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Effect of Sulphur and Zinc on Nodulation Dry Matter Yield and Nutrient Content of Soybean

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Abstract: The effect of sulphur (S) and zinc (Zn) on nodulation, dry matter yield, nutrient content of soybean cv. Shohag (Pb-1) was studied during December, 2001 to March, 2002. The levels of S and Zn employed were 0, 10, 20, 30 and 50 kg S ha^{-1} and 0, 2.5, 5, 10 and 20 kg Zn ha^{-1}, respectively. The results indicated that among the S treatments, S_{30} gave the highest number of nodules $plant^{-1}$ mostly at the later stages of growth though the effect was not significant. Zinc also did not show any significant influence on nodulation of soybean. The highest number of nodules were obtained from Zn_{20} at 90 (DAS). Dry matter yield at different growth stages were significantly affected with the increasing levels of S and Zn application. Sulphur and zinc contents were also significantly increased with the increasing levels of S and Zn up to 30 kg S and 20 kg Zn ha^{-1} in most of the growth stages and then decreased with higher levels of S.

Key words: Nodulation, dry matter, nutrient content, sulphur, zinc, soybean

Introduction

Inadequate supply of organic manures and S containing fertilizers have in one hand led to low S content in soil and on the other, depletion of soil fertility creating a serious constraint to higher crop production in Bangladesh. The farmers use in general 102 kg ha^{-1} of nutrients annually against a crop removal of 200 kg (Islam *et al.*, 1994). In addition, a significant amount of the nutrients is being lost every year through leaching from arable land of Bangladesh (Ali, 1994). Soybean (*Glycine max* L. Merrill) belongs to the family Leguminosae, subfamily Papilionoideae has occupied the top position in term of oil source in the world and has been placed second in respect of use as oil in Bangladesh. Soybean contains about 20-22% edible oil, 42-45% best quality protein, 20.9% carbohydrate and a good amount of other nutrients like calcium, phosphorus, iron, vitamin etc. (Gopalan, 1971). Sulphur, though a major plant nutrient, nobody thought of its application for crop production a few years back. Sulphur may enhance seed formation and protein quality through the synthesis of certain amino-acids such as cystine, cysteine, methionine and also plant hormones and some vitamins (Aulakh and Pasricha, 1988) increase nodulation (Singh and Bansal, 2000), dry matter yield (Babhulkar *et al.,* 2000) and nutrient content (Agrawal *et al.,* 2000) of soybean. An adequate S supply to plants is important because S deficiency can reduce yield and can effect product quality (Morris *et al.*, 1984; Randal and Wrigley, 1986).

In Bangladesh, Zn deficiency is recurrently expanding owing to a general negligence for the use of such vital element in agricultural field. About 1.74 M $ha^{-1}$of land are suspected to be potentially Zn deficient in Bangladesh (Choudhury and Hore, 1989). Zinc plays an important role in many physiological functions of plants. Zinc is involved in the biosynthesis of tryptophane, a precurser of auxin which is essential for cell elongation. Zinc has been found to be essential for normal chlorophyll formation in the plants (Tisdale and Nelson, 1984). Zinc application increased nodulation efficiency and nodule nitrogenase activity (Zhang *et al.,* 1996).

Information in relation to the effect of S and Zn on soybean in Bangladesh soil, is a meagre. Some research have been done under field conditions on the effect of S-Zn combination on wetland rice. But limited works have been performed in non-calcareous dark grey floodplain soils particularly on soybean. Thus, this research work was, therefore, undertaken to evaluate the suitable levels of S and Zn, eventually their influence on nodulation, dry matter yield and nutrient content of soybean.

Materials and Methods

The experimental location was the Horticulture Farm of Bangladesh Agricultural University, Mymensingh having a medium high land with silty loam soil, pH 6.7, 1.71% O.M., 0.09% N, 0.06 me K 100 g^{-1} soil, available Sulphur 8 $\mu g\ g^{-1}$and available Zn 1.71 $\mu g\ g^{-1}$ soil.

The experiment was laid out in randomized complete block design (RCBD) with 3 replications. Each block was further divided into 25 unit plots for placement of 25 treatment combinations. Thus, the total number of plots under the experimental design were 75. The size of the unit plot was 4×2.5 m^2. The spacing between blocks was 1 m and between plots 0.5 m. There were 5 treatments each of S and Zn including a control viz 0, 10, 20, 30 and 50 kg S ha^{-1} and 0, 2.5, 5, 10 and 20 kg Zn ha^{-1}, respectively. Sulphur was used as gypsum ($CaSO_4.2H_2O$) and zinc as $ZnSO_4.H_2O$. In calculating the amount of S, its content in $ZnSO_4.H_2O$ was reduced from that of gypsum.

The soil of each plot was uniformly fertilized with 175 kg P_2O_5 ha^{-1} as triple super phosphate (TSP) and 120 kg K_2O ha^{-1} as muriate of potash (MP). Fertilizers were applied at the time of final land preparation. Basal doses of N as urea @ 60 kg ha^{-1} was applied in 3 equal splits at final land preparation, 20 and 50 days after sowing (DAS).

Soybean seeds of cv. Shohag (Pb-1) were collected from the Department of Genetics and Plant Breeding, BAU and sown on the 13th December 2001 in line (spacing 30 cm) carefully. Each plot received 75 g (75 kg ha^{-1}) seed. Intercultural operations were done as and when needed to keep the crop free from weeds and to protect from various pests and diseases. Dry matter yield was worked out on oven dry-weight basis. Samples for estimating nodulation, dry matter yield and nutrient content of S and Zn on soybean were recorded from 10 randomly selected plants at 30, 45, 60, 90 and 110 days after sowing. The grain and straw samples were digested by di-acid mixture (Page *et al.*, 1982) to determine the nutrient concentration of the crops. Sulphur was determined turbidemetrically following the method of Wolf (1982) and Zn was determined by atomic absorption spectrophotometer directly (Lindsay and Norvell, 1979). Data were analyzed following analysis of variance technique with the computer package programme MSTAT and mean differences were adjudged by least significant difference test (LSD) (Gomez and Gomez, 1984).

Results and Discussion

Main root nodules plant^{-1}: The results showed that the number of main root nodules plant^{-1} was not significantly influenced neither by S nor by Zn application at all the growth stages (Table 1). The maximum number of main root nodules plant^{-1} was obtained from S_{30} (2.92) and Zn_{20} (3.52) and the minimum from control (1.52 and 0.94, respectively). The number of nodules increased with the advancement of growth stages up to 90 DAS and then decreased. As the plants grew older, the number of nodules increased but at later stages of growth the increase was at slower rate.

The interaction effects of S and Zn were also not significant in respect of main root nodules number plant^{-1} (Table 1). Maximum main root nodules plant^{-1} was recorded at 90 DAS in $S_{10}Zn_{2.5}$ (6.67) treatment combination. There was no nodulation in control until 90 DAS (Table 1).

Branch root nodules plant^{-1}: The highest number of branch root nodules plant^{-1} (3.43) was obtained from S_{30} treatment at 110 DAS which was statistically identical with all other treatments (Table 1), the second highest number was found in S_{20} treatment. It was noticed that branch root nodules were much higher than that of main root at all the growth stages which might be due to higher number of branch roots compared to single main root.

The interaction effects of S and Zn were not significant in respect of branch root nodules plant^{-1} (Table 1). Maximum number of branch root nodules plant^{-1} (7.67) was recorded at 90 DAS in $S_{10}Zn_{2.5}$ treatment combination and minimum (0.33) in $S_{30}Zn_{10}$ at 110 DAS.

Total nodules plant^{-1}: At 90 DAS the number of total nodules plant^{-1} ranged from 2.99–6.22 (Table 1). The highest number of total nodules were found in S_{30} at 90 DAS and the lowest from S_0 at 60 DAS. Total number of nodules increased up to 90 DAS and then decreased at 110 DAS in both the cases. The increase might be due to the growth of plant, increased levels of S application which in turn enhanced the formation of main and branch root nodules. Singh and Bansal (2000) reported that S application increased nodulation of soybean. Similar results were also observed by Ganeshamurthy and Reddy (2000), Hemantarajan and Trivedi (1997) and Singh and Chaudhari (1997).

The interaction effects of S and Zn were not significant in respect of nodulation (Table 1). Maximum number of nodules plant^{-1} was recorded at 90 DAS in $S_{10}Zn_{2.5}$ and the minimum in $S_{30}Zn_{10}$ at 110 DAS.

Dry matter yield: Dry matter yield was significantly influenced by S fertilization at all the growth stages except at 90 DAS. The highest dry matter yield was recorded with 30 kg S ha^{-1} and the lowest by 0 kg S ha^{-1} at all the growth stages except 90 DAS. The dry matter yield increased with increase in S levels upto S_{30} beyond which it again decreased.

Dry matter yield increased with the age of plant and the increase was accelerated between 45 and 90 DAS. This might be due to quick growth of plant, increase in leaf number, plant height and increase in levels of S. Similar findings was obtained by Singh *et al.* (1995),

Table 1: Effect of sulphur and zinc on nodulation of soybean cv. Shohag (Pb-1) at different growth stages

	Nodules plant^{-1} (No.)							
	30 DAS	45 DAS	60 DAS		90 DAS		110 DAS	
Treatments	Main root	Main root	Main root	Branch root	Main root	Branch root	Main root	Branch root
S_0	0.00	0.20	0.13	0.20	1.52	1.47	1.16	1.53
S_{10}	0.27	0.27	0.13	0.33	1.88	2.11	1.69	1.73
S_{20}	0.20	0.33	0.20	0.22	2.24	2.67	1.78	2.53
S_{30}	0.21	0.32	0.13	0.47	2.92	3.30	2.55	3.43
S_{50}	0.20	0.53	0.13	0.53	1.98	2.15	2.31	1.72
Zn_0	0.07	0.13	0.067	0.20	0.94	0.99	0.69	0.95
$Zn_{2.5}$	0.33	0.13	0.067	0.53	1.44	1.52	1.53	1.75
Zn_5	0.27	0.13	0.130	0.35	1.77	1.69	2.10	2.02
Zn_{10}	0.13	0.73	0.200	0.40	2.04	2.83	2.18	2.66
Zn_{20}	0.07	0.53	0.270	0.27	3.52	3.68	2.99	2.99

	30 DAS	45 DAS	60 DAS			90 DAS			110 DAS		
Treatments	Main root	Main root	Main root	Branch root	Total	Main root	Branch root	Total	Main root	Branch root	Total
$S_0 Zn_0$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.67	1.00
$S_0 Zn_{2.5}$	0.33	0.33	0.00	0.33	0.33	3.20	2.33	5.53	0.33	0.50	0.83
$S_0 Zn_5$	0.00	0.33	0.00	0.33	0.33	0.67	0.67	1.34	0.87	1.22	2.09
$S_0 Zn_{10}$	0.33	0.33	0.33	0.33	0.66	0.33	0.33	0.66	0.67	0.73	1.40
$S_0 Zn_{20}$	0.33	0.67	0.33	0.67	1.00	3.95	2.67	6.62	3.62	4.50	8.12
$S_{10} Zn_0$	0.00	0.67	0.67	0.75	1.42	4.27	3.08	7.35	3.33	4.07	7.40
$S_{10} Zn_{2.5}$	0.00	0.33	0.00	0.00	0.00	6.67	7.67	14.34	1.00	1.10	2.10
$S_{10} Zn_5$	0.00	0.33	0.00	0.00	0.00	0.33	0.83	1.16	1.89	2.17	4.06
$S_{10} Zn_{10}$	0.00	0.00	0.00	0.00	0.00	3.33	4.67	8.00	4.33	5.67	10.00
$S_{10} Zn_{20}$	0.00	0.00	0.00	0.33	0.33	1.73	0.25	1.98	2.17	4.17	6.34
$S_{20} Zn_0$	0.00	0.00	0.67	0.33	1.00	0.67	1.27	1.94	0.67	0.67	1.34
$S_{20} Zn_{2.5}$	1.00	0.66	0.00	0.67	0.67	0.22	6.10	6.32	3.47	4.67	8.14
$S_{20} Zn_5$	0.00	0.33	0.00	0.00	0.00	0.67	1.00	1.67	0.33	0.67	1.00
$S_{20} Zn_{10}$	0.00	0.00	0.00	0.67	0.67	0.67	5.00	5.67	0.38	5.00	5.38
$S_{20} Zn_{20}$	0.33	0.00	0.00	0.67	0.67	2.00	1.33	3.33	1.07	1.67	2.74
$S_{30} Zn_0$	0.00	1.33	0.00	0.00	0.00	1.83	2.48	4.31	1.76	2.33	4.09
$S_{30} Zn_{2.5}$	0.00	0.00	0.00	0.00	0.00	4.00	4.62	8.62	6.33	5.34	11.60
$S_{30} Zn_5$	0.33	0.00	0.67	0.33	1.00	3.03	2.10	5.13	1.95	2.02	3.97
$S_{30} Zn_{10}$	0.33	0.33	0.00	0.33	0.33	0.53	1.00	1.53	0.00	0.33	0.33
$S_{30} Zn_{20}$	0.33	0.00	0.33	0.33	0.66	0.00	0.33	0.33	0.33	0.67	1.00
$S_{50} Zn_0$	0.00	1.33	0.00	0.33	0.33	0.33	0.33	0.66	1.56	1.00	2.56
$S_{50} Zn_{2.5}$	0.33	1.33	0.33	0.67	1.00	1.67	2.60	4.27	0.33	3.33	3.66
$S_{50} Zn_5$	0.00	0.00	0.00	0.33	0.33	0.00	0.33	0.33	2.50	0.67	3.17
$S_{50} Zn_{10}$	0.00	0.00	0.00	0.67	0.67	2.33	3.13	5.46	3.33	1.33	4.66
$S_{50} Zn_{20}$	0.67	0.00	0.33	0.67	1.00	3.26	4.33	7.59	3.33	2.30	5.63
CV (%)	223.03	210.71	216.21	130.89	347.10	169.32	161.19	330.41	164.52	156.49	321.01

DAS= Days After sowing

Table 2: Interaction effect of sulphur and zinc on dry matter yield of soybean cv. Shohag (Pb-1) at different growth stages

Treatments	Dry matter yield (g plant^{-1}) 30 DAS	45 DAS	60 DAS	90 DAS	110 DAS
S_0 Zn_0	0.310	0.553	1.27	4.42	3.80
S_0 $Zn_{2.5}$	0.318	0.518	1.31	3.40	4.01
S_0 Zn_5	0.315	0.552	1.48	4.48	4.30
S_0 Zn_{10}	0.316	0.510	1.57	3.14	4.37
S_0 Zn_{20}	0.412	0.660	1.68	4.53	4.55
S_{10} Zn_0	0.313	0.501	1.33	4.44	3.81
S_{10} $Zn_{2.5}$	0.318	0.504	1.42	4.20	4.20
S_{10} Zn_5	0.324	0.505	1.53	4.75	4.43
S_{10} Zn_{10}	0.326	0.548	1.60	4.56	4.42
S_{10} Zn_{20}	0.413	0.570	1.70	3.17	4.70
S_{20} Zn_0	0.347	0.507	1.34	3.97	3.82
S_{20} $Zn_{2.5}$	0.313	0.508	1.51	5.29	3.97
S_{20} Zn_5	0.317	0.532	1.46	3.70	4.31
S_{20} Zn_{10}	0.344	0.560	1.62	4.50	4.32
S_{20} Zn_{20}	0.416	0.608	1.67	3.82	4.48
S_{30} Zn_0	0.350	0.529	1.46	4.20	3.89
S_{30} $Zn_{2.5}$	0.382	0.555	1.51	3.31	4.29
S_{30} Zn_5	0.356	0.566	1.59	3.53	4.43
S_{30} Zn_{10}	0.360	0.613	1.64	3.97	4.59
S_{30} Zn_{20}	0.420	0.723	1.78	3.03	4.82
S_{50} Zn_0	0.334	0.498	1.35	2.41	3.76
S_{50} $Zn_{2.5}$	0.311	0.512	1.48	4.81	4.02
S_{50} Zn_5	0.384	0.512	1.48	2.10	4.11
S_{50} Zn_{10}	0.350	0.530	1.50	4.54	4.23
S_{50} Zn_{20}	0.421	0.616	1.62	3.74	4.58
CV (%)	9.470	7.360	4.76	24.60	4.56

Hemantarajan and Trivedi (1997) who reported that dry matter production was higher with increased S application. In contrast, Wu *et al.* (1996) found that S alone did not significantly affect the dry matter yield of rape seed (*Brassica napus* L.).

Zinc showed a significant effect on dry matter yield at all the growth stages except at 90 DAS. The highest dry matter yield was obtained by Zn_{20} at 110 DAS and the lowest dry matter yield was obtained from control treatment. The results indicated that the application of Zn increased the dry matter up to the highest Zn dose applied (20 kg ha^{-1}) at all stages. The dry matter yield increased progressively upto 110 DAS due to application of Zn except Zn_{20} at 90 DAS (Table 2).

Results revealed that interaction effect of S and Zn on dry matter yield was not significant at all the growth stages except 90 DAS (Table 2). The highest dry matter yield was recorded by 30 kg S + 20 kg Zn, at 110 DAS. This treatment combination was found superior to all other treatments combination in producing dry matter at all growth stages. The lowest dry matter weight was produced by control treatment at 30 DAS. From the results, it is clear that interaction effect of increased levels of S and Zn induced increased dry matter yield due to the

Table 3: Interaction effect of sulphur and zinc on zinc and sulphur content by soybean cv. Shohag (Pb-1) at different growth stages

Treatmensts	30 DAS Zinc (µg g^{-1})	30 DAS Sulphur (%)	45 DAS Zinc (µg g^{-1})	45 DAS Sulphur (%)	60 DAS Zinc (µg g^{-1})	60 DAS Sulphur (%)	90 DAS Zinc (µg g^{-1})	90 DAS Sulphur (%)	110 DAS Zinc (µg g^{-1})	110 DAS Sulphur (%)
S_0 Zn_0	70	0.137	100	0.167	100	0.170	70	0.149	75	0.198
S_0 $Zn_{2.5}$	80	0.159	100	0.188	110	0.185	80	0.154	85	0.305
S_0 Zn_5	80	0.195	100	0.192	100	0.247	90	0.207	92	0.218
S_0 Zn_{10}	90	0.150	110	0.122	150	0.194	80	0.181	85	0.280
S_0 Zn_{20}	100	0.187	130	0.216	150	0.201	110	0.186	113	0.265
S_{10} Zn_0	90	0.192	100	0.185	120	0.181	80	0.185	85	0.214
S_{10} $Zn_{2.5}$	80	0.177	110	0.225	110	0.210	90	0.163	95	0.273
S_{10} Zn_5	80	0.162	90	0.218	120	0.208	90	0.174	95	0.226
S_{10} Zn_{10}	90	0.179	120	0.187	150	0.196	110	0.228	114	0.201
S_{10} Zn_{20}	100	0.162	110	0.184	130	0.224	90	0.190	95	0.258
S_{20} Zn_0	100	0.213	110	0.205	130	0.229	90	0.174	95	0.305
S_{20} $Zn_{2.5}$	90	0.193	110	0.229	110	0.241	80	0.180	82	0.273
S_{20} Zn_5	80	0.192	100	0.190	110	0.215	90	0.188	95	0.273
S_{20} Zn_{10}	80	0.177	110	0.185	130	0.218	100	0.208	105	0.296
S_{20} Zn_{20}	100	0.166	110	0.206	130	0.201	100	0.177	103	0.288
S_{30} Zn_0	90	0.203	100	0.196	120	0.194	90	0.157	95	0.269
S_{30} $Zn_{2.5}$	80	0.207	110	0.177	120	0.214	100	0.190	105	0.338
S_{30} Zn_5	80	0.167	90	0.214	110	0.224	90	0.246	95	0.254
S_{30} Zn_{10}	90	0.166	110	0.230	110	0.196	80	0.177	82	0.271
S_{30} Zn_{20}	110	0.230	120	0.237	150	0.249	120	0.253	122	0.344
S_{50} Zn_0	70	0.185	80	0.236	100	0.215	80	0.237	85	0.240
S_{50} $Zn_{2.5}$	90	0.186	100	0.197	120	0.191	100	0.184	105	0.226
S_{50} Zn_5	90	0.174	110	0.209	130	0.230	90	0.151	95	0.339
S_{50} Zn_{10}	90	0.155	110	0.204	140	0.204	100	0.181	105	0.270
S_{50} Zn_{20}	100	0.213	130	0.202	170	0.195	110	0.178	115	0.245
CV%	18.42	18.14	16.96	18.84	14.40	10.88	10.94	15.98	11.20	15.08

favourable effect of these two elements. The best performance in respect of dry matter production was observed with the combination of 30 kg S + 20 kg Zn ha^{-1} (Table 2).

Sulphur and zinc content of soybean at different growth stages: Sulphur content was significantly influenced by S at 110 DAS. Sulphur content showed increasing trend with increasing growth stages. Its content at 110 DAS was higher than that of other growth stages throughout the growth period. At all the growth stages (30, 45, 60, 90 and 110 DAS) the highest S content was observed in S_{30} treatment and the lowest was in control (S_0). The highest S content at 110 DAS might be due to the fact that during this period plants got enough time to receive adequate light, water and nutrients for their growth and development which ultimately caused to produce highest S content. These results are in good agreement with those of Agrawal *et al.* (2000) who explained that S application increased the concentration of S in the sunflower at different growth stages of the crop growth (Table 3).

Sulphur content of soybean was not significantly influenced by Zn at any growth stage except 60 DAS which showed an increasing trend with the advancement of growth. At all the growth stages the highest S content was observed in Zn_{20} and the lowest was in control. The interaction effect of S and Zn was significant on S content at all the growth stages except 30 and 45 DAS. The highest S content was found in $S_{30}Zn_{20}$ treatment and lowest in control (Table 3).

Zinc content was not significantly influenced by S at any growth stage of soybean. The highest Zn content was observed in S_{30} treatment and the lowest in control (S_0). It was observed that the Zn content was increased upto 60 DAS and then decreased.

Zinc content was also significantly and positively influenced by Zn application at 45, 60, 90 and 110 DAS and showed an increasing trend with advanced growth stages. At all the growth stages, the highest Zn content was observed in Zn_{20} treatment and the lowest in control (Zn_0). The interaction effect was observed significant only 90 and 110 DAS on Zn content. The highest Zn content was observed in $S_{30}Zn_{20}$ and the lowest in control (Table 3). From this discussion it is evident that the application of different levels of S and Zn accelerated nodulation, increased dry matter yield and nutrient content of soybean.

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