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Influences of sulphur and zinc levels on soybean and residual effect on succeeding crop in soybean-wheat cropping system

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Abstract
To study the influences of sulphur and zinc levels on soybean and residual effect on succeeding crop in soybean-wheat cropping system. The treatments were five sulphur and four zinc levels with control. A field experiment was conducted at the research block of Aroma College Roorkee, Haridwar, (U.K.) during *Rabi* 2014 and *Rabi* 2015. On the basis of field experiment it can be concluded that soybean responds up to 40 kg S and 30 kg Zn ha^{-1}. The residual effect of sulphur and zinc applied to soybean was noted up 40 kg sulphur and 30 kg Zn ha^{-1} for succeeding wheat crop

Keywords: Sulphur, zinc, soybean, wheat, residual effect

Introduction
Soybean is the world's first ranking crop as a source of vegetable oil and in India too. It will continue to play a key role in fighting edible oil deficit in the country, Damodaran and Hegde (2010) [5]. Soybean is well known for its nutritional and health benefits. It contains about 40% good quality protein, 20% oil having about 85% unsaturated fatty acids including 55% polyunsaturated fatty acids (PUFA), 25-30% carbohydrates and almost no starch (useful to diabetic patients), 4-5% minerals, anti-oxidants, *viz*. ascorbic acid (9-10 mg/100g sprouted soybean) and beta-carotene (0.2 mg/100g sprouted soybean) and about 0.3% is flavones (daidzein and genestein). That's why it is also known as a 'wonder crop', 'Miracle crop' and ‘Golden bean'. Sulphur plays multiple roles in the nutrition of soybean. It involves in the synthesis of amino acids, the building blocks of the proteins. A number of studies Aulakh *et al*. (1990) [2] have reported relatively high requirement of sulphur for soybean which could be attributed to its high protein and oil content. Sulphur also plays a vital role in chlorophyll formation and produces heavier seed and higher oil content. Use of cheap and effective source of sulphur in appropriate dose is necessary for augmenting the productivity as well as quality returns from the soybean cultivation. The favourable effect of zinc on soybean is also being reported now–a-days. Soybean is sensitive to zinc deficiency which is needed for protein metabolism and involved in the chlorophyll formation, growth hormone stimulators, enzymatic activity and reproductive processes.

Further, under assured rainfall or irrigated conditions, there is a vast scope for growing of wheat in the succeeding season after the soybean. With many problems associated with the traditional rice-wheat cropping system coming to after the crop diversification with soybean-wheat cropping system is likely to mitigate the problems associated with the farmer, Verma and Sharma (2007) [17]. This will help to arrest the slowing down of productivity of rice-wheat cropping system as well as deterioration in the soil health. In view of the facts mentioned above, a field experiment was carried out to study the effects of sulphur and zinc on soybean and succeeding wheat crop.

Material and Methods
The field experiments were conducted during *Rabi* 2014 and *Rabi* 2015 at the research block of Aroma College Roorkee, Haridwar (U.K.). The farm is situated at a distance of 10 km from Roorkee on the Roorkee - Haridwar road (NH-58) and at 29.52˚ N latitude, 78.53˚ E longitude and at altitude of 270 meters above the mean sea level. The mean – maximum temperature during hottest month of May and June varies from 32 to 42˚ C while minimum temperature is

found during coldest month of December and January frost being commonly during these months. The soil of experimental site was sandy loam and slightly alkaline in reaction (pH 7.7). The treatments consisted of five sulphur levels *viz*. (S_0- control, S_1- 10 kg S ha^{-1}, S_2- 20 kg S ha^{-1}, S_3- 30 kg S ha^{-1} and S_4 40 kg S ha^{-1}; four zinc levels *viz*. Zn_0- control, Zn_1- 10 kg Zn ha^{-1}, Zn_2- 20 kg Zn ha^{-1} and Zn_3- 30 kg Zn ha^{-1}). The experiments were laid out in factorial randomized block design and replicated in thrice. The graded levels of sulphur and zinc were applied through elemental sulphur and zinc sulphate and mixed in soil after layout and before sowing. Healthy seeds of soybean *cv. PK 1042* and wheat *cv. HD 2687* were used @ 80 kg and 100 kg ha^{-1} respectively. The experimental data were statistically analyzed by applying "Analysis of variance" technique for factorial randomized block design (Cochran and Cox, 1992) [3]. The standard error of mean ($SEM^{\pm}$) and critical difference (CD) at 5% significance level were worked out for each parameter. Protein content in soybean grain was estimated by kjeldhal method. The protein content in grain was obtained by multiplying the nitrogen content with the standard factor by 6.25 (AOAC, 1960) [1]. Oil content in grain of soybean was recorded with Nuclear Magnetic Resonance technique. Protein content in wheat grain was determined by under noted biurete method Williams (1961) [18]. Nutrient uptake from each sample S and Zn were determined separately as per standard procedures (Jackson, 1965; Tabatabai and Bremner, 1970) [7, 15].

Results and Discussion

Growth Attributes

The data on all the growth character were found homogenous over the experiments except plant height at 30 DAS and 60 DAS and dry weight $plant^{-1}$ at 30 DAS. Application of sulphur increased all the growth attributes of soybean but significant increase up to 40 kg ha^{-1} was observed in plant height at 90 DAS (Table-1) number of branches $plant^{-1}$ and dry weight $plant^{-1}$ at all the stage except 30 DAS and harvest stage (Table-1) while the growth characters at remaining stages were found increased only up to 30 kg ha^{-1}. Besides, soybean has been reported to be much responsive to sulphur in promoting growth characters (Dabhi *et al*., 2008) [4], Whereas application of zinc significantly increased the plant height at 90 DAS (Table-1) while other characters mainly number of branches $plant^{-1}$ (Table-1), dry matter accumulation $plant^{-1}$ at 90 DAS and at harvest (Table-1) were increased significantly by zinc application but the pattern of increase was not regular and systemic as in some cases 10 kg was found at par with control and 20 kg with 10 kg ha^{-1}, however, there was positive effect of zinc application (Tripathi *et al*. 1999 and Huger and Kurdikeri, 2000) [16, 6].

Yield attributes and yield

Data collected from the field revealed that with the increasing levels of sulphur, grain and biological yield of soybean significantly increases up to 40 kg ha^{-1} over remaining treatments. These results due to significant increase in the number of pods $plant^{-1}$ up to 40 kg ha^{-1} (Table-2), number of grain $plant^{-1}$ (Table-2), grain weight $plant^{-1}$ (Table-2) and 1000-grain weight (Table-2) while no significant influences were observed between 30 & 40 kg S ha^{-1} in the number of grains pod^{-1} (Table-2) (Sonune *et al*., 2001 and Singh *et al.* 2018) [14, 13]. While the zinc level also had significant influence on the number of pods $plant^{-1}$, number of grains pod^{-1}, pod length, pod weight $plant^{-1}$, test weight, grain weight $plant^{-1}$, biological yield and harvest index. When field fertilized with the 30 kg Zn ha^{-1} was found to be at par with. 20 kg Zn ha^{-1} during the investigation (Table-2) over the rest of treatments (Huger and Kurdikeri, 2000 and Dabhi *et al.*, 2008) [6, 4].

Quality and uptake

The results of the present experiment confirmed the increase in protein content of soybean grain when field is fertilized with 40 kg S ha^{-1} and also Increase in the uptake of sulphur and zinc significantly while zinc up to 30 kg Zn ha^{-1} was also found to be significant (Table-3). It is well known that uptake of nutrients by a crop is associated with the crop vigour and productivity. Similar findings collaborated by (Sonune *et al.,* 2001 and Singh and Thenua, 2016) [14, 12].

Residual Effect on Succeeding Crop

Residual effect of sulphur and zinc on wheat

The graded doses of sulphur were applied to soybean and their residual effect was studied on the succeeding wheat crop. The results indicated that the residual effect of sulphur up to 40 kg ha^{-1} come out to be suitable on the basis of growth and yield attributes (Table -4 & 5) where the response ceased at 30 kg ha^{-1} but only up to 30 kg S ha^{-1} on the basis of grain yield of wheat (Table-5). The effect of residual sulphur of straw yield was the same as that of grain yield (Table-5) sulphur applied to soybean might have left more effect on growth attributes of wheat which ultimately were reflected in the yield attributes and yield. The residual effect of sulphur applied to different pulse crops on succeeding crop of wheat has been reported by (Krishna 1995 and Singh *et al*. 2004) [8, 10].

Although zinc left less residual effect than sulphur as supported by growth and yield attributes of wheat, however, the grain yield recorded under 30 kg ZnSO4 ha^{-1} applied to previous crop was higher than control and 30 kg ha^{-1} (Table-5) (Singh *et al*., 2006 and Shivakumar and Ahlawat 2008) [11, 9] also reported slight residual effect of zinc on succeeding wheat crop.

Protein content in wheat grain

The significant effect of sulphur levels on the protein content of the grain. Sulphur levels 40 kg S ha^{-1} (S_4) was found to be the highest during the experiment (Table-6) Whereas Zinc level 30 kg Zn ha^{-1} (Zn_3) showed higher protein content in the grain but the effect was found to be statistically non-significant (Table-6).

Nutrient uptake by wheat crop

Data recorded from different treatment revealed that the total uptake of sulphur by the wheat crop was significantly higher at 40 kg S ha^{-1} (S_4) level and it was found at par with 20 kg S ha^{-1} (S_2) level and 30 kg S ha^{-1} levels. Increase in the sulphur levels also significantly increased the zinc uptake by the wheat crop. Highest zinc uptake was observed with 40 kg S ha^{-1} (S_4) and it was found to be at par with 20 kg S ha^{-1} (S_2) and 30 kg S ha^{-1} (S_3) (Table- 6).While zinc level 30 kg Zn ha^{-1} (Zn_3) showed significantly higher total sulphur uptake by the wheat crop. Increase in the zinc level also increased the total uptake of zinc by wheat crop. Zinc level 30 kg ha^{-1} (Zn_3) showed significantly higher uptake of zinc by wheat (Table-6).

Soil Chamical Analysis

Effect of soybean on available sulphur and zinc status

Available status of S and Zn after the harvest of the soybean crop was non-significantly influenced by any of the treatment. Thus all treatments under levels of sulphur and zinc were at par after the harvest of soybean. The comparison to initial value of available sulphur there was slight build up with increased level of sulphur. It was found declining in the available zinc status after the harvesting of the soybean. It is evident that there was no clear cut effect of zinc level on available zinc after the soybean and lower levels of fertility during the experimentation (Table-7).

Table 1: Growth attributes of soybean as influenced by different levels of sulphur and zinc.

Treatments	Plant height (cm) at				No. of branches plant^{-1} at				No. of nodules	Dry wt. plant^{-1}				LAI		
	30 DAS	60 DAS	90 DAS	Harvesting	30 DAS	60 DAS	90 DAS	Harvesting	45 DAS	30 DAS	60 DAS	90 DAS	Harvesting	30 DAS	60 DAS	90 DAS
Sulphur level (kg ha^{-1})																
S_0	30.5	61.2	68.2	72.9	2.42	5.38	5.77	5.84	27.2	18.10	41.05	70.20	70.71	0.419	1.441	3.074
S_1	30.9	63.1	70.5	75.2	2.54	6.11	6.02	6.19	31.4	18.50	41.70	73.70	73.11	0.425	1.482	3.179
S_2	31.4	66.4	73.3	78.4	2.76	6.21	6.65	6.49	33.6	18.60	42.80	75.12	75.61	0.438	1.509	3.342
S_3	31.1	67.2	75.6	79.8	2.79	6.59	6.83	6.85	35.2	18.90	43.50	76.40	78.35	0.442	1.544	3.416
S_4	31.6	68.2	75.2	80.7	2.83	6.71	7.05	7.42	36.1	19.25	44.20	77.18	79.90	0.451	1.571	3.434
SEm ±	0.34	1.41	1.79	1.84	0.09	0.28	0.36	0.39	2.08	0.84	0.96	1.63	2.02	0.004	0.026	0.046
CD at 5%	NS	4.39	5.58	5.74	0.29	0.87	1.12	1.29	6.49	NS	3.17	5.38	6.30	0.012	0.091	0.152
Zinc level (kg ha^{-1})																
Zn_0	30.9	63.6	69.6	73.3	2.49	5.29	5.64	5.81	26.2	17.60	40.08	68.31	70.24	0.421	1.445	3.105
Zn_1	31.4	64.2	71.7	75.6	2.62	6.02	6.08	6.22	32.9	18.80	42.17	74.55	74.59	0.429	1.527	3.211
Zn_2	31.5	66.2	74.2	78.9	2.74	6.44	6.92	6.67	35.7	18.90	43.74	77.40	76.65	0.437	1.543	3.309
Zn_3	31.7	66.2	75.9	81.7	2.87	6.82	7.01	7.48	36.2	19.22	44.50	77.95	79.41	0.441	1.561	3.411
SEm±	0.43	1.52	1.66	1.68	0.12	0.17	0.37	0.39	1.43	0.72	0.92	1.87	1.95	0.003	0.032	0.041
CD at 5%	NS	3.87	3.99	4.28	0.13	0.43	0.95	0.99	3.66	NS	2.35	4.77	4.97	0.007	0.083	0.107

Table 2: Yield attributes & Yield of soybean as influenced by different levels of sulphur and zinc.

Treatments	No. of pods plant^{-1}	Pod length (cm)	No. of grains pod^{-1}	Pods wt. Plant^{-1}	Test wt. (g)	Grain wt. Plant^{-1}	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Sulphur level (kg ha^{-1})									
S_0	112.50	11.10	2.24	47.29	93.72	23.14	1782	3680	0.332
S_1	117.74	11.50	2.27	52.11	94.98	25.49	1842	3889	0.330
S_2	122.79	11.82	2.34	55.04	97.78	27.32	1917	3943	0.334
S_3	126.90	12.02	2.39	56.29	98.41	29.31	1952	3974	0.333
S_4	131.31	12.25	2.42	57.15	99.58	29.49	1983	4031	0.349
SEm ±	3.17	0.42	0.04	1.79	1.59	0.89	23.01	29.80	0.051
CD at 5%	9.89	NS	0.12	5.58	4.96	2.70	71.76	92.98	NS
Zinc level (kg ha^{-1})									
Zn_0	109.6	10.82	2.26	48.25	93.12	23.92	1834	3678	0.331
Zn_1	119.1	11.72	2.26	51.31	95.37	25.71	1868	3880	0.333
Zn_2	127.7	12.08	2.39	55.78	98.84	28.44	1918	3972	0.336
Zn_3	132.4	12.26	2.41	57.59	99.91	29.88	1958	4075	0.339
SEm±	5.62	0.32	0.02	2.02	1.47	0.91	11.74	19.49	0.014
CD at 5%	14.33	0.82	0.05	5.17	3.76	2.32	30.05	49.89	NS

Table 3: Quality and uptake of nutrients by soybean as influenced by different levels of sulphur and zinc.

Treatments	Quality		Uptake	
	Protein content (%)	Oil content (%)	S-uptake (kg/ha)	Zn-uptake (kg ha^{-1})
Sulphur level (kg ha^{-1})				
S_0	39.77	20.46	9.44	0.637
S_1	41.61	20.84	9.92	0.793
S_2	42.74	21.48	10.56	0.807
S_3	43.19	21.80	11.09	0.847
S_4	43.76	22.06	11.51	0.868
SEm ±	0.42	0.31	0.26	0.033
CD at 5%	1.31	0.96	0.81	0.103
Zinc level (kg ha^{-1})				
Zn_0	40.92	20.51	9.54	0.698
Zn_1	41.24	21.84	9.83	0.773
Zn_2	42.82	21.51	10.84	0.836
Zn_3	43.91	21.39	11.84	0.867
SEm±	0.19	0.23	0.21	0.035
CD at 5%	0.49	0.59	0.53	0.093

Table 4: Growth attributes of wheat as influenced by different levels of sulphur and zinc.

Treatments	Plant height (cm) at				Number of tillers meter^{-1} row length				Dry matter accumulation (g) meter^{-1} row length at				LAI		
	30 DAS	60 DAS	90 DAS	Harvesting	30 DAS	60 DAS	90 DAS	Harvesting	30 DAS	60 DAS	90 DAS	Harvesting	30 DAS	60 DAS	90 DAS
Sulphur level (kg ha^{-1})															
S_0	31.7	52.2	75.4	102.1	32.1	56.6	66.1	63.1	31.7	61.2	108.1	132.9	2.31	3.18	3.79
S_1	32.9	54.7	78.3	104.1	33.6	58.9	69.3	67.2	33.1	67.3	118.1	141.2	2.58	3.46	3.88
S_2	33.4	56.3	79.4	106.5	34.2	61.4	70.5	68.3	38.8	69.8	126.5	159.5	2.64	3.52	4.08
S_3	33.8	57.1	80.2	107.1	34.9	62.9	72.2	70.8	39.3	72.1	141.3	165.6	2.72	3.69	4.22
S_4	34.6	59.2	81.3	108.3	35.8	63.1	73.8	71.1	41.7	73.1	174.5	176.7	2.85	3.81	4.29
SEm ±	0.92	1.08	1.21	0.91	0.63	0.81	1.02	0.92	1.70	2.14	3.33	7.82	0.07	0.10	0.11
CD at 5%	NS	3.56	3.99	2.84	1.96	2.53	3.18	2.87	5.30	6.68	10.38	24.39	0.22	0.31	0.34
Zinc level (kg ha^{-1})															
Zn_0	31.6	52.6	75.2	100.5	32.2	57.2	67.2	65.3	34.4	63.2	107.2	133.8	2.36	3.21	3.72
Zn_1	32.4	54.8	77.8	103.5	33.8	58.5	69.2	67.3	37.5	66.9	126.7	145.3	2.53	3.44	3.96
Zn_2	33.4	57.3	79.4	106.1	35.1	62.5	72.1	68.5	39.2	71.2	136.3	165.1	2.68	3.68	4.19
Zn_3	35.8	59.2	80.5	107.5	35.5	63.7	73.8	71.3	41.9	73.7	164.7	180.3	2.87	3.78	4.33
SEm±	0.49	1.15	1.39	0.74	0.82	1.07	1.3	0.81	1.52	3.42	3.08	6.14	0.06	0.11	0.13
CD at 5%	1.25	2.94	3.56	1.89	2.10	2.74	3.35	2.07	3.89	8.76	7.88	15.72	0.15	0.25	0.33

Table 5: Yield attributes and yield of wheat as influenced by different levels of sulphur and zinc.

Treatments	Yield parameters				Yield		
	No. of spike m^{-1} row length	Spikes length (cm)	No. of seeds spike^{-1}	Test wt. (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Sulphur level (kg ha^{-1})							
S_0	31.7	52.2	75.4	102.1	32.1	56.6	66.1
S_1	32.9	54.7	78.3	104.1	33.6	58.9	69.3
S_2	33.4	56.3	79.4	106.5	34.2	61.4	70.5
S_3	33.8	57.1	80.2	107.1	34.9	62.9	72.2
S_4	34.6	59.2	81.3	108.3	35.8	63.1	73.8
SEm ±	0.92	1.08	1.21	0.91	0.63	0.81	1.02
CD at 5%	NS	3.56	3.99	2.84	1.96	2.53	3.18
Zinc level (kg ha^{-1})							
Zn_0	31.6	52.6	75.2	100.5	32.2	57.2	67.2
Zn_1	32.4	54.8	77.8	103.5	33.8	58.5	69.2
Zn_2	33.4	57.3	79.4	106.1	35.1	62.5	72.1
Zn_3	35.8	59.2	80.5	107.5	35.5	63.7	73.8
SEm±	0.49	1.15	1.39	0.74	0.82	1.07	1.3
CD at 5%	1.25	2.94	3.56	1.89	2.10	2.74	3.35

Table 6: Protein content, nutrient uptake, Available sulphur and zinc (ppm) as influenced by different levels of sulphur and zinc as influenced by different levels of sulphur and zinc.

Treatments	Protein content (%)	Uptake		Available S and Z status in soil			
		S-uptake (kg/ha)	Zn-uptake (kg/ha)	Before sowing of soybean		After harvesting of soybean	
				S- status	Zn- status	S- status	Zn- status
Sulphur level (kg ha^{-1})							
S_0	12.31	11.07	0.745	11.70	8.21	11.51	7.71
S_1	12.72	11.32	0.758	11.62	9.02	11.04	8.62
S_2	12.93	12.09	0.819	11.58	8.63	11.54	8.51
S_3	13.18	12.38	0.869	11.69	8.72	10.81	6.68
S_4	13.51	12.63	0.902	11.72	8.43	11.08	8.31
SEm ±	0.02	0.29	0.033	0.17	0.52	0.11	0.13
CD at 5%	0.06	0.90	0.103	NS	NS	NS	NS
Zinc level (kg ha^{-1})							
Zn_0	12.41	10.92	0.712	11.81	8.31	10.94	8.02
Zn_1	12.71	11.51	0.751	11.02	9.04	11.04	8.63
Zn_2	13.12	12.14	0.873	11.53	8.52	11.32	8.41
Zn_3	13.63	13.08	0.933	11.41	8.74	11.27	8.61
SEm±	0.26	0.909	0.031	0.14	0.19	0.14	0.14
CD at 5%	NS	0.23	0.079	NS	NS	NS	NS

Conclusion

On the basis of field experiment carried out at research block of Aroma College, Roorkee, Haridwar (U.K.) during *Kharif* and *Rabi* seasons 2015-16 with graded levels of sulphur and zinc applied to soybean and residual effect on wheat grown in sandy loam soil having low content of sulphur and zinc, it can be concluded that soybean responds up to 40 kg S and 30 kg Zn/ha. The residual effect of sulphur and zinc applied to soybean was noted up 40 kg sulphur and 30 kg Zn/ha for succeeding wheat crop.

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