Original Research Article

INFLUENCE OF SULPHUR AND ZINC LEVELS ON GROWTH, YIELD AND QUALITY OF SOYBEAN (*Glycine max* L.)

ABSTRACT

Field experiments were conducted during *kharif* season of 2014 and 2015 to study the influences of sulphur and zinc levels on growth, yield and quality of soybean. The experiment comprised 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}). Application of sulphur and zinc increased all the growth and yield attributes of soybean but significant increase up to 40 kg S ha^{-1} and 30 kg Zn ha^{-1} were observed in plant height, number of branches $plant^{-1}$ at all stage, grain yield kg ha^{-1}, increased the protein content in grain of soybean. 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 $plant^{-1}$. Highest level (Zn_3) *i.e.* 30 kg Zn ha^{-1} was found at par with (Zn_2) *i.e.* 20 kg Zn ha^{-1} during the investigation. Increase in the uptake of sulphur and zinc significantly up to 40 kg S ha^{-1} and zinc up to 30 kg Zn ha^{-1} was observed.

Keywords**:** Soybean, sulphur, zinc, protein, nutrient uptake

INTRODUCTION

Soybean [*Glycine max*. (L) Merill] belongs to the family fabaceae (Leguminosae). It is an important crop worldwide, because it has a wide range of geographical adaption, unique chemical composition, good nutritional value, functional health benefits and variety of end-uses (food, feed and non-edible). It is extremely resilient and performs even under severe water stress conditions. It fits well in cropping systems/rotations including inter/mixed cropping systems. It improves soil fertility by fixing atmospheric N_2 to the extent of 50-300 kg ha^{-1}, depending on the agro-climatic conditions, variety, strains *etc*. Keyser and Li (1992) and adds about 1.0-1.5 tons of leaf litter per season ha^{-1}. 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). 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'. India ranks third after Argentina and Brazil to have registered a phenomenal growth in the production of soybean, India must increase indigenous production of vegetables oil and protein to meet its critical deficit. This would make one to think that adequate and balanced application to the soybean is must to increase productivity. The prospects of soybean expanding further into a major crop in India are good. Know-how to cultivate or soybean farming in India is already considerable advanced and industry is becoming increasingly aware of the varied use of soybean. It appears that the importance of soybean is increasing with the availability of pulses, the natives cheapest source of protein is decreasing. The soybean production in our country during 2014-15 has been about 10.528 mt in 11.086 mha area with average productivity of 950 kg ha^{-1}. In India, Madhya Pradesh, Maharashtra and Rajasthan are the major soybean producing states, contributing about 95% of the total area and production of soybean in the country, Madhya Pradesh has 54% of the country's area and contributes 59% to the total production of soybean in the country and disserves to be called 'soya state'. The encouraging results of the new varieties-which take 100-130 days to maturity with the yield potential of 30-45 q ha^{-1}. Sulphur plays multiple roles in the nutrition of soybean. It involves in the synthesis of amino acids, the building blocks of the proteins. Several studies Aulakh *et al*. (1990) 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). 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

Field experiments were conducted during the *kharif* season of 2014 and 2015 at the research block of Aroma College Roorkee, Haridwar (U.K.), India. The farm is situated at 29.52˚ N latitude, 78.53˚ E longitude and at altitude of 270 meters above the mean sea level. The soil of experimental site was sandy loam and slightly alkaline in reaction (pH 7.7), organic carbon (0.58% and 0.56%), low in available nitrogen (265 and 268 kg N ha^{-1}), low in available phosphorus (18.4 and 18.3 kg P ha^{-1}) and medium in available potassium (259.4 and 254.6 kg K ha^{-1}) in 2014 and 2015, respectively. The initial sulphur status was 22.5 kg ha^{-1} and 23.4 kg ha^{-1} and the available zinc was 0.54 and 0.56 mg kg^{-1} soil, respectively during 2014 and 2015 cropping seasons. 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 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* were used @ 80 kg ha^{-1}. The sowing of seed using the hand plough at a depth of 5 cm was done soybean in last week of June. First thinning was done after full germination and after thinning the first-hand weeding was done at 30 DAS to remove the weeds. Five representative plants of soybean from each treatment were selected randomly at 30, 60, 90 DAS and at maturity for recording biometric observations, as well as post-harvest studies on various aspects. The experimental data were statistically analysed by applying "Analysis of variance" technique for factorial randomized block design (Cochran and Cox, 1992). 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). 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). Nutrient uptake from each sample S and Zn were determined separately as per standard procedures (Jackson, 1965; Tabatabai and Bremner, 1970).

RESULTS AND DISCUSSION

EFFECT OF SULPHUR

The finding showed that the pplication of sulphur increased all the growth and yield attributes of soybean but significant increase up to 40 kg ha^{-1} was observed in plant height, number of branches $plant^{-1}$, dry weight $plant^{-1}$, leaf area index (Table-1), no of pods $plant^{-1}$, no of grains pod^{-1}, pod wright $plant^{-1}$, test weight (Table-2). The highest yield components were found with the application of 40 kg S ha^{-1} and control treatment produced lowest values. It could be function of various external and internal factors, nutrient supply being one of the factor. It might be due to the improvement of sulphur in synthesis of amino acids. Soybean has been reported to be much responsive to sulphur in promoting growth characters as already reported by Tewari (1965), Jethmalani *et al*. (1969), Singh *et al*. (1971), Sharma *et al*. (1991), Jayapaul and Ganeshareja (1990) and Dabhi *et al*. (2008).

EFFECT OF ZINC

Application of zinc also have a significant effect on growth and yield attributes. Zinc significantly increased the plant height, number of branches $plant^{-1}$, dry matter accumulation $plant^{-1}$, leaf area index (Table-1), no of pods $plant^{-1}$, pod length, no of grains pod^{-1}, pod wright $plant^{-1}$, test weight, (Table-2). Similar effect of zinc, particularly up to 10 kg dose was recorded on the yield and yield attributes. Zinc also increased the oil and protein content but the optimum dose 20 kg which is supported by Singh *et al*. (1972), Reddy *et al.* (1984), Jha and Chandel (1987), Tripathi *et al*. (1999) and Huger and Kurdikeri. (2000).

GRAIN YIELD

Significant variation on grain yield were observed with the application of different sulphur levels (Table-2). Increasing the sulphur levels increased the grain yield of soybean significantly up to 40 kg ha^{-1} numerically superior to 30 kg ha^{-1}. Similar results were observed in the biological yield. These results were supported by significant increase in the number of pods $plant^{-1}$ up to 40 kg ha^{-1}, number of grain $plant^{-1}$, grain weight $plant^{-1}$ and 1000-grain weight while no significant influences were observed between 30 & 40 kg S ha^{-1} in the number of grains pod^{-1} (Table-2). Since, there was differential response to sulphur on the basis of yield attributes and also in the grain yield and straw yield. In the earlier work, also a dose of 30 kg S ha^{-1} or above has been recommended by Jethmalani *et al*. (1969), Thakur and Hasan (1972), Bishnoi and Ramdutta (1983), Elkadi *et al*. (1982), Katoch *et al*. (1983), Sharma *et al*. (1991) and Sonune *et al*. (2001).

The zinc levels also increased the biological yield with their highest level with 30 kg Zn ha^{-1} (Zn_3). Likewise, application of zinc @ 30 kg Zn ha^{-1} (Zn_3) recorded the highest harvest index as compared to their lower levels *viz*. Control (Zn_0), 10 kg Zn ha^{-1} (Zn_1) and 20 kg Zn ha^{-1} (Zn_2) but the differences were found non-significant (Table-2). Same findings also reported by Singh *et al.* (1972), Reddy *et al.* (1984), Jha and Chandel (1987), Sharma *et al.* (1991), Huger and Kurdikeri (2000), Dabhi *et al.* (2008).

QUALITY AND UPTAKE

Increasing levels of sulphur increased the protein content in grain of soybean but different workers reported variable results pertaining to the effect of sulphur on oil content in grain. Soybean seed contain protein namely Glycine, which consist approximately 50 % of seed protein, is relatively rich in sulphur containing amino acid Coates *et al.* (1985). Increase in the protein content in soybean grain by increasing levels of sulphur has been reported by Haby *et al*. (1982), Bishnoi and Ramdutta (1983), Das and Das (1994), Singh and Thenua (2016) on the other hand positive effect of sulphur on oil content of soybean and other oilseed crops.

Besides oil and protein content, sulphur plays an important role in plant metabolism by virtue of being on essential constituent of diverse types of metabolically active compounds amino acids, proteins and nucleic acids. The biological role of chlorophyll in harvesting solar energy, phosphorylated compounds in energy transformation, nucleic acid in the transfer of genetic information and the relation of cellular metabolism and protein as structural units and biological catalyst is well known.

Increase in the uptake of sulphur and zinc significantly up to 40 kg S ha^{-1} and zinc up to 30 kg Zn ha^{-1} was observed (Table-3). It is well known that uptake of nutrients by a crop is associated with the crop vigour and productivity. Sulphur particularly at the desirable level of 40 kg S ha^{-1} improved the growth characters accompanied by yield attributes and yield. Therefore, finally increasing the uptake of not only sulphur but also zinc, effect of sulphur on increased uptake of sulphur by pulses and oilseed crops has been reported by Singh and Saxena (1973), Reddy *et al.* (1984), Sharma *et al.* (1991), Zaman and Das (1991), Tomer *et al*. (2000), Sonune *et al.* (2001) and Singh and Thenua (2016).

CONCLUSION

Based on our two years of study, it may be concluded that the application of sulphur 40 kg ha^{-1} zinc 30 kg ha^{-1} increased the growth, yield attributes, yield, quality and uptake of sulphur and zinc of soybean compared with the other levels. Application of sulphur 40 kg ha^{-1} and zinc 20-30 kg ha^{-1} is sufficient to sustain the productivity of soybean in Indo-gangatic plains.

REFERENCES

AOAC (1960). Association of official Agricultural chemists. *Official method of analysis.* Washington D.C. 9th edition, pp. 15-16

Aulakh, M.S.; Pasricha, N.S. and Azad, A.S. (1990). Phosphorus sulphur inter-relationship for soybean on P and S deficient soil. *Soil Science*, 150 (4): 221-224.

Bishnoi, K.C. and Ramdutta (1983). Studies on effect of method of inoculation on yield and yield attributes of soybean under varying nitrogen levels. *Indian Journal of Agronomy,* 28(1): 79-81.

Cochran, W.G. and Cox, G.M. (1992). *Experimental design*. 2nd Edition Published by John Willey and Sons. U.S.A.

Coates, J.B., Medeiros, J.S., Thanh, V.H., Nielsen, N.C. (1985). Characterization of the subunits of β-conglycinin. *Arch Biochem Biophys* 243: 184-194

Dabhi, B.M.; Gabasavlag, S.S. and Polara, J.V. (2008). Effect of Potash, Sulphur and Zinc on yield and economics of soybean (*Glycine max*). In: National symposium on "*New Paradigms in Agronomic Research*", Nov., 19-21, 2008, Navsari, Gujarat, pp. 100-101

Damodaran T and Hegade D M (2010). Oilseed Situation: A Statistical Compendium. Directorate of Oilseed Research, Hyderabad. p 486.

Das, K.N. and K. Das (1994). Effects of Sulphur and nitrogen fertilization on yield and N uptake by rapeseed. *Journal Indian Society of Soil Science*, 42: 476-478.

Elkady, M.M., Mansour, M.A. and Salim, A.H. (1982). Physiological study on soybean plants in relation to different nitrogen levels 1- Growth, nodulation and yield. *Manufia Journal Agriculture Research*, 5: 19-40.

Haby, V.A.; Black, A.L.; Bergman, J.W. and Larson, R.A. (1982). Nitrogen fertilizer requirement of irrigated safflower in northern great plains. *Agronomy Journal*, 74(2): 331: 335.

Huger, A.B. and Kurdikeri, M.B. (2000). Effect of application methods and levels of zinc and molybdenum of field performance and seed yield in soybean. *Karnataka Journal of agriculture Science,* 13(2): 439-441.

Jackson; M.L. (1965). *Soil Chemiceal Analysis*, Advanced course, Madison, Wisconsin, U.S.A.

Jayapaul, P. And Ganesharaja, V. (1990). Studies on response of soybean varieties to nitrogen, phosphorus and sulphur. *Indian Journal of Agronomy*, 35(3): 329-330.

Jethmalani, S.C.; Tiwari, K.L. and Motiramani, D.P. (1969). Soybean fertilization and inoculation. *Indian Farming*, 19(4):17-18.

Jha, A.N. and Chandel, A.S. (1987). Response of soybean to zinc application. *Indian Journal of Agronomy*. 32(4): 354-358.

Katoch, K.K.; Agrwal, C.C. and Garg, F.C. (1983). Effect of nitrogen, soil compaction and moisture stress on nodulation and yield of soybean. *Journal of Indian Society of Soil Science*, 31: 215-219.

Keyser Harold H. and Li Fudi (1992). Potential for increasing biological nitrogen fixation in soybean. *Plant and Soil,* 141: 119-135.

Reddy, G.B.; Kondap, S.M. and Rao, A.R. (1984). Effect of molybdenum, zinc and gypsum with different levels of phosphorus on growth and yield of groundnut. *Journal of Oil Seeds Research*, 1: 129-136.

Sharma, R.A.; Saxena, K.K. and Mishra, O.P. (1991). Soybean ke utpadan hetu santulit poshak tatwa. *Farmers and Parliament*, 25(2): 43-44.

Singh, H.G.; Surajbhan; Singh, A and Gupta, R. B. (1972). Response of groundnut [*Arachis hypogaea* (L)] to zinc in Uttar Pradesh. *Indian Journal of Agriculture Research*. 6(2): 107-110.

Singh, J.N; Negi, P.S. and Tripathi, S.K. (1971). Response of inoculated soybean varieties to levels of nitrogen and phosphorus in Tarai region of U.P. *Indian Journal of Agronomy*. 16: 305-308.

Singh, N.P. and Saxena, M.C. (1973). Pattern of dry matter accumulation in soybean as affected by nitrogen, inoculation and phosphorus fertilization. *Indian Journal of Agriculture Science*, 43(1): 62-66.

Singh, S.B. and Thenua, O.V.S. (2016). Effect of phosphorus and sulphur fertilization on yield and NPS uptake by mustard (*Brassica juncea* L.). *Progressive Research- An International Journal,* 11(1): 80-83.

Sonune, B.A.; Naphade, P.S. and Kankal, D.S. (2001). Effect of zinc and sulphur on protein and oil control of soybean. *Agriculture Science Digest*, 21(4): 259-260.

Tabatabai, M.A. and Bremner, J.M. (1970). A simple turbidometric method of determination of total sulphur in plant material. *Agronomy Journal*, 62: 805-806.

Tewari, G.P. (1965). Effect of nitrogen, phosphorus and potassium on flowering and yield of soybean in Nigeria. *Experimental Agriculture*, 1: 185-188.

Thakur, B.K. and Hasan, W. (1972). Effect of nitrogen and inoculums on the yield and yield attributes of soybean. *Indian Journal of Agronomy*, 16(4): 303-305.

Tomar, U.S.; Badaya, A.K.; Tomar, I.S.; Vani, D.K. and Ambavatia, G.R. (2000). Influence of different levels and sources of sulphur on growth and productivity of soybean. *Crop Research Hisar* 19(1): 142-143.

Tripathi, S.K.; A.K. Patra and S.C. Samui (1999). Effect of micronutrient on nodulation, growth, yield and nutrient uptake by groundnut *(Arachis hypogaea)*. *Indian Journal of Plant Physiology*, 4: 207-209.

Verma, S. and Sharma, P.K. (2007). Effect of long-term manuring and "the fertilizes on carbon pools, soil structure and sustainability under different cropping systems in west temperate zone of north-west Himalayas. *Biology and Fertility of Soil*, 44(1): 235-240.

Williams, P.C. (1961). The determination of protein in whole wheat meal and flour by the biurate method. *Journal of Science Food and Agriculture,* 12: 58-61 (1961).

Zaman, A. and Das, P.K. (1991). Effect of irrigation and nitrogen on yield and quality of safflower. *Indian Journal of Agronomy*, 36(2): 177-179.

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

Treatments	Plant height (cm)	No. of branches plant^{-1} at	No. of nodules	Dry wt. plant^{-1}	LAI
Sulphur level (kg ha^{-1})					
S_0	72.9	5.84	27.2	70.71	3.074
S_1	75.2	6.19	31.4	73.11	3.179
S_2	78.4	6.49	33.6	75.61	3.342
S_3	79.8	6.85	35.2	78.35	3.416
S_4	80.7	7.42	36.1	79.90	3.434
SEm ±	1.84	0.39	2.08	2.02	0.046
CD at 5%	5.74	1.29	6.49	6.30	0.152
Zinc level (kg ha^{-1})					
Zn_0	73.3	5.81	26.2	70.24	3.105

Zn_1	75.6	6.22	32.9	74.59	3.211
Zn_2	78.9	6.67	35.7	76.65	3.309
Zn_3	81.7	7.48	36.2	79.41	3.411
SEm$^{\pm}$	1.68	0.39	1.43	1.95	0.041
CD at 5%	4.28	0.99	3.66	4.97	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$^{\pm}$	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$^{\pm}$	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$^{\pm}$	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$^{\pm}$	0.19	0.23	0.21	0.035
CD at 5%	0.49	0.59	0.53	0.093