International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(6): 2903-2907

Received: 09-09-2018
Accepted: 12-10-2018

Gurpreet Singh
Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh, India

Pawan Pathania
Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh, India

SS Rana
Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh, India

Suresh Kumar
Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh, India

VK Sharma
Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh, India

Correspondence
Gurpreet Singh
Department of Agronomy, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh, India

Response of soybean to levels and sources of sulphur on growth and yield under mid - hill conditions of Himachal

Gurpreet Singh, Pawan Pathania, SS Rana, Suresh Kumar and VK Sharma

Abstract
A field experiment was laid out at Palampur during *Kharif* 2015 to study the response of soybean to levels and sources of sulphur under mid - hill conditions of Himachal Pradesh. The treatments comprising of all possible combinations of three levels of sulphur *viz.* 20, 40 and 60 kg /ha and four sources of sulphur *viz.* SSP, Gypsum, Elemental sulphur and Epsom salt along with absolute control and 100% NPK + 10 t FYM/ha. The result revealed that growth, yield attributes, seed and straw yield of soybean increased with the application of S upto 40 kg/ha. Higher dose of sulphur could not significantly influence growth, yield attributes and seed and straw yield of soybean. The response per kg S apply was 14.5 kg of soybean grain. Among the sources of sulphur gypsum gave the better response in terms of growth, yield attributes and seed and straw yield of soybean over the other sources. Gross returns (78959 ₹/ha), net returns (37360 ₹/ha) and B: C (1.91) ratio was significantly higher at 40 kg S/ha. Gypsum gave highest gross returns (75086 ₹/ha), net returns (43998 ₹/ha) and B: C ratio (2.11).

Keywords: Sulphur, growth, yield attributes yields, economics, and soybean

Introduction
Soybean (*Glycine max* (L.) Merill) is an important and extensively grown also known as “Miracle” or “Golden bean”. Because of high leguminous protein (40%) and fatty (20%) oil, (Singh and Chung 2007) [17] carbohydrate (35%) and ash (5%). Soybean meal is a high-protein supplement for livestock. it is gaining popularity in human diets as well. Soybean, being rich source of amino acids lycine (5%), unsaturated fatty acids (Omega-6 and Omega-3), vitamins (vitamin B complex) and minerals are being widely used in different forms and acquire special importance in Indian and other Asian countries as a substitute to relieve from hunger and malnutrition.
Sulphur is an essential macronutrient in plant growth and development. Sulphur (S) is now being recognized as the fourth major plant nutrient (Tandon, 2004; Morris 2007) [21, 13]. Sulphur also plays an important role in the chemical composition of seeds. It plays key role in protein synthesis, chlorophyll formation and oil synthesis (Tisdale *et al*. 2002) [23]. Cysteine and methionine are the most important sulphur containing amino acids in plants, where they both occur as free acids and as building blocks of proteins (Mengel and Kirkby 1996) [12]. Sulphur requirements and benefit from sulphur fertilization are the maximum for the oilseed crops (Tandon, 1990) [22] followed by pulses (Singh 2001) [16] and are lowest for cereals. Research evidences raveled that sulphur nutrition is essential in increasing the oil content in soybean (Dixit *et al*. 2009) [5]. Keeping these points in view present investigation was initiated to evaluate the effect of different sulphur sources and levels on growth and yield of soybean (*Glycine max*).

Materials and Methods
A field experiment was conducted during the *kharif* season of 2015 at Palampur 32.06' N latitude, 76.03' E longitude and 1290.8 m altitude. Temperature during the cropping period ranged between 11.56 to 31.2 ºC, the humidity 45.52% to 93.25% with 10.5-11.0 hours day length and a moderate to high rainfall. The soil of the experimental site was silty clay loam in texture with pH 5.5, organic carbon 0.78%, total nitrogen 333 (kg/ha), available phosphorus 23 kg/ha, sulphur 37.24 kg/ha and potassium 250 kg/ha.

Three levels *viz*., S_1=20 kg S/ha, S_2=40 kg S/ha, S_3=60 kg S/ha and 4 sources of sulphur *viz*., 1. Single Super Phosphate (SSP, 12% S), 2. Gypsum ($CaSO_4.2H_2O$) (18.62% S), 3. Elemental Sulphur (S) (100% S) and 4. Epsom Salt ($MgSO_4$) (13% S) plus absolute control and recommended practice are evaluated in RBD with three replications. Harit Soya a variety of soybean was sown in lines with a spacing of 30cm × 10 cm on 23th June, 2015. Recommended doses of N, P and K, in the form of urea, DAP and MOP, were applied. Where SSP was used as a source of sulphur, phosphorus supplementation was done through DAP application. All other recommended agronomic practices were followed during the period of crop growth. The crop was harvested from a net plot of 3.9m * 1.6m on 26th Oct., 2015. The data on growth and yield parameters were recorded periodically and analyzed statistically to find out the treatment difference and the mean differences were compared using CD values (Gomez and Gomez, 1984).

Results and Discussion

Effect on growth

The data on maximum plant height of soybean at harvest stage of the crop have been presented in Table. 1. Application of sulphur increased the plant height with increase in its level upto 60 kg S/ha (78.3cm). The increase in plant height observed in the experiment may be due to the favorable effect of sulphur on N metabolism and consequently on the vegetative growth of soybean plant. Similar finding was reported by Akter *et al*. (2013) [1] in soybean plant. Source of sulphur also had significant influence on plant height at all stages of observation. Plant height was found to be maximum with application of sulphur through gypsum (82.3 cm) as compared to the other source of sulphur. Souza *et al*. (2012) [19] also reported, increase in the accumulation of nutrients in the soybean shoot with the use of gypsum. Thus increased accumulation of nutrients might have increased plant height in the present crop. Epsom salt was found to have minimum plant height but was comparable to SSP. Application of sulphur significantly increased plant height over absolute control (No sulphur). The results of the current study is in concurrence with the earlier reports of Tabatabai (1986) [20], who reported that lack of sulphur reduced plant height. INM treatment could not significantly influence shoot height as compared to the overall mean of other treatments. Similarly application of sulphur at the rate of 60 kg/ha had significantly higher total dry matter (659.2 g/ m^2) as compared to other levels. Application of sulphur through gypsum significantly increased dry matter accumulation over other sources of sulphur i.e. SSP, elemental sulphur and Epsom salt which were at par with each other in term of dry matter production. Increased growth under gypsum might be attributed to the readily available sulphate which enhanced the uptake of nutrients even at the initial stages of crop growth. Similar findings were earlier reported by Kandpal and Chardel (1993) [10]. On an average application of the sulphur significantly increased the dry matter accumulation over the control. Yadav *et al*. (2013) [24] had also reported significant effect of S on growth parameters. Dry matter accumulation was not significantly influenced due to integrated nutrient management over the overall mean of other treatments.

Nodule numbers per plant were significantly influenced due to varied levels and sources of sulphur application. Number of nodules at 45 days after sowing and at initiation of flowering were significantly increased with increase in level of sulphur up to 60 kg S/ha. The increase in nodule numbers due to application of sulphur might be because of positive interaction of sulphur with phosphorus, which helped in better root development. Moreover, sulphur stimulates the cell division and helpful in the promotion of root nodules Yadav *et al*. (2013) [24]. Source of sulphur also had significant influence of root nodules. Significantly higher number of nodules was recorded with the application of gypsum both at 45 DAS and at initiation of flowering stage. However, gypsum was statistically at par with elemental sulphur in influencing nodules per plant at both the observational stages. SSP, elemental sulphur and Epsom salt were statistically equal in influencing number of nodules per plant at initiation of flowering. Similar result was reported earlier by Ganeshamurthy and Reddy (2000) [6]. On an average S application (35.6/plant & 34.3/plant) increased number of nodules by 19.9 and 16.3% over control at 45 DAS and at initiation of flowering stage, respectively. INM treatment significantly increased the nodule count at 45 DAS and at initiation of flowering stage over the other treatment. As INM treated plot had more organic matter addition through FYM facilitating less soil compaction, better root development and hence increased number of nodules, therefore, was obvious. Ganeshamurthy and Reddy (2000) [6] reported that maximum number of nodules were observed in the treatment receiving 8 tones FYM/ha.

Table 1: Effect of levels and sources of sulphur on plant height at harvest, dry matter accumulation at harvest and n the number of nodules per plant of soybean

Treatment	Plant height at harvest (cm)	Dry matter accumulation at harvest (g m^{-2})	Nodules/plant (no)	
			45 DAS	at initiation of flowering
Sulphur level (kg/ha)				
20	71.9	622.0	32.9	32.3
40	77.0	652.8	36.6	35.0
60	78.3	659.5	37.4	35.6
SE(m±)	1.5	10.3	0.8	0.8
LSD(p=0.05)	4.3	29.9	2.4	2.2
Source				
SSP	73.0	638.7	33.2	32.3
Gypsum	82.3	681.6	37.9	36.8
Elemental sulphur	76.4	638.8	37.2	34.6
Epsom salt	71.2	620.1	34.2	33.5
SE(m±)	1.7	11.9	1.0	0.9
LSD(p=0.05)	5.0	34.5	2.8	2.5
Control v/s Sulphur				
Control	67.0	597.3	28.5	28.7
Sulphur	75.7	644.8	35.6	34.3

SE(m±)	2.2	15.1	1.2	1.1
LSD(p=0.05)	6.4	44.0	3.6	3.2
INM v/s Others				
INM	72.2	665.3	39.1	37.5
Others	75.0	641.1	35.1	33.9
SE(m±)	2.2	15.1	1.22	1.1
LSD(p=0.05)	NS	NS	3.6	3.2

Table 2: Effect of levels and sources of sulphur on yield contributing characters of soybean

Treatment	Pods/ plant	Seeds/pod	1000-seed weight (g)
Sulphur level (kg/ha)			
20	54.0	4.1	127.3
40	57.0	4.4	132.1
60	57.1	4.4	132.1
SE(m±)	0.8	0.1	1.5
LSD(p=0.05)	2.4	0.2	4.4
Source			
SSP	54.6	4.2	128.8
Gypsum	59.1	4.6	136.6
Elemental sulphur	55.6	4.2	129.1
Epsom salt	54.7	4.1	127.4
SE(m±)	1.0	0.1	1.7
LSD(p=0.05)	2.8	0.3	5.1
Control v/s Sulphur			
Control	50.4	3.7	123.7
Sulphur	56.0	4.3	130.5
SE(m±)	1.2	0.1	2.2
LSD(p=0.05)	3.5	0.3	6.5
INM v/s Others			
INM	54.5	4.1	127.7
Others	55.6	4.2	130.0
SE(m±)	1.2	0.1	2.2
LSD(p=0.05)	NS	NS	NS

Yield Attributes

The growth of the crop as described in the previous section was appeared to be reflected in the yield attributes of soybean. Levels of sulphur brought about significance variation in all the yield attributes of soybean. Like growth parameters yield attributes *viz*. number of plant height, total dry matter accumulation, pods/plant. Seeds/pod and 1000- seed weight increased with increase in level of sulphur up to 60 kg S/ha. Improvement in pods/plant seeds/pod and 1000- seed weight with the application of S have been reported by various workers (Shivran *et al*. 2012; Devi *et al*. 2012) [15, 3]. Source of sulphur also significantly influenced number of pods/plant, seeds/pod and 1000-seed weight. Among the source of sulphur, gypsum excelled all the other in terms of pods/plant, seeds/pod and 1000- seed weight. The superiority of gypsum in influencing yield attributes in soybean (Meena *et al*. 2015) [11] and other legumes (Jawahar *et al*. 2013) [9] have been amply documented. However, elemental sulphur was statistically at par with gypsum in influencing branches/plant. SSP, Epsom salt and Elemental sulphur were comparable to each other in influencing the seeds/pod and 1000-seed weight. The overall effects of sulphur application were found to be significantly superior as compared to control (no application of sulphur). Sulphur applications increased pods/plant, seeds/pod and 1000-seed weight by about 21.0, 11.1, 16.2 and 5.4% respectively, over control. However, INM treatment was not significantly different from the overall effect of other treatments in influencing any of the above yield contributing characters.

Table 3: Effect of levels and sources of sulphur on yield (kg ha-1), harvest index and protein content in grains and B: C Ratio of soybean

Treatment	Seed yield	Straw yield	Harvest index	Protein content (%)	B: C Ratio	Gross Returns (₹) ha^{-1}	Net Returns (₹) ha^{-1}
Sulphur level (kg/ha)							
20	1533	2469	0.38	38.3	1.76	71977	30984
40	1678	2747	0.38	38.6	1.91	78959	37360
60	1688	2784	0.38	38.4	1.86	79514	36199
SE(m±)	32	57	0.01	0.7	0.04	1440	1440
LSD(p=0.05)	93	167	NS	NS	0.11	4187	4186
Source							
SSP	1611	2621	0.38	38.5	1.96	75734	37091
Gypsum	1777	2898	0.38	38.3	2.11	83551	43998
Elemental sulphur	1593	2639	0.38	38.5	1.68	75086	30355
Epsom salt	1552	2508	0.38	38.4	1.62	72896	27948
SE(m±)	37	66	0.01	0.8	0.04	1663	1662
LSD(p=0.05)	107	193	NS	NS	0.12	4834	4834
Control v/s Sulphur							
Control	1307	2240	0.37	37.3	1.58	61880	22669
Sulphur	1633	2667	0.38	38.4	1.84	76817	34848
SE(m±)	47	85	0.01	1.0	0.05	2119	2119
LSD(p=0.05)	137	246	NS	NS	0.16	6162	6162
INM v/s Others							
INM	1500	2610	0.36	38.3	1.75	71190	30479
Others	1608	2634	0.38	38.4	1.82	75668	33911
SE(m±)	47	84	0.01	1.0	0.05	2113	2113
LSD(p=0.05)	NS	NS	NS	NS	NS	NS	NS

Yield

Significant variation in seed yield of soybean was observed due to varied levels of sulphur application. Like growth parameters and yield contributing traits, seed yield of soybean increased with increase in sulphur application up to 60 kg S/ha. On an average 40 kg S/ha increased seed yield of soybean by 9.46% over 20 kg S/ha. The further higher levels of sulphur (i.e. 60 kg/ha) could not significantly increase seed yield of soybean over 40 kg S/ha. Generally the response of fertilizers is quadratic in nature. In the present investigation the response of S appeared to be quadratic. The quadratic response function ($Y = a + bx + cx^2$) worked out is given as below:

$$Y = 1304 + 14.5x - 0.135x^2 \quad (R^2 = 0.875)$$

Where Y is seed yield in kg/ha and x is sulphur in kg/ha. As indicated by the equation, the response per kg S applied was 14.5 kg of soybean grain. The application of sulphur might have increased the availability of the nutrients to soybean plant due to improved nutritional environment which in turn favorably influenced the energy transformation, activation of enzymes, chlorophyll synthesis as well as increased carbohydrate metabolism. This statement is in agreement with Dhage *et al*. (2014) [4], Banger *et al*. (2014). Different source of sulphur also had significant variation in seed yield of soybean. Application of gypsum resulted in significantly higher seed yield (1777 kg/ha) over rest of sources *viz*. SSP (1611 kg/ha), elemental sulphur (1593 kg/ha) and Epsom Salt (1552 kg/ha). All the three sources were statistically equal in response as to seed yield of soybean. On an average, gypsum increased seed yield of soybean by 14.5, 11.5 and 10.3% over Epsom salt, elemental sulphur and SSP respectively. Ram and Dwivedi (1992) [14] also obtained the positive response of the black gram to gypsum which could be due to higher solubility and increased photosynthetic activity of the crop. Higher yield obtained with gypsum application might be due to the presence of sulphur more readily available form as well as more solubility of gypsum to water (Sounda *et al*. 2006) [18].

In general sulphur had significant influence on seed yield as compared to absolute control. Sulphur application increased the seed yield of soybean by 24.9% over absolute control showing indispensability of S nutrition in oilseed crop. Different levels and sources of sulphur and INM treatment did not significantly influenced the harvest index. The protein content in soybean was not significantly influenced due to different levels and sources of sulphur under investigation. The protein content ranged from 37.3 to 38.6% under different treatments (Table. 3).

Economics

Application of gypsum gave highest B: C ratio. However, SSP excelled over Epsom salt and elemental sulphur in influencing the B: C ratio. SSP is commonly used source of P and it is a cheaper fertilizer. Hosmath *et al*. (2014) reported that the application of gypsum gives higher net returns and B: C ratio. On an average application of S increased gross returns, net returns and B: C ratio by ₹ 14937/ ha, ₹ 12179/ha and 0.2%, respectively over the absolute control (no application of S).

Conclusion

These result conclusively inferred the importance of S nutrition in crop which not only increased productivity but profitability as well. The yield maxima was realized at 53.9 kg S/ha. The optimum dose depends on the source of sulphur and on an average was little lower (51 kg/ha) than maximum yield. Thus it is worthwhile to recommend dose of 51 kg S/ha for a general crop of soybean under the prevalent conditions. If S is not to be applied through fertilizers, INM where 50% of NPK were supplied through fertilizers (other than S sources) and 50% N through FYM may be followed as alternative to S fertilizers. This is indicated from the present study that like yield, INM treatment was comparable to the overall mean of the other treatments in influencing the gross returns, net returns and B: C ratio.

Reference

1. Akter F, Islam MDN, Shamsuddoha ATM, Bhuiyan MSI, Shilpi S. Effect of Phosphorus and Sulphur on Growth and Yield of Soybean (*Glycine max* L.). International Journal of Bio-resource and Stress Management. 2013; 4:555-560
2. Bangar S, Khagale GB, Tajane D. Role of sulphur and Boron on the Growth, Yield and Protein Content of Soybean (*Glycine max* L.). Trends in Biosciences. 2014; 7:3565-3569
3. Devi KN, Singh LNK, Singh MS, Singh SB, Singh KK. Influence of sulphur and boron fertilization on yield, quality, nutrient uptake and economics of soybean (*Glycine max*) under upland conditions. Journal of Agricultural Science. 2012; 4:1-10
4. Dhage SJ, Patil VD, Patange MJ. Effect of various levels of phosphorus and sulphur on yield, plant nutrient content, uptake and availability of nutrients at harvest stages of soybean [*Glycine max* (L.)]. International journal of Current Microbiology and Applied Science. 2014; 3:833-844
5. Dixit AK. Arvind Saxena; Tomar, DS., Kaushik, SK., Rekha Tiwari, Lalit Jain, Ghazala Khan, Importance of sulphur nutrition on productivity of soybean in vertisols of M.P. Indian Journal of Fertilisers. 2009; 5(10):61-63
6. Ganeshamurthy AN, Reddy KS. Effect of Integrated Use of Farmyard Manure and Sulphur in a Soybean and Wheat Cropping System on Nodulation, Dry Matter Production and Chlorophyll Content of Soybean on Swell-Shrink Soils in Central India. Journal of Agronomy and Crop Science. 2000; 185:91-97
7. Gomez GA, Gomez AA. Statistical procedure for agricultural research (2nd ed.). John Wiley and sons, New York. 1976, 680
8. Hosmath JA, Babalad HB, Basavaraj GT, Jahagirdar S, Patil RH, Athoni BK *et al*. Sulphur nutrition in soybean [*Glycine max* (L.) Merril] in India. International Conference on Biological, Civil and Environmental Engineering (BCEE-2014) March 17-18, Dubai (UAE), 2014.
9. Jawahar S, Vaiypuri V, Suseendran K, Kalaiyarasan C, Sriramachandrasekharan MV. Effect of sources and levels of sulphur on growth and yield of rice fallow black gram (*Vigna mungo*). International research journal of chemistry. 2013; 3:1-7
10. Kandpal BM, Chandel AS. Effect of gypsum and pyrites as sources of sulphur on nitrogen fixation dry matter yield and quality of soybean (*Glycine max*). Indian journal of Agronomy. 1993; 38:137-139
11. Meena I, Meena RH, Sharma SK, Jat G, Choudhary JL. Effect of phosphorus and sulphur on yield and quality of soybean (*Glycine max*) in Typic Haplustept. Annual Agriculture Research. 2015; 36:98-102

12. Mengel lK, Kirkby AE. Principles of Plant Nutrition. New Delhi: Panima Publishing Corporation, 1996, 46
13. Morris RJ. Sulphur in Agriculture: International Perspective. In: Proceedings of TSI-FAI-IFA Symposium-cum-Workshop on Sulphur in Balanced Fertilization, 2007.
14. Ram H, Dwivedi KN. Effect of sources and levels of sulphur on yield and grain quality of chick pea. Indian Journal of agronomy. 1992; 37:112-114
15. Shivran RK, Rokadia P, Kumar R. Phosphorus and Sulphur Nutrition with P-Solubilizing Bacterial Inoculation Enhanced the Quality and Yield of Soybean (Cultivar JS-335). Madras Agriculture Journal. 2012; 99:68-72
16. Singh MV. Importance of sulphur in balanced fertilizer use in India. Fertilizer News. 2001; 46:13-35
17. Singh RJ, Chung GH. Cytogenetics of soybean: Progress and perspectives. The Nucleus. 2007; 50:403-425
18. Sounda G, Nandini Devi K, Maiti S, Mondal SS. Productivity and water use efficiency of spring soybean (*Glycine max*) as affected by levels of irrigation and sources of sulphur. Journal of Crop and Weed. 2006; 2:5-8
19. Souza MAS, Faquin V, Guelfi DR, Oliveira GC, Bastos CEA. Macronutrient accumulation in the soybean in influenced by prior cultivation marandi grass and soil remediation and compaction. Revi clenc agron. 2012; 43:611-622
20. Tabatabai MA. Sulphur in agriculture (Agronomy) monograph series, no 27 Madison Washington, USA, 1986.
21. Tandon HLS. Fertilizers in Indian Agriculture from 20th to 21st Century. New Delhi: FDCO, 2004.
22. Tandon HSL. Fertilizer management in oilseed crops. In: Fertilizer Recommendations for Oilseed Crops, ed. H. L. S. Tandon, New Delhi: FDCO, 1990, 27-60.
23. Tisdale SL, Nelson WL, Beaton JD, Havlin JL. Soil Fertility and Fertilizers. New Delhi: Prentice Hall of India, 2002.
24. Yadav H, Shekh MA, Takar SS, Kherawat BS, Shivran A, Agarwal MC. Effect of phosphorus and sulphur on growth and yield of summer soybean. International Journal of Agricultural Sciences. 2013; 9:168-171.