Biological Forum – An International Journal 15(4): 307-312(2023)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Effect of Sulphur and Zinc Fertilization on the Quality and Economics of Soybean (*Glycine max* L. Merrill) under Nagaland Condition

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(Received: 17 February 2023; Revised: 14 March 2023; Accepted: 19 March 2023; Published: 20 April 2023)
(Published by Research Trend)

ABSTRACT: The role of nutrients is profound in playing a vital role in the quality of soybean crops and as such its supplementation to the crop is pertinent for increased productivity. In relation to this, 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 different levels of sulphur and zinc fertilization on the quality and economics of soybean (*Glycine max* L. Merrill) under Nagaland condition. 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}, 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. The results from the two years study showed that the oil and protein content in the crop were significantly influenced by the treatment combination of $S_{20}Zn_{20}$ as compared to the other levels of treatments. A higher oil and protein content were observed with the application of 20 kg S ha^{-1} which was comparatively at par with the application of 40 kg S ha^{-1} and superior over control while 20 kg Zn ha^{-1} fertilization recorded significantly the highest oil and protein content followed by the application of 15 kg Zn ha^{-1}. In terms of the economics of the treatments, $S_{20}Zn_{20}$ gave the highest gross returns, net returns and B:C ratio followed by $S_{20}Zn_{15}$ for both the years and pooled. Thus, based on the results of the two years experiment, the treatment combinations of $S_{20}Zn_{20}$ was found to be a suitable fertilizer dosage for soybean.

Keywords: Soybean, Sulphur, Zinc, Protein, Oil content, Economics, B:C ratio.

INTRODUCTION

Soybean is one of the most valuable food crops today in the global oilseed cultivation scenario contributing about 25% of the world's vegetable oil production and about two-thirds of the global protein concentrates. It is grouped as an oilseed rather than a pulse and is known as legumes, vegetables, or even fuel sources based on their usage. Its protein is rich in valuable amino acid lysine (5%), generally deficient in most cereals and therefore its inclusion in the diet will aid in providing overall health security to the Indian masses where more than 40% of the population suffers from protein malnutrition. In India, soybean has become an important oilseed crop in the country within a short period. Its success story is evident from the productivity front where its growth has tripled. The crop particularly has been fetching more from the export of de-oiled cake, a by-product of oil extraction plants, the demand for which is projected to be higher in the coming years. In order to meet these demands, we will need to produce millions of tons of edible oil. These can be made possible only if there is a greater emphasis on the nutrient requirement of the plants for increasing the productivity of the crops (Strategic Plan, 2011-2016) as deficiencies of nutrients in crops particularly soybean is a limiting factor in obtaining increased crop yield (Sahu *et al*., 2017). Lately, "biofortification" has garnered attention globally (Graham *et al*., 2001) to address the growing dietary micronutrient deficiency and to combat food security (Burchi *et al*., 2011). It is 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) Therefore, it becomes imperative that these deficiencies are addressed to and biofortification is one such approach considered as one of the most cost-effective approaches in addressing this micronutrient malnutrition (Qaim *et al*., 2007).

Among these nutrients, sulphur and zinc are now studied and emphasized on how they influence the plant. Pulses particularly are responsive to sulphur containing fertilizers in places where sulphur deficiency is reported in soil. The application of sulphur increases the nitrogen percentage as well as the yield on sulphur-deficient soils and is required to fix nitrogen from the soil. It is a major nutrient for the photosynthesis process and the synthesis of tertiary structures of proteins, chlorophyll and oil content in oilseeds. Its requirement in oilseeds is the highest compared to other crops and therefore plays a vital role in oil biosynthesis (Ahmad *et al*., 2007). However, lately, a widespread deficiency of S in the soil of crop fields in many parts of India has occurred (Jamal *et al*., 2005). In India, more than 41 percent of the soils have been reported to be deficient in sulphur (Singh, 2001) and areas of sulphur deficiency are becoming widespread globally (Irwin *et al*., 2002) due to the increased use of sulphur-free fertilizers, little or no addition of sulphur fertilizers, removal of sulphur from the soil and intensive cropping systems (Scherer, 2001). The role of sulphur in pulses growth becomes pertinent as 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).

Micronutrients such as zinc are essential elements used by plants in small quantities. It is a pivotal component of many enzymes requisite for plant hormone balance and helps in synthesizing proteins, DNA, RNA and is a precursor of auxin essential for cell elongation (Awlad *et al*., 2003). Its uptake by crops is very less however; critical plant functions are finite if it's deficient causing stunted growth, reduced internode length, and young leaves that appear smaller than usual. In such scenarios, the use of expensive and high-requirement crop inputs may be dissipated. In India, soil zinc deficiency is estimated to be 50% (Sharma, 2008). Its deficiencies were found to be even more severe (60%) in the acidic soils of North Eastern India and in Nagaland. The district of Dimapur recorded the most zinc-deficient district (25.6% of TSA) (Bandyopadhyay *et al*., 2018). The climatic and soil factors such as an increase in rainfall, leaching, an increase of Fe and Al oxides in the soil, a slower rate of decomposition of organic matter and a high critical level of nutrient availability may have attributed to these deficiencies in the soil. Thus, micronutrient fertilization on such soils becomes important as the major nutrients alone cannot improve the crop yield unless supplemented by application of micronutrients (Kumar *et al*., 2016). The importance of such findings has significant implications for crop production and productivity, necessitating a thorough understanding and study of the importance of these nutrients. Therefore, taking into account all these, an effort was made to study the effect of sulphur and zinc fertilization on the quality content of soybean i.e. oil and protein content and also to find the economics of soybean.

MATERIALS AND METHODS

The research was conducted in the 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 the 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 ºC, 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 i.e. 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 randomly allocated within the plots of a block and the well decomposed farmyard manure, 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 as basal dose 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 @ 2g/L of water and *Rhizobium japonicum* @ 20 g kg^{-1} were then sown at a depth of 1.5 cm^{-2} cm maintaining 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. After harvesting, the seed samples were drawn randomly and then analysed for the oil and protein content. The oil content was determined by the Soxhlet extraction method (A.O.A.C., 1955). The protein content was obtained by multiplying per cent nitrogen (N) content of soybean seed by 6.25 (A.O.A.C., 1960). The data from the two years recorded were analysed statically by applying the techniques of Analysis of Variance and the significant of different sources of variation were tested by F test (Cochran & Cox 1957).

RESULTS AND DISCUSSION

Effect of sulphur and zinc fertilization on the quality of soybean. The seed protein and oil content are important parameters which govern the quality of soybean. Based on the findings of the research work carried out for two years, a significant influence could be observed with the application of sulphur and zinc on the oil and protein content in soybean.

Effect of sulphur and zinc fertilization on quality of soybean

Oil content in soybean (%)

Effect of sulphur levels. The increasing levels of sulphur significantly improved the quality of soybean in terms of the oil content in the seed (Table 1). The oil content in soybean was comparatively higher with the application of 20 kg S ha^{-1} (17.69%) in the initial year while the lowest oil content was recorded at 0 kg S ha^{-1} (14.63%). In the subsequent year, not much variation could be seen as the treatments of 20 kg S ha^{-1} (17.27%) and 40 kg S ha^{-1} (17%) were at par with each other but significantly higher than the control (14.91%). The pooled data also showed a similar trend with 20 kg S ha ha^{-1} (17.48%) recording higher oil content and at par with 40 kg S ha^{-1} (16.95%) while control recorded the lowest (14.77%). Oilseeds require a higher amount of sulphur as compared to other crops for the synthesis of lipids, fatty acid synthesis, acetyl-CoA enzyme activity. The increase in oil content might therefore be associated with the increase in acetyl-CoA, carbohydrate activity on the addition of sulphur. The above findings were consistent with the previous studies conducted by Farhad *et al.* (2010); Hosmath *et al*. (2014) who also reported a significant increase in the oil content of soybean with the application of sulphur @ 20 kg ha ha^{-1} compared to sulphur levels 10 kg ha^{-1}, 30 kg ha ha^{-1} and 40 kg ha^{-1}. Chauhan *et al.* (2013) reported the oil percentage increased by 1.3 and 1.1% at K_{20} S_{20} Zn_5 combination dose among all other combination doses during the course of two years of experimentation. Similar finding was also carried out by Pable *et al.* (2010).

Effect of zinc level. Based on the data presented in Table 1, the oil content in soybean increased with the increasing levels of zincat 5, 10, 15 and 20 kg Zn ha^{-1}. A significant increase in oil content was observed with the application of 20 kg Zn ha^{-1} (17.53 %) while the lowest was recorded in control (15.03%) in the first year. In the subsequent year, the application of 20 kg Zn ha^{-1} (17.19%) recorded the highest oil content at par with 15 kg Zn ha^{-1} (16.82%). The pooled data also showed a similar trend with 20 kg Zn ha^{-1} (17.36%) recording higher oil content while control recorded the lowest (15.29%). The deficiency of zinc has been reported to avert the activity of some antioxidant enzymes leading to severe damage to lipid membranes and decreasing the oil content of seeds (Choudhary *et al*., 2015). However, the presence of zinc increases the oil content due to the improvement of lipid membranes (Chakmak, 2000). Thus, the increase in oil content in soybean seed may be attributed to the activation of NADPH-dependent dehydrogenase involved in fat synthesis by Zn application (Raghuwanshi *et al*., 2017). The application of zinc has also been found to increase plant weight and thereby increase carbohydrate production and oil percentage in seeds (Morshedi and Naghibi 2004). The results obtained were broadly in line with the works carried out by Pable *et al*. (2010); Singh *et al*. (2017) wherein the application of zinc led to an increase in the oil content. Application of zinc @ 20 kg ha^{-1} also recorded at par effect in respect of oil and protein content with the treatment of the application of zinc @ 10 kg ha^{-1} (Kakad *et al*., 2008). The interaction effect between sulphur and zinc level exhibited a significant variation in the first year but showed non-significant variation in the second year with 20 kg Zn ha^{-1} recording the highest oil content. The pooled value showed the highest oil content of the crop with the addition of 20 kg Zn ha^{-1}.

Protein content in soybean (%)

Effect of sulphur levels. Based on the data collected, there was a notable variation in the protein content of soybean with the application of different levels of sulphur (Table 1). Significantly higher protein content was observed with the application of 20 kg ha^{-1} (36.47%, 36.64% and 36.55%) comparable with that of 40 S kg ha^{-1} (36.14%, 36.43% and 36.28%) and superior over control (32.69%, 35.46% and 34.08%) for both the years of experiments and pooled data. Sulphur is required by crops for protein structure, vitamins and other structural components and also to improve plant growth and yield (Marshner, 2005; Kopriva *et al.,* 2002). It is required for the synthesis of fatty acid and S-containing amino acids, such as cystine, cysteine and methionine which are essential components of protein. The application of sulphur enhances the process of protein synthesis (Ahmed and Abdin 2000) and its synthesis in soybean is reported to be highly influenced by minerals such as phosphorus, potassium, nitrogen and sulphur (Peak *et al.,* 1997; Utsumi *et al.,* 2002; Mahmoodi *et al.,* 2013). Therefore, the addition of graded levels of sulphur may have significantly influenced the protein content in soybean. These results are in tandem with previous works by Sharma *et al*. (2014) who concluded that gypsum @ 20 kg S ha^{-1} alone or in combination with recommended nitrogen doses improved the total storage protein, glycinin fraction of globulin, S-containing amino acids and seed yield in soybean. Aulakh (1995); Farhad *et al*. (2010) also reported an increase in the protein content in soybean with the application of $N_{100}S_{20}$ and $K_{40}S_{20}$ treatments respectively. The above findings were also in close conformity with the works carried out by Mamatha *et al*. (2018); Gokhale *et al*. (2005) who reported an increase in protein content in soybean seed over control at 30 kg S ha^{-1}.

Effect of zinc levels. The different levels of zinc resulted in the increase of the protein content in soybean seed with increasing levels of zinc (5, 10, 15 and 20 kg Zn ha^{-1}). The application of the two levels of zinc 20 kg Zn ha^{-1} and 15 kg Zn ha^{-1} had a significant influence on the protein content over control but the difference between the two levels of Zn was found to be non-significant. The highest protein content was recorded in the zinc level of 20 kg Zn ha^{-1} (37.14 and 36.99%) while the control recorded the lowest (33.09 and 34.41%) for the initial year and pooled. The data showed a non-significant influence in the second year. The application of zinc may have attributed to increased N-metabolism enhancing the accumulation of amino acids and leading to protein synthesis thereby increasing the protein content in the seeds (Sonune *et al*., 2001). The application of zinc in soil was also found to enhance the zinc concentration in soybean thereby aiding in RNA and ribosome synthesis which might have resulted in accelerated protein synthesis (Pable and Patil 2011). This was in tandem with the works carried out by Bairagi *et al*. (2007); Kulhare *et al*. (2014). Awlad *et al*. (2003) also reported similar findings whereby zinc was involved in nitrogen and protein metabolism by controlling RNase activity, auxin bio-synthesis and carbohydrate metabolism. No statistical inference could be established in the interaction effect between sulphur and zinc levels.

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

Treatments	Quality of soybean					
	Oil %			Protein %		
	2017	2018	Pooled	2017	2018	Pooled
S_0	14.63	14.91	14.77	32.69	35.46	34.08
S_{20}	17.69	17.27	17.48	36.47	36.64	36.55
S_{40}	16.91	17.00	16.95	36.14	36.43	36.28
SEm ±	0.16	0.17	0.10	0.58	0.23	0.31
CD (P=0.05)	0.48	0.48	0.29	1.67	0.66	0.89
Zn_0	15.03	15.56	15.29	33.09	35.72	34.41
Zn_5	15.90	16.04	15.97	34.71	35.87	35.29
Zn_{10}	16.71	16.36	16.53	34.86	36.09	35.48
Zn_{15}	16.87	16.82	16.84	35.70	36.35	36.02
Zn_{20}	17.53	17.19	17.36	37.14	36.84	36.99
SEm ±	0.21	0.22	0.13	0.74	0.29	0.39
CD (P=0.05)	0.62	0.63	0.37	2.16	NS	1.41

Economics. The production economics of the different treatments are presented in Table 2. The perusal of the data showed that the cost of cultivation differed for the different treatment combinations. Among the different treatments applied, the lowest cost of cultivation was recorded in the control treatment (₹54,718.2) while the highest cost of cultivation i.e. ₹60,114.7 was incurred in the treatment combinations of 40 kg S ha^{-1} and 20 kg Zn ha^{-1}. The gross returns (₹83,100 and ₹1,00,790) and net returns (₹23,541.3 and ₹41,231.3) were however found to be highest in the treatment combinations of 20 kg S ha^{-1} and 20 kg Zn ha^{-1} during the two years of research. The lowest gross returns (₹27,120 and ₹35,560) and a net deficit of (₹27,598.2 and ₹19,158.2) due to low yield of the crop were obtained in the treatment where no treatment combinations were applied in both the years. In the initial year of research, the B: C ratio was found to be highest in the treatment combinations of 20 kg S ha^{-1} and 20 kg Zn ha^{-1} (1.40) followed by the combinations of 20 kg S ha^{-1} and 15 kg Zn ha^{-1} (1.33). In the subsequent year, the treatments of 20 kg S ha^{-1} and 20 kg Zn ha^{-1} (1.69) recorded the highest B.C ratio followed by 20 kg S ha^{-1} and 15 kg Zn ha^{-1} (1.43). In both years, the control treatment recorded the lowest (0.50 and 0.65) B: C ratio as compared to all the treatments.

Table 2: Economics of treatments under study.

Treatments interactions	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})		Net returns (₹ ha^{-1})		Benefit cost ratio	
		2017	2018	2017	2018	2017	2018
S_0Zn_0	54718.2	27120	35560	-27598	-19158	0.5	0.65
S_0Zn_5	55789.2	50540	50630	-5249.2	-5159.2	0.91	0.91
S_0Zn_{10}	56861.7	54740	52080	-2121.7	-4781.7	0.96	0.92
S_0Zn_{15}	57932.7	68760	56290	10827.3	-1642.7	1.19	0.97
S_0Zn_{20}	59003.7	69870	62600	10866.3	3596.3	1.18	1.06
$S_{20}Zn_0$	55273.2	70410	66840	15136.8	11566.8	1.27	1.21
$S_{20}Zn_5$	56344.2	71900	67570	15555.8	11225.8	1.28	1.2
$S_{20}Zn_{10}$	57416.7	72630	70400	15213.3	12983.3	1.26	1.23
$S_{20}Zn_{15}$	58487.7	77780	83720	19292.3	25232.3	1.33	1.43
$S_{20}Zn_{20}$	59558.7	83100	100790	23541.3	41231.3	1.4	1.69
$S_{40}Zn_0$	55829.2	70320	64720	14490.8	8890.8	1.26	1.16
$S_{40}Zn_5$	56900.2	71060	66860	14159.8	9959.8	1.25	1.18
$S_{40}Zn_{10}$	57972.7	71790	68280	13817.3	10307.3	1.24	1.18
$S_{40}Zn_{15}$	59043.7	76700	76010	17656.3	16966.3	1.3	1.29
$S_{40}Zn_{20}$	60114.7	77470	78840	17355.3	18725.3	1.29	1.31

CONCLUSIONS

Based on the results of the two years experiment, the treatment combination of 20 kg S ha^{-1} and 20 kg Zn ha^{-1} was found to be a suitable fertilizer dosage for soybean compared to the other treatments. The quality parameter of soybean was seen to be significantly influenced by the application of sulphur and zinc at 20 kg S ha^{-1} and 20 kg Zn ha^{-1}. The application of $S_{20}Zn_{20}$ also led to good results recording the highest gross returns, net returns and B:C ratio.

FUTURE SCOPE

With continuing works done on improving the nutrients deficiencies in soil, there is also a need to do further research on the residual effects of these treatments on other crops. The nutrient requirement for each region will differ and hence more research is recommended to study the most suitable fertilizer dosage for the said regions. On farm trials should also be conducted to know the applicability and utility in the farmer's level.

Acknowledgement. My sincere gratitude goes to my supervisor Dr. Lanunola Tzudir, Assistant Professor, Department of Agronomy and the Advisory Committee members for their unwavering support and guidance throughout the research study.
Conflict of Interest. None.

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How to cite this article: Watisenla Imsong, Lanunola Tzudir, L.T. Longkumer, T. Gohain and Z. Kawikhonliu (2023). Effect of Sulphur and Zinc Fertilization on the Quality and Economics of Soybean (G*lycine max* L. Merrill) under Nagaland Condition. *Biological Forum – An International Journal, 15*(4): 307-312.