

INFLUENCE OF SULPHUR AND ZINC FERTILIZATION ON YIELD, YIELD COMPONENTS AND QUALITY TRAITS OF SOYBEAN (GLYCINE MAX L.)

PRATIBHA CHOUDHARY¹, ARUN JHAJHARIA^{2*}, ROHIT KUMAR³

¹Department of Plant Breeding & Genetics, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur - 482 004, Madhya Pradesh, INDIA

²Department of Farm Engineering, ³Department of Agricultural Economics, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi - 221 005, Uttar Pradesh, INDIA
e-mail: arunstistics@gmail.com

KEYWORDS

Soybean
Fertilization
Nutrient uptake
Sulphur
Zinc
Protein

Received on :
02.09.2013

Accepted on :
19.01.2014

*Corresponding
author

ABSTRACT

A pot experiment was carried out using factorial CRBD with four replications during *Kharif* 2012 to investigate S and Zn application effects on soybean (*Glycine max* L.) yield, yield attributing traits and quality parameters. The experiment comprised four levels of sulphur (0, 20, 40 and 60 ppm) and zinc (0, 2.5, 5.0 and 7.5 ppm). Cultivar PK 1024 was used as the test crop. The results revealed that all these mentioned parameters were significantly affected by the addition of sulphur and zinc doses. Highest grain yield 14.59 and 14.25 g pot⁻¹ were obtained when S (40 ppm) and Zn (5 ppm) were applied individually. The highest yield (15.30 g pot⁻¹) and the yield attributes viz; plant height (43.5 cm), branches plant⁻¹ (6.7), capsule plant⁻¹ (13.0), grains capsule⁻¹ (3.2), 100-grain weight (9.96 g) were also obtained for the treatment combination of 40 ppm S and 5 ppm Zn. On the other hand content and uptake of Zn increased up to 40 ppm S and thereafter decreases at 60 ppm S level. Contents of S increased with increase in S doses up to 60 ppm. However the values at 40 and 60 ppm were statistically *at par*. Zinc content increased up to 20 ppm S and thereafter decreased. Highest protein (38.64%) and oil (21.54%) content was observed due to application of 60 ppm S, while 5 ppm Zn gave the highest protein (38.42%) and oil (20.90%) content of soybean grain. Therefore, it was concluded that application of 60 ppm S and 5 ppm Zn should be used for improvement of yield and quality traits of soybean grain.

INTRODUCTION

Soybean (*Glycine max* L.) is important oil and protein crop belongs to family *Fabaceae*; it contains about high quality protein (40-42 %), oil (18-20%) and other nutrients like calcium, iron and glycine (Devi *et al.*, 2012). Soybean is preferable for human nutrition due to its high protein content. It is a good source of isoflavones and therefore it helps in preventing heart diseases, cancer and HIVs (Kumar, 2007). Soybean oil is the leading vegetable oil in the world and is used in many industrial applications including biodiesel. Because of its high nutritional value and myriad form of uses, it is recognized as 'Golden Bean'. In India, The annual soybean production in India was 12.21 million tonnes (2011-12) with its area under cultivation was 10.1 million hectares. Madhya Pradesh is known as the soybean bowl of India, contributing 59% of the country's soybean production, followed by Maharashtra with 29% contribution and Rajasthan with a 6% contribution. Andhra Pradesh, Karnataka, Chhattisgarh and other parts of India also produce the bean in small quantities (Anonymous, 2013).

The most important constraints to crop growth are those caused by shortage of plant nutrients. Sulphur is an essential macronutrient in plant growth and development. It is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium. Among

the fertilizer elements sulphur requirement of oilseed crops is quite high as compared to other crops (Das and Das, 1994). Sulfur deficiencies in crops have increasingly occurred due to less to no addition of S to soil because of increased use of S-free fertilizers, greater S removal from soil by crops with enhanced yield and under more intensive cropping systems (Scherer, 2001). Soils with coarse texture, low organic matter, and good drainage are often S deficient (Waddoups, 2011). In addition, conservation-till soils are more prone to S deficiency since soil temperatures are usually lower (Hill, 2000). Low soil temperatures reduce the mineralization of organic S to sulfate, and thus increase the probability of crop responses to S fertilization (Havlin *et al.*, 2005). Recently, widespread deficiency of S in the soil of crop fields has been noticed in many parts of India (Jamal *et al.*, 2005).

The role of sulphur in the seed production of soybean has been reported by several investigators. Bhuiyan *et al.* (1998) found that application of sulphur at 20 kg per hectare produced the highest seed yield in soybean, but Mohanti *et al.* (2004) reported sulphur at 30 kg per hectare produced the highest seed yield and found that sulphur was involved in the synthesis of fatty acids and also increases protein quality through the synthesis of certain amino acids such as cysteine, cysteine and methionine. Srivastava *et al.* (2000) observed that among the fertilizer elements, sulphur requirement of oilseed crops is quite high as compared to other crops. Sounda

and Nandini (2003) studied the effect of different levels of irrigation and sources of sulphur on the productivity of soybean and found that the sulphur content and uptake was significantly higher with the application of gypsum as a source of sulphur in soybean. Prasad and Prasad (2003) revealed that sulphur at 30 kg per hectare treated pea plants had higher number of grains per plant which was 24.18% higher than the control one. More recently, Devi *et al.* (2012) reported that application of sulphur improved nitrogenase activity, nitrogen fixation, plant dry matter and quality of soybean grain in sulphur deficient soil.

Out of seventeen essential elements, zinc is now being recorded most important micronutrient for plant growth and development in crop production, but the amount of Zn required by plant is not large. It plays a vital role in the synthesis of protein and nucleic acid, membrane integrity, enzyme activation and helps in the utilization of nitrogen and phosphorus in plant. Plant available Zn in soil is provided by weathering of soil parent rocks, biotic and atmospheric processes such as litter decomposition, volcanic deposition and Zn fertilizer application. Plant availability of soil Zn is affected by soil pH, soil type, organic matter, soil moisture, mineralogy, Zn diffusion and plant uptake (Yin *et al.*, 2011). Darwish *et al.*, (2002) reported that application of Zn gave the highest seed, oil yield/fed in soybean. Yasari (2012) studied the effect of applying Zn to compare the effects that incorporating them in the soil and spraying them on the soybean crop on seed oil and protein contents and percentages.

Zizala *et al.*, (2008) reported that sulphur and zinc content and uptake were significantly higher with the application of $ZnCl_2$ as a source of zinc in soybean. Pable and Patil (2011) studied the effects of sulphur application rates and zinc fertilization on soybean yields and quality. Devi *et al.*, (2012) studied the effect of sulphur and boron fertilization on yield, quality and nutrient uptake by soybean under upland condition and found useful for obtaining maximum yield attributes.

There is little information available in the current literature on yield and their yield attributing traits responses of soybean to S and Zn fertilization and their interactions. But these data are insufficient to provide a basis for evolving a management technology of S application with appropriate amount of Zn to optimize N-assimilation efficiency and seed as well as oil yield of soybean. In this experiment, therefore, an attempt was made to evolve appropriate technology of S and Zn application for optimum growth, seed and oil yield of soybean.

The objectives of this study were to examine the effects of S and Zn applications and their interactions on soybean (*Glycine max* L.) yield, their yield attributing traits and quality parameters.

MATERIALS AND METHODS

A pot culture experiment was conducted in cemented pot at Department of Soil Science and Agriculture Chemistry, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh during *Kharif* season 2012.

Cultivar PK 1024 was used as the test crop. Air dried and then

oven dried at 105°C alluvial soil from student's instruction farm was taken for pot filling. Soil having pH 7.8, 0.56 EC, 12.84 CEC, 0.48 % organic carbon, 240 kg ha⁻¹ available N, 10.10 kg ha⁻¹ available P, 108.00 kg ha⁻¹ available K, 0.56 mg kg⁻¹ available Zn and 9.20 mg kg⁻¹ available S. There were 16 treatment combinations consisting of four rates of both S (0, 20, 40 and 60 ppm) and Zn (0, 2.5, 5.0 and 7.5 ppm). The experiment was laid out in a factorial combination of S and Zn following randomized complete block design (Fisher, 1947). Sulphur and Zinc fertilizers were applied as per design and treatments and all other fertilizers were applied according to the fertilizer recommendation guide (Anonymous 1997). Grain was sown @ 40 kg ha⁻¹ in line and Intercultural operations were done as and when necessary. Grain and straw yields were recorded from the whole plot harvest. Soybean grain from every plot was chemically analyzed for the determination of total N, oil, S and Zinc contents.

Total nitrogen in the grain was determined by Micro-Kjeldhal method (AOAC, 1965), Phosphorus by Vanadomolybdate phosphoric acid yellow colour method as described by Chapman and Pratt (1961) and Potassium by flame photometer given by Black (1965).

The grain samples were digested in mixture of nitric + perchloric acids to determine Zn by AAS method. In the extract sulphur was determined turbidimetric by the procedure as given by Chesin and Yien (1951). Protein was calculated by % total N x 6.25 (Morrison 1956). Oil content was determined by NMR method.

The uptake of S and Zn were calculated by multiplying the concentration of S and Zn with grain yield. The data were analyzed statistically and significant differences among the treatment means were determined by least significant difference (Steel and Torrie, 1980) test for interpretation of results.

RESULTS AND DISCUSSION

Effect of sulphur

The data in Table 1 revealed that the yield components; All yield attributing characters viz., plant height, branches plant⁻¹, capsule plant⁻¹, grains capsule⁻¹, 100-grain weight (g) and grain yield pot⁻¹ (g) of the experimental crop significantly influenced by different sulphur levels. The highest yield components were found when the crop was fertilized with 40 ppm S. In all the cases control treatment produced the lowest. From the above findings, it was clear that yield attributing characters were greatly affected by sulphur application. It might be due to involvement of sulfur in the synthesis of fatty acids and also increases protein quality through the synthesis of certain amino acids such as cysteine, cysteine and methionine. The results support the earlier findings of Vishwakarma *et al.* (1998), Pable and Patil (2011) and Devi *et al.* (2012) in soybean. The above results are in conformity with the results of Varun *et al.* (2011) who reported that plant height, number of branches, pod plant⁻¹, 100 grain weight of soybean were significantly higher by the application of sulphur. Similar result was on put forward by Mahmoodi *et al.* (2013) who reported that sulphur enhanced the branches plant⁻¹, capsules plant⁻¹, grains

Table 1: Effect of sulphur and Zinc on yield and yield attributes of PK 1024

Treatment	Plant height (cm)	Branches plant ¹	Capsule plant ¹	Grains Capsule ¹	Test weight 100 grain (g)	Grain yield pot ¹ (g)	Stover yield pot ¹ (g)
S ₀	38.6	4.6	10.5	2.6	7.72	11.32	16.48
S ₂₀	40.8	5.4	11.5	2.9	8.67	13.49	19.56
S ₄₀	42.9	5.8	12.3	3.1	9.3	14.59	21.29
S ₆₀	42.3	4.7	12.2	3	9.12	14.05	21.2
Zn ₀	39.7	4.7	11	2.7	7.97	11.96	17.55
Zn _{2.5}	41.8	5.3	11.9	2.9	8.78	13.45	19.58
Zn ₅	41.7	5.58	12.1	3	9.15	14.25	21.22
Zn _{7.5}	41.4	4.9	11.4	2.9	8.44	13.8	20.18
S ₀ Zn ₀	36.4	4.2	9.4	2.3	7.51	9.8	14.11
S ₀ Zn _{2.5}	39	4.7	10.5	2.7	7.71	11.06	16.03
S ₀ Zn ₅	39.9	4.9	11.6	2.8	7.85	12.32	17.98
S ₀ Zn _{7.5}	39	4.7	10.5	2.7	7.8	12.12	17.81
S ₂₀ Zn ₀	40.3	4.9	10.8	2.8	7.97	11.42	16.55
S ₂₀ Zn _{2.5}	41.5	5.6	12.1	2.9	8.72	13.18	19.11
S ₂₀ Zn ₅	40.8	5.8	11.6	3.02	9	15.1	21.89
S ₂₀ Zn _{7.5}	40.8	5.2	11.5	3.1	8.99	14.28	20.7
S ₄₀ Zn ₀	41.9	5	11.9	2.9	8.14	13.06	19.19
S ₄₀ Zn _{2.5}	43.3	5.8	12.5	3.1	9.32	14.89	21.18
S ₄₀ Zn ₅	43.5	6.7	13	3.2	9.96	15.3	22.59
S ₄₀ Zn _{7.5}	43	5.6	11.9	3.1	9.8	14.28	22.19
S ₆₀ Zn ₀	40.2	4.8	11.9	3	8.25	13.57	20.35
S ₆₀ Zn _{2.5}	43.4	5.1	12.5	3.1	9.38	14.67	22
S ₆₀ Zn ₅	42.8	4.6	12.4	3.1	9.8	14.28	22.42
S ₆₀ Zn _{7.5}	42.8	4.2	11.9	2.8	9	13.68	20.04
SEm ±	0.67	0.18	0.24	0.13	0.19	0.49	0.67
CD 5%	NS	NS	0.58	NS	0.38	0.99	1.33

Table 2: Effect of sulphur and zinc on sulphur, zinc, protein and oil content of the grain of PK 1024

Treatments	Grain sulphur		Grain Zinc		Protein content (%)	Oil content (%)
	Content (%)	Uptake (mg pot ¹)	Content (ppm)	Uptake (mg pot ¹)		
S ₀	0.19	21.09	40.67	0.91	36.24	18.89
S ₂₀	0.35	46.76	52.15	1.42	38.01	20.63
S ₄₀	0.39	56.79	51.92	1.51	38.58	21.33
S ₆₀	0.42	58.69	50.22	1.35	38.64	21.54
Zn ₀	0.35	43.43	31.17	0.74	36.69	20.08
Zn _{2.5}	0.34	47.03	50.52	1.36	38.17	20.68
Zn ₅	0.33	47.95	55.87	1.55	38.42	20.90
Zn _{7.5}	0.32	44.59	57.40	1.55	38.27	20.73
S ₀ Zn ₀	0.21	20.58	23.4	0.44	35.36	18.30
S ₀ Zn _{2.5}	0.19	21.01	45.3	0.94	36.44	18.92
S ₀ Zn ₅	0.18	22.18	46.4	1.11	36.69	19.35
S ₀ Zn _{7.5}	0.17	20.60	47.6	1.14	36.47	19.00
S ₂₀ Zn ₀	0.36	41.11	34.2	0.77	36.53	19.80
S ₂₀ Zn _{2.5}	0.36	47.45	54.6	1.41	38.03	20.91
S ₂₀ Zn ₅	0.34	51.34	58.9	1.77	38.84	21.00
S ₂₀ Zn _{7.5}	0.33	47.12	60.9	1.74	38.67	20.80
S ₄₀ Zn ₀	0.41	53.35	34.0	0.85	37.30	20.82
S ₄₀ Zn _{2.5}	0.39	58.07	54.4	1.63	39.11	21.28
S ₄₀ Zn ₅	0.39	59.67	59.0	1.78	39.14	21.64
S ₄₀ Zn _{7.5}	0.37	55.87	60.3	1.77	38.75	21.58
S ₆₀ Zn ₀	0.43	58.49	33.1	0.89	37.57	21.40
S ₆₀ Zn _{2.5}	0.42	61.58	47.8	1.45	39.12	21.60
S ₆₀ Zn ₅	0.41	58.60	59.2	1.52	39.00	21.69
S ₆₀ Zn _{7.5}	0.41	56.09	60.8	1.54	38.87	21.55
SEm ±	0.03	1.02	2.65	0.03	0.83	0.21
CD %	NS	NS	NS	NS	NS	NS

capsule⁻¹ and 100-grain weight of soybean.

Effect of zinc

Different levels of Zinc also brought a significant variation in respect of yield components (Table 1). Zinc @ of 5 ppm produced the highest plant height, branches plant¹, capsule

plant¹, grains capsule⁻¹, 100- grain weight (g) and grain yield pot¹ (g), lowest from control in all the yield components. Earlier works mark the evidence that application of zinc influenced the yield component. Also, results achieved from present research were conformed to those established by Ghasemian (2000) on the significant increase in the filled pod weight due

to application of Zn fertilizer treatments in soybean. Kanase *et al.* (2006) conclusively suggested that application of Zn increased branches plant⁻¹, capsule plant⁻¹, grains capsule⁻¹ and 100 grain weight. However, the highest value for most of the yield components was obtained when the crop was fertilized with 40 ppm S in combination with 5 ppm Zn and control treatment produced the lowest.

The beneficial effect of sulphur and zinc application on yield attributing characteristics have also been recorded by Raghuvanshi *et al.* (2009), Imade *et al.* (2010), Kumar and Sidhu, (2010), Pable and Patil, (2011). Combination of sulphur and zinc was not found to have significant effect on yield attributes.

Grain yield

Significant variations on Grain yield were obtained from different sulphur levels (Table 1). Among the treatment 40 ppm S produced the highest grain yield (14.59 g) and lowest (11.32 g) was obtained at control. Likewise sulphur, zinc application showed significant effect on grain yield. It increased up to 5 ppm level and their after decrease at 7.5 ppm level. The result obtained in this regard is in accordance with the findings of Chandel and Khandelwal (2009) who stated that Zn increased the grain yield of Soybean.

Zinc showed a significant variation on grain yield. The grain yield was highest (14.25 g) when the crop received 5 ppm Zn and lowest (11.96 g) was found from control. This might be due to boron deficiency which helps grain formation (Brady, 1996). Results of this study were consistent with that of Ferguson *et al.*, (2006); Pable and Patil (2011), who reported that grain yield increased significantly with each increment of zinc. Results also noticed that interaction of sulphur and zinc was not significant regarding grain yield.

Combination of sulphur and zinc had significant effect on grain yield. The highest grain yield (15.30 g pot⁻¹) was recorded with 40 ppm sulphur and 5 ppm zinc obtained 56.12% higher than the lowest grain yield 9.6 g pot⁻¹ at control. Similar opinion was on put forward by Pable *et al.* (2010) who reported that S and Zn produced higher grain yield of soybean.

Grain nutrient uptake

Grain sulphur and zinc uptake showed a significant variation by the application of different levels of sulphur (Table 2). The highest S and Zn uptake were found when sulphur was applied @ 60 and 40 ppm respectively and lowest uptake were obtained from no sulphur application. The above results revealed that S dose increases its uptake due to high S content and high grain yield. These results are in agreement with those of Layek and Shivakumar (2009), who reported that sulphur significantly increased the S uptake in soybean. Similar result was found by Chand *et al.* (1997) in mustard. But the results differed from that of Krishna (1995), who stated that S uptake decreased with its increased application. Zinc had significant variation in relation to Zn and S uptake by soybean (Table 1). Application of zinc on its uptake in grains did not have obvious effect. However, on an average, zinc uptake increased at different level of zinc in comparison to control. The value of zinc uptake at 5.0 and 7.5 ppm were statistically equal. The

highest S uptake was achieved by the application of 5 ppm S and lowest from control. In this study it might be concluded that Zn uptake was influenced by Zn application. The results are in concurrent with the findings observed by Pable and Patil (2011), who reported that uptake of boron increased due to Zinc application. However, the highest S and Zn uptake was found from the treatment combination of S₆₀Zn_{2.5} and S₄₀Zn₅ respectively and lowest from control.

Protein and oil content

Grain protein and oil content was not significantly influenced by different levels of S (Table 2). Sulphur @ 60 ppm produced the highest protein and oil content and lowest was in control. It is evident from the results that S had remarkable influence on protein and oil content. Because S is required for the synthesis of fatty acids and S containing amino acids, such as cystine, cysteine and methionine which are essential components of protein (Havlin *et al.* 1999).

Oil content increased in the linear order with increase in sulphur doses being lowest at control and highest at 60ppm level. The increase in oil content on addition of sulphur might be associated with increase in acetyl-CoA carbohydrate activity through the enhancement of acetyl CoA concentration (Ahmad *et al.* 2000). Soybean is oilseed and leguminous crop and increase in oil content on addition of sulphur has also been reported by a number of research workers (Varun *et al.*, 2011; Pable *et al.*, 2010; Raghuvanshi *et al.*, 2009).

However, the zinc addition did not show obvious effect on the oil content of grains, though slight increase in oil content with an addition in zinc up to 5.0 ppm level was observed. The increase in oil content on addition of zinc has also been reported by Pable *et al.* (2010).

Addition of sulphur and zinc both had significant positive effect on the protein content of soybean. Sulphur is a constituent of sulphur containing amino acid. Hence, it is expected that addition of sulphur would have increased the protein content of. The result of present study in concordantly supported by the findings of Pable and Patil, 2011; Varun *et al.*, 2011; Umbarkar *et al.*, 2010 and Vaiyapuri *et al.*, 2009. The increase in protein content an addition of zinc has also been reported by Husain and Kumar, 2006. The interaction, S × Zn did not have significant effect on the quality characteristics i.e., oil and protein contents of grain.

CONCLUSION

This study demonstrated that highest protein (38.64%) and oil (21.54%) content was observed due to application of 60 ppm S, while 5 ppm Zn gave the highest protein (38.42%) and oil (20.90%) content of soybean grain.

REFERENCES

- Ahamad, A., Khan, I. and Abdin, M.Z. 2000. Effect of sulphur fertilization on oil accumulation, Acetyl-CoA concentration and Acetyl-CoA carbohydrate activity in the developing grain of rapeseed (Brassica napus L.). *Australian J. of Agril. Res.* **51**: 1023-1029.
- Anonymous, 2013. http://www.icexindia.com/profiles_html/soybean.html.

- A. O. A. C. 1965.** Association of official agricultural chemist 9th Ed. Washington.
- Bhuiyan, M.A.H., Kabir, M.S. and Khanam, D. 1998.** Effect of boron, molybdenum and rhizobial inoculant on nodulation and yield of lentil. *Bangla. J. Seed Sci. Tech.*, **2**: 39-44.
- Black, C. A. 1965.** Methods of soil analysis. American Soc. Agro., Mandison, Wisconsin.
- Brady, N. C. 1996.** The Nature and Properties of Soils. 11th ed. McMillan Pub. Co., Inc. New York. pp. 444-487.
- Chand, L., Sharma, A. S. and Jat, S. C. 1997.** Quality and uptake of nutrients in mustard as affected by foliar spray of urea and sulphur application. *Ann. of Bio., Ludhiana*, **13**: 103-106.
- Chandel, D. and Khandelwal, R. B. 2009.** Effect of zinc and phosphorus on yield, nutrient uptake and oil content of mustard grown on the gypsum-treated sodic soil. *J. Ind. So. Soil Sci.* **57(1)**: 66-70.
- Chapman, H. D. and Pratt, F. 1961.** Methods of analysis for soils, plant and water. Uni. of California, U.S.A. p. 309.
- Chesnin, L. and Yien, C. H. 1951.** Turbid metric determination of available sulphur in soil. *Soil Sci. Soc. America Pro.* **15**: 199-151.
- Darwish, D. S., El-Gharreib, G., El-Hawary, M. A. and Rafft, O. A. 2002.** Effect of some macro and micronutrients application on peanut production in a saline soil in El-Faiyum Governorate. *Egypt. J. Appl. Sci.* **17**: 17-32.
- Das, K. N. and Das, K. 1994.** Effect of sulphur and nitrogen fertilization on yield and nitrogen uptake by rapeseed. *J. Ind. Soc. Soil Sci.* **42**: 476-478.
- Devi, K. N., Singh, L. N. K., Singh, M. S., Singh, S. B. and Singh, K. K. 2012.** Influence of Sulphur and Boron Fertilization on Yield, Quality, Nutrient Uptake and Economics of Soybean (*Glycine max*) under Upland Conditions. *Journal of Agricultural Science.* **4(4)**: 1-10.
- Ferguson, R. B., Shapiro, C. A., Dobermann, A. R., Wortmann, C. S. 2006.** Fertilizer recommendations for soybeans. Neb Guide. University of Nebraska-Lincoln Extension Publications. Available at URL: <http://www.ianrpubs.unl.edu/pages/publicationD.jsp?publicationId=146>.
- Fisher, R. A. 1947.** The design of experiments, Oliver and Boyd. Edinberg 4th Ed.
- Ghasemian, V. 2000.** Evaluation of micro nutrient elements effects on quality and quantity of soybean seeds in East Azerbaijan. M. Sc. Thesis, Tarbiat Modarres University.
- Havlin, J. L., Beaton, J. D., Tisdale, S. L. and Nelson, W. L. 2005.** Sulfur, calcium, and magnesium. In J.L. Havlin et al. (ed.) Soil fertility and fertilizers. 7th Ed. Pearson Prentice Hall, Upper Saddle River, NJ. p. 219-243.
- Havlin, L. J., Beaton, D. J., Tisdale, L. S. and Nelson, L. W. 1999.** Soil fertility and fertilizers. Prentice Hall of Indian, 6th Ed. pp. 227-228, 277, 319-346.
- Hill, P. 2000.** Crop response to tillage systems. In R. Reeder (Ed.) conservation tillage systems and management. Midwest Plan Serv. Publ. 45. Iowa State Univ., Ames. p. 47-60.
- Husain, M. F. and Kumar, R. 2006.** Influence of sowing dates and application of zinc on the performance of mustard in south-west semi-arid zone of Uttar Pradesh. *International Journal of Agricultural Sciences.* **2(2)**: 601-604.
- Imade, S. R., Kubde, K. J., Thakur, M. R. and Gudade, B. A. 2010.** Response of biofertilizer under different levels of phosphorus and sulphur to yield, nutrient uptake and quality of soybean. *Ann. Pl. Phy.* **24(1)**: 21-24.
- Jamal, A., Fazli, I. S., Ahmad, S., Abdin, M. Z., and Yun, S. J. 2005.** Effect of sulphur and nitrogen application on growth characteristics, seed and oil yields of soybean cultivars. *Korean J. Crop Sci.* **50(5)**: 340-345.
- Kanase, N., Jadhao, S. M., Konde, N. M. and Patil, J. D. 2006.** Response of soybean to application of zinc in inceptisol. *Ann. Pl. Phy.* **20(1)**: 135-136.
- Krishna 1995.** Effect of sulphur and zinc application on yield, sulphur and zinc uptake and protein content of mung (green gram). *Legume Research*, **18**: 89-92.
- Kumar, A. 2007.** A study of consumer attitudes and acceptability of soy food in Ludhiana. MBA research project report, Department of Business Management, Punjab Agril. Uni., Ludhiana, Punjab.
- Kumar, D. and Sidhu, S. 2010.** Effect of soil applied sulphur and boron on yield and uptake of boron in soybean. *Ann. Agril. Bio. Res.* **15(1)**: 57-62.
- Layek, J. and Shivakumar, B. G. 2009.** Effect of sulphur and boron nutrition on nutrient uptake and quality of soybean (*Glycine max* L. Merrill). *J. Oilgrains Res.* **26(Special Issue)**: 369-371.
- Mahmoodi, B., Mosavi, A. A., Daliri, M. S. and Namdari, M. 2013.** The evaluation of different values of phosphorus and sulfur application in yield, yield components and seed quality characteristics of soybean (*Glycin Max* L.). *Advances in Environmental Biology.* **7(1)**: 170-176.
- Mohanti, A. K., Sunil K., Jha, S. K., Sanjeev, M. and Chandrakara, B. L. 2004.** *Plant Archives.* **4(2)**: 375-377.
- Morrison, F. B. 1956.** Feeds and feeding. Morrison Pub. Co., Ithaca, NY.
- Pable, D. and Patil, D. B. 2011.** Effect of sulphur and zinc on nutrient uptake and yield of soybean, *International Journal of Agricultural Sciences.* **7(1)**: 129-132.
- Pable, D., Paul, D. B. and Deshmukh, P. W. 2010.** Effect of sulphur and zinc on yield and quality of soybean. *Asian J. Soil Sci.* **5(2)**: 315-317.
- Prasad, K. and Prasad, R. 2003.** Effect of varieties and sulphur on yield and yield attributes of field pea (*Pisum sativum* var. *Arvense*). *Crop Res.* **25**: 419-422.
- Raghuwanshi, S. R. S., Raghuwanshi, O. P. S., Unat, R., Ambawatika, G. R. and Bhargav, K. S. 2009.** Effect of different doses of sulphur on productivity and quality of soybean (*Glycine max* L. Merrill). *Soybean Res.* **7**: 93-95.
- Scherer, H. W. 2001.** Sulphur in crop production. *Eur. J. Agron.* **14**: 81-111.
- Sounda, G. and Nandini Devi, K. 2003.** Relative efficacy of different sources of sulphur on soybean and its nutrition under different levels of irrigation in an alluvial soil. *J. Interacad.*, **7**: 160-164.
- Srivastava, U. K., Rajput, R. L. and Devedi, M. L. 2000.** Response of soybean-mustard cropping system to sulphur and biofertilizers on farmer's field. *Legume Res.* **23**: 23
- Steel, R. G. D. and Torrie, J. H. 1980.** Principles and Procedures of Statistics. A biochemical approach 2nd edⁿ. McGraw Hill, Kugakusha Ltd. New Delhi. p. 532.
- Umbarkar, R. B., Shaikh, F. G., Kalegore, N. K. and Thakur, B. K. 2010.** Response of rainfed soybean (*Glycine max*) to sulphur and zinc application. *J. Oilgrain Res.* **27(2)**: 185-186.
- Vaiyapuri, K., Amanullah, M. M. and Sundareswaran, S. 2009.** Influence of sulphur and boron on yield, protein content and sulphur and boron uptake of soybean. *Green Farming.* **2(10)**: 664-666.
- Varun, B. K., Patel, B. A., Panchal, H. D. B., Dalwadi, M. R. and Patel, J. C. 2011.** Effect of different sources and levels of sulphur on yield and quality of soybean under inceptisol of middle Gujrat. *Asian J. Soil Sci.* **6(1)**: 85-87.
- Vishwakarma, S. K., Sharma, R. S. and Khatik, S. K. 1998.** Influence of varying sources and levels of sulphur on root characteristics and nodulation activity in soybean (*Glycine max* L. Merrill). *Journal of Soils and Crops.* **8**: 116-118.

Waddoups, M. 2011. Interpreting soil & plant tissue tests. Available at <http://www.nwag.com/interpre.shtml> (accessed 21 Apr. 2011; verified 15 Sept., 2011). Northwest Agric. Consultants, Kennewick, WA.

Yasari, E. 2012. Micronutrients Impact on Soybean (*Glycine max* (Merrill)) Qualitative and Quantitative Traits. *International Journal of Biology*. **4(2)**:112-118.

Yin, X., Gwathmey, O., Main, C. and Johnson, A. 2011. Effects of sulfur application rates and foliar zinc fertilization on cotton lint yields and quality. *Agronomy Journal*. **103(6)**:1794-1803.

Zizala, V. J., Yadav, N. B. and Gorfad, P. S. 2008. Effect of sulphur and zinc on yield, quality and its concentration on mustard. *Asian J. Soil Sci.* **3(1)**: 173-177.