recorded with the application of sulphur at 20 kg S ha^{-1} at 25-50 and 50-75 DAS over control and statistically at par with 40 kg S ha^{-1}. With increasing sulphur doses, a positive correlation was observed between the different growth indices and the leaf area index, leaf area duration, crop-growth rate and biomass production were reported to increase (Jamal *et al*. 2005). The above findings are also directly in line with previous findings of Vyas *et al*. (2008) who reported a significant response of crop growth rate with sulphur application up to 20 kg S ha^{-1}. The number of nodules also showed significant differences with the application of 20 kg S ha^{-1} recording the maximum number of nodules at par with 40 kg S ha^{-1} at all the crop stages (Table 1). Both treatments had a relatively higher significant effect over control. In sulphur deficient soil, the application of sulphur improved nitrogenase activity, nitrogen fixation, plant dry matter and the quality of soybean grain (Morshed *et al*. 2009) resulting in an increase in the number of nodules. Chauhan *et al*. (2013) reported an increase in number of nodules by 91% significantly due to the application of S_{20} kg ha^{-1}.

Effect of sulphur on yield attributes

The perusal of the data as shown in Table 2 recorded that the application of 20 kg S ha^{-1} had a notable effect on the number of pods; seed yield and stover yield as compared to the control and was at par with the treatment 40 kg S ha^{-1}. The increase in the yield parameters was due to the sulphur supplementation and availability in the vegetative and reproductive growth of the plant aiding in its chlorophyll formation, photosynthetic process and activation of enzymes and grain formation (Yadav *et al*. 2013). The findings deduced are in line with the works carried out by Akter *et al.* (2013); Hosmath *et al*. (2014) and Das *et al*. (2022) who also reported the highest seed yield in soybean due to sulphur's application at 20 kg ha^{-1} compared to other sulphur levels. Even though, the findings did not replicate the previously reported works concluded by Ram *et al*. (2014) the results suggest that sulphur requirement of the crop on the experimental soil may have been satisfied at 20 kg S ha^{-1} and therefore further addition of increased level of sulphur was not envisaged as the higher levels of sulphur were at par (Bhattacharjee *et al*. 2013).

Effect of zinc on growth attributes

The increasing levels of Zn significantly influenced the yield attributes of soybean. The highest plant height, number of leaves and branches were recorded with 20 kg Zn ha^{-1} while the lowest was noted in the control (Table 1). There was a compelling difference with the application of the different levels of zinc *i.e*. 5, 10, 15 and 20 kg Zn ha^{-1} over the control at 50 and 75 DAS though the Zn levels were found to be at par amongst them. These enhanced growth parameters could be ascribed to zinc's role in the synthesis of tryptophan, nitrogen metabolism and production of growth hormones such as indole acetic acid. The above results are in tandem with the work of Sonkar *et al.* (2012) and Singh *et al*. (2017) who reported the increased growth attributes of soybean

Table 1: Effect of sulphur and zinc fertilization for biofortification on growth attributes of soybean.

	Plant height (cm)			No. of leaves per plant			No. of branches per plant			Shoot dry weight (g plant^{-1})			LAI			Crop growth rate (g m^{-2} day^{-1})			Number of nodules per plant		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
S_0	35.37	38.75	37.06	17.85	19.98	18.92	3.4	3.78	3.59	14.81	20.42	17.61	0.8	0.86	0.83	9.06	13.39	11.22	52.33	42.33	47.33
S_{20}	44.94	46.74	45.84	23.53	27.53	25.53	4.15	4.25	4.2	24.9	26.72	25.81	1.14	1.25	1.2	14.3	16.03	15.17	81.93	65.47	73.7
S_{40}	43.78	45.32	44.55	22.08	26.99	24.54	4.1	4.12	4.11	23.78	25.38	24.58	1.08	1.2	1.14	13.61	15.31	14.46	76.93	64	70.47
SEm ±	0.54	0.6	0.36	0.57	0.5	0.44	0.05	0.05	0.03	0.45	0.26	0.22	0.02	0.04	0.02	0.75	0.61	0.5	2.22	2.27	1.73
CD (P=0.05)	1.58	1.75	1.06	1.64	1.44	1.27	0.15	0.16	0.09	1.31	0.76	0.64	0.06	0.11	0.07	2.16	1.78	1.44	6.44	6.57	5.02
Zn_0	37.64	40.06	38.85	18.22	21.78	20	3.51	3.76	3.63	17.76	21.38	19.57	0.82	0.91	0.87	11.27	14.3	12.78	58.67	46.22	52.44
Zn_5	39.81	42.45	41.13	20.36	23.27	21.81	3.77	3.98	3.87	19.5	22.9	21.2	0.92	1.06	0.99	11.2	14.05	12.63	67.22	55.11	61.17
Zn_{10}	40.61	43.8	42.21	21.37	25.26	23.31	3.9	4.13	4.02	21.92	24.06	22.99	1.02	1.09	1.06	13.05	14.71	13.88	69.89	57.22	63.56
Zn_{15}	43.71	45.17	44.44	22.16	26.29	24.22	4.09	4.17	4.13	22.87	25.64	24.26	1.11	1.21	1.16	13.13	15.71	14.42	75	60.56	67.78
Zn_{20}	45.05	46.55	45.8	23.67	27.58	25.62	4.15	4.22	4.19	23.77	26.89	25.33	1.16	1.25	1.21	12.96	15.78	14.37	81.22	67.22	74.22
SEm ±	0.7	0.78	0.47	0.73	0.64	0.57	0.07	0.07	0.04	0.58	0.34	0.29	0.03	0.05	0.03	0.96	0.79	0.64	2.87	2.93	2.24
CD (P=0.05)	2.03	2.26	1.36	2.12	1.86	1.64	0.2	0.21	0.12	1.69	0.98	0.83	0.08	0.15	0.09	NS	NS	NS	8.32	8.49	6.48

Table 2: Effect of sulphur and zinc fertilization for biofortification on yield attributes of soybean.

	Number of pods per plant			Seed yield (t ha^{-1})			Stover yield (t ha^{-1})		
	2017	2018	Pooled	2017	2018	Pooled	2017	2018	Pooled
S_0	20.98	27.77	24.37	0.75	0.71	0.74	1.43	1.59	1.51
S_{20}	34.12	46.83	40.48	1.04	1.09	1.07	2.08	1.84	1.97
S_{40}	32.21	46.50	39.36	1.02	0.99	1.01	1.79	1.78	1.79
SEm±	1.21	1.44	0.76	0.03	0.02	0.02	0.10	0.03	0.05
CD (P=0.05)	3.50	4.17	2.20	0.09	0.07	0.06	0.30	0.10	0.16
Zn_0	22.43	31.67	27.05	0.78	0.77	0.78	1.35	1.57	1.46
Zn_5	26.98	39.36	33.17	0.90	0.86	0.88	1.73	1.72	1.73
Zn_{10}	29.73	40.66	35.19	0.92	0.88	0.91	1.75	1.76	1.76
Zn_{15}	31.60	43.16	37.38	1.04	1.01	1.02	1.85	1.77	1.81
Zn_{20}	34.78	47.01	40.89	1.07	1.13	1.10	2.15	1.88	2.02
SEm±	1.56	1.86	0.98	0.04	0.03	0.03	0.13	0.04	0.07
CD (P=0.05)	4.52	5.38	2.85	0.12	0.09	0.08	0.38	0.12	0.20

with zinc application. The highest shoot dry weight was noted with 20 kg Zn ha^{-1} followed by 15 kg Zn ha^{-1} and the lowest shoot dry weight was found with 0 kg Zn ha^{-1}. The leaf area index as shown in Table 1 revealed that the treatments of 20 kg S ha^{-1} and 40 kg S ha^{-1} did not show much variation and were at par with each other while the lowest LAI was seen in control. The application of 20 and 15 kg Zn ha^{-1} was found to be significantly superior to 10 and 5 kg Zn ha^{-1} but the difference between the two Zn levels was found non-significant for both years. The application of zinc was found to invariably increase the dry matter production of soybean (Sarkar and Aery, 1990) and an increase in the cell division, elongation and photosynthesis resulting in increased leaf size and consequently a higher LAI. The increase in dry matter up to the highest Zn dose applied at 20 kg ha^{-1} at all the stages of the crop was also reported by (Awlad *et al.*, 2003; Jadhav *et al.,* 2009) The Crop Growth Rate showed a notable increase with the application of different levels of zinc at 25-50 DAS. However, it failed to exert a significant influence on the crop growth rate at 50-75 DAS. The perusal data revealed that the control treatment recorded the lowest CGR while 20 kg Zn ha^{-1} recorded the highest CGR and was statistically at par amongst the different zinc treatments. Zinc is involved in auxin metabolism and hormonal activity and hence an increase in crop growth. The findings were in partial conformity with that of Saxena and Chandel, (1997) who reported that the plant height, CGR and yield attributes of soybean were increased due to zinc application. The effect of different levels of zinc showed a significant effect on the number of nodules (Table 1) with 20 kg Zn ha^{-1} recording a higher number of nodules at all the crop growth stages at par with 15 kg Zn ha^{-1} while control recorded the lowest number of nodules. Zinc is known to be involved in nitrogen fixation through nodule formations and therefore, the supplementation of zinc has increased the nodulation efficiency and nodulation activity (Zhang *et al.*, 1996). Previous works carried out by Awlad *et al*. (2003) and Thenua *et al*. (2014) also reported a significant increase in the number of nodules per plant at 20 kg Zn ha^{-1}.

Effect of zinc on yield attributes

There was an increase in the number of pods, seed yield and stover yield with increasing levels of zinc at 5, 10, 15 and 20 kg Zn ha^{-1} (Table 2). The increase in levels of zinc exhibited an increment in the yield attributes of soybean up to 20 kg Zn ha^{-1} at par with 15 kg Zn ha^{-1} and significantly higher over the lower levels of zinc as shown in Table 2. The increase in the number of pods, seed yield and stover yield may be attributed to zinc role as the structural constituent of different enzymes and proteins in many important biochemical pathways like carbohydrate metabolism, photosynthesis, auxin metabolism, conversion of sugars to starch, biosynthesis of plant growth regulator (IAA), N metabolism reflecting in higher yield (Suresh *et al*., 2013). The finding was also in partial conformity with the work of Thenua *et al*. (2014) who outlined higher seed yield with 30 kg Zn ha^{-1} during both years of research and it was found to be at par with 20 kg Zn ha^{-1}. These basic findings are also consistent with the research carried by Singh and Singh (1995).

Interaction

The interaction effect between sulphur and zinc was observed to be significant in the pooled data of the seed yield and stover yield. A higher seed yield and stover yield were observed with the treatment combination of 20 kg S ha^{-1} + 20 kg Zn ha^{-1} indicating their synergistic interaction while the lowest seed yield and stover yield was observed under control.

CONCLUSION

Based on the results of the two years experiment, it can be concluded that the treatments of 20 kg S ha^{-1} and 20 kg Zn ha^{-1} were found to be a suitable fertilizer dosage for soybean. The application of the treatment ($S_{20}Zn_{20}$) led to good results recording better growth and yield of soybean compared to control.

Conflict of interest: None.

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