A-6091
[1-7]

RESEARCH ARTICLE Indian Journal of Agricultural Research

Response of Phosphorus, Sulphur and Foliar Spray of GA_3 on Nutrient Content and Uptake of Soybean [*Glycine max* (L.) Merrill]

Bahnu Pratap Ghasil[1], Manoj[3], Harphool Meena[2], Rajendra K. Yadav[2], Shankar Lal Yadav[2], Govind K. Yadav[3], Monika Choudhary[4]

10.18805/IJARe.A-6091

ABSTRACT

Background: Soybean is an important oil seed crop grown in a varied range of climate and soils in India. Phosphorous and sulphur is an important macronutrient required for plants. Their deficiency in soil is a worldwide concern for production of oil seed crops. The gibberellic acid involved in plant growth and development. Therefore, investigation was carry out to study influenced of phosphorus, sulphur and gibberellic acid on nutrient content and uptake of soybean.

Methods: An experiment conducted during *kharif*-2020 on soybean in sub-sub split plot design with three replications. The twenty four treatment combinations were comprised *viz*. four levels of phosphorus (Control, 20, 40 and 60 kg ha^{-1}), three levels of sulphur (15, 30 and 45 kg ha^{-1}) and two levels of gibberellic acid (Foliar spray of GA_3 @ 75 ppm and no spray).

Result: Results revealed that application of 40 kg phosphorus ha^{-1} and 30 kg sulphur ha^{-1} is optimum dose for obtaining higher available nitrogen, phosphorus, potassium and sulphur in the soil after crop harvest, nutrient content in seed and straw and uptake of soybean crop. The foliar spray of gibberellic acid @ 75 ppm is also beneficial for improving productivity and profitability of soybean crop.

Key words: Gibberellic acid, Nutrient content, Phosphorus, Quality, Sulphur.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is an important oilseed and food grain legume crop. It has paramount importance in human and animal nutrition, because it is a major source of edible vegetable oil and high protein feed as well as food in the world. It is highly nutritious containing higher amount of 22-24% protein, 1.3% fat and 60% carbohydrates on dry weight basis and it is rich source of calcium and iron. On the national basis, soybean occupied an area of 12.09 million ha with production and productivity of 11.22 metric tonnes and 928 kg ha^{-1}, respectively (Anonymous, 2020). Inadequate fertilizer used and emergence of multiple-nutrient deficiencies due to poor recycling of organic resources and unbalanced use of fertilizers are important factors to be considered for low productivity of soybean (Jadon *et al*., 2019).

Phosphorus fertilizer sources have been shown to positively influence soybean yields (Gonyane and Sebetha, 2022). Diammonium phosphate fertilizer source is known to significantly increase the number of pods per plant in the case of common beans, while the lowest number of pods per plant have been recorded in cases where there have been no applications of phosphorus fertilizer (Meseret and Amin, 2014). The triple superphosphate, rock phosphate phosphorus and monoammonium phosphate resulted in higher seed mass across the planting seasons (Gonyane and Sebetha, 2022). Sulphur is essential for synthesis of proteins, vitamins and sulphur containing essential amino acids and is also associated with nitrogen metabolism. The good yield of soybean can be achieved by balanced and adequate supply of phosphate, sulphur and other deficient, nutrients (Suman *et al*., 2018). Sulphur is used as soil amendment for amelioration, as plant nutrient for increasing yield and quality of crop produce, as chemical agent to acidulate other nutrient and pesticides (Kanwar and Mudahar,1986). It is also implicated in oil biosynthesis in soybean seed (Fazli *et al*., 2005). The sulphur is required in high amount by the oilseeds and hence has been identified as key nutrient responsible for high production.

[1]College of Agriculture, Agriculture University, Kota-324 001, Rajasthan, India.
[2]Agricultural Research Station, Agriculture University, Kota-324 001, Rajasthan, India.
[3]Departemnt of Soil Science and Agricultural Chemistry, Sri Karan Narendra Agriculture University, Jobner, Jaipur-303 329, Rajasthan, India.
[4]Departemnt of Agronomy, Rajasthan College of Agricultural, Udaipur-313 001, Rajasthan, India.

Corresponding Author: Harphool Meena, Agricultural Research Station, Agriculture University, Kota-324 001, Rajasthan, India.
Email: hpagron@rediffmail.com

How to cite this article: Ghasil, B.P., Manoj, Meena, H., Yadav, R.K., Yadav, S.L., Yadav, G.K. and Choudhary, M. (2023). Response of Phosphorus, Sulphur and Foliar Spray of GA_3 on Nutrient Content and Uptake of Soybean [*Glycine max* (L.) Merrill]. Indian Journal of Agricultural Research. DOI: 10.18805/IJARe.A-6091.

Submitted: 10-03-2023 **Accepted:** 30-11-2023 **Online:** 05-01-2024

Plant growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates there by helping in improve the physiological efficiency, photosynthetic ability, effective partitioning of accumulates from source to sink and ultimately enhance productivity of the soybean crop (Solamani *et al*., 2001). Gibberellic acid constitutes a group of tetracyclic diterpenoids, involved in plant growth and development (Aftab *et al*., 2010). The productivity of soybean to greater extent depends on efficient use of phosphorus, sulphur and gibberellic acid strategies. It has been now well understood that phosphorus and sulphur nutrient management with foliar spray of gibberellic acid play a very important role for sustaining crop productivity. Hence, considering above facts, the investigation was planned to find out the effect of phosphorus, sulphur and gibberellic acid on productivity, nutrient content, uptake and available nutrient status in the soil after crop harvest.

MATERIALS AND METHODS

An experiment conducted during *kharif* 2020 at Instructional Farm, College of Agriculture, Kota (Rajasthan), which is situated at south eastern part of Rajasthan. In Rajasthan, this region falls under Agro-climatic Zone-V of Rajasthan. This zone possesses typical sub-tropical conditions with maximum and minimum temperatures ranged between 30.2°C to 42.3°C and 20.3°C to 23.0°C during *kharif,* 2020. The total rainfall received during crop growing season 676 mm. The soil samples were collected and analysed for initial physicochemical properties followed by standard methods (Piper, 1950 and Black, 1965). The soil was clay loam in texture, slightly saline in reaction, medium in available nitrogen (264 kg ha^{-1}) and phosphorus (21.7 kg ha^{-1}) while high in potassium (388 kg ha^{-1}) and sufficient in DTPA extractable micronutrients with pH (7.61) and EC (0.52 dS m^{-1}). Recommended dose of fertilizer 20:40:40:30 (NPKS kg ha^{-1}) along with *Rhizobium japonicum* culture seed inoculation. Among these nitrogen and potassium was applied as basal dose through urea and muriate of potash, whereas phosphorus and sulphur were applied through triple super phosphate and elemental sulphur according to various treatments as basal dose.

The twenty-four treatment combinations consisted of four levels of phosphorus (control, 20, 40 and 60 kg ha^{-1}) allocated in main plots, three levels of sulphur (15, 30 and 45 kg ha^{-1}) in sub plots and two levels of gibberellic acid (foliar spray of GA_3 @ 75 ppm and no spray) in sub-sub plots were under taken in sub-sub split plot design with three replications. Data on nutrient content in seed and straw, nutrient uptake by crop, nutrient status in the soil were recorded as per standard procedures (Subbiah and Asija, 1956 and Olsen *et al*., 1954). Plant samples (Grain and straw) were collected after harvest of soybean crop from each plot. Data were statistically analysed by adopting appropriate method of standard analysis of variance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of phosphorus on nutrient content and uptake

It is obvious from data presented in Table 1 further indicated that the significantly higher nitrogen, phosphorus and sulphur content in soybean seed (6.47, 0.653 and 0.45 per cent) were recorded with the application of 60 kg P_2O_5 ha^{-1} over application of 20 kg P_2O_5 ha^{-1} (6.18, 5.81 and 0.37 per cent) and control (5.83, 4.91 and 0.32 per cent). However, it was found at par with 40 kg P_2O_5 ha^{-1} (6.47, 0.619 and 0.44 per cent). The maximum phosphorus and sulphur content (0.182 and 0.35 per cent) was found with application of 60 kg P_2O_5 ha^{-1}, which was closely followed by 40 kg P_2O_5 ha^{-1} (0.178 and 0.34 per cent). However, it was found significantly superior over application of 20 kg P_2O_5 ha^{-1} (0.168 and 0.29 per cent) and control (0.151and 0.21 per cent) in soybean straw. The various levels of phosphorus fertilizer did not significantly influence potassium content in seed and straw and nitrogen content in straw of soybean.

Significantly highest nitrogen, phosphorus, potassium and sulphur uptake by soybean seed (128.8,12.81, 28.87 and 8.78 kg ha^{-1}) was recorded with application of 60 kg P_2O_5 ha^{-1}, which was found at par with 40 kg P_2O_5 ha^{-1} (121.5, 11.63, 27.18 and 8.53 kg ha^{-1}) over application of 20 kg P_2O_5 ha^{-1} (96.6, 9.08, 23.20 and 5.97 kg ha^{-1}) and control (68.9, 5.80,16.20 and 3.80 kg ha^{-1}). The maximum nitrogen, phosphorus, potassium and sulphur uptake by straw of soybean (70.1, 6.26, 77.60 and 11.94 kg ha^{-1}) was recorded with application of 60 kg P_2O_5 ha^{-1}, which was found at par with 40 kg P_2O_5 ha^{-1} (63.4, 5.80, 72.30 and 11.15 kg ha^{-1}) over 20 kg P_2O_5 ha^{-1} (55.0, 4.93, 64.8 and 8.77 kg ha^{-1}) and control (37.8, 3.32, 48.0 and 4.76 kg ha^{-1}). Significantly higher total nitrogen, phosphorus, potassium and sulphur uptake by soybean crop (197.7,19.08, 106.4 and 20.73 kg ha^{-1}) with application of 60 kg P_2O_5 ha^{-1} over 20 kg P_2O_5 ha^{-1} (151.7, 14.01, 86.0 and 14.75 kg ha^{-1}) and control (106.7, 9.12, 64.2 and 8.56 kg ha^{-1}). However, it was found at par nitrogen uptake by total (184.9,17.43, 98.3 and 19.69 kg ha^{-1}) with 40 kg P_2O_5 ha^{-1} (Table 2).

In Nigeria, Amba *et al*. (2011), reported increases in number of root nodules after varying levels of phosphorus fertilizer. The maximum nitrogen content, phosphorus content, potash content as well as sulphur content were recorded in seed and straw of soybean. Similar results obtained were corroborating with those reported by Devi *et al*. (2012) and Dhage *et al*. (2014). Results showed that the maximum uptake of nitrogen, phosphorus, potassium and sulphur by seed, straw and total of soybean crop were recorded with application of 60 kg phosphorus ha^{-1} over rest of treatments similar findings was reported by Thakur *et al*. (2009). Similarly, the effect of phosphorus fertilizer in improvement of biological nitrogen fixation have been several times reported in other studies. For instance, in Kenya, Mugendi *et al*. (2010) observed increase in root nodule weight with the increase in doses of phosphorus fertilization.

Table 1: Effect of phosphorus, sulphur and gibberellic acid on nutrient content of soybean and soil nutrient status.

Treatments	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)		Sulphur content (%)		Available soil nutrient (kg ha^{-1})			
	Seed	Straw	Seed	Straw	Seed	Straw	Seed	Straw	Nitrogen	Phosphorus	Potassium	Sulphur
Phosphorus (kg ha^{-1})												
0	5.83	1.73	0.491	0.151	1.38	2.20	0.32	0.22	270	16.86	416	16.09
20	6.18	1.87	0.581	0.168	1.48	2.23	0.37	0.29	281	25.07	430	19.51
40	6.41	1.95	0.619	0.178	1.55	2.25	0.44	0.34	285	33.28	438	21.97
60	6.47	2.04	0.653	0.182	1.61	2.26	0.45	0.35	290	34.45	443	22.77
SEm±	0.06	0.09	0.005	0.002	0.16	0.03	0.003	0.003	2.20	0.35	4.23	0.27
CD at 5%	0.22	NS	0.015	0.006	NS	NS	0.013	0.010	7.60	1.21	14.62	0.93
Sulphur (kg ha^{-1})												
15	5.98	1.86	0.568	0.159	1.50	2.21	0.33	0.24	279	24.43	426	16.66
30	6.24	1.90	0.590	0.173	1.51	2.24	0.41	0.31	282	28.32	429	20.56
45	6.44	1.93	0.599	0.178	1.52	2.24	0.45	0.35	285	29.50	433	23.05
SEm±	0.06	0.02	0.005	0.001	0.01	0.02	0.004	0.002	1.47	0.29	4.02	0.13
CD at 5%	0.19	NS	0.017	0.004	NS	NS	0.014	0.006	4.41	0.89	12.05	0.40
Gibberellic acid												
No spray	6.15	1.87	0.577	0.168	1.50	2.23	0.38	0.29	281	27.28	428	19.72
GA_3 @ 75 ppm	6.30	1.92	0.594	0.172	1.51	2.24	0.41	0.31	282	27.55	434	20.45
SEm±	0.06	0.02	0.004	0.001	0.01	0.02	0.004	0.001	1.58	0.22	2.43	0.27
CD at 5%	NS	NS	0.013	0.004	NS	NS	0.011	0.003	NS	NS	NS	NS

Table 2: Effect of phosphorus, sulphur and gibberellic acid on nutrient uptake by seed, straw and total by soybean crop.

Treatments	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})			Sulphur uptake (kg ha^{-1})		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
Phosphorus (kg ha^{-1})												
0	68.9	37.8	106.7	5.80	3.32	9.12	16.2	48.0	64.2	3.80	4.76	8.56
20	96.6	55.0	151.7	9.08	4.93	14.01	23.2	64.8	86.0	5.97	8.77	14.75
40	121.5	63.4	184.9	11.63	5.80	17.43	27.1	72.3	98.3	8.53	11.15	19.69
60	128.8	70.1	197.7	12.81	6.26	19.08	28.8	76.6	106.4	8.78	11.94	20.73
SEm±	2.99	1.97	5.21	0.20	0.13	0.27	0.76	2.07	3.03	0.20	0.30	0.38
CD at 5%	10.38	6.83	15.10	0.72	0.46	0.94	2.63	7.18	10.50	0.62	1.06	1.33
Sulphur (kg ha^{-1})												
15	90.5	51.6	141.2	8.72	4.42	13.15	20.8	61.1	81.9	5.17	6.86	12.03
30	107.3	57.6	165.0	10.11	5.23	15.35	23.2	66.8	89.9	7.16	9.65	16.82
45	114.0	60.5	174.6	10.65	5.58	16.23	24.5	69.1	93.2	7.98	10.96	18.95
SEm±	2.23	0.98	2.15	0.14	0.11	0.25	0.54	1.10	1.26	0.13	0.21	0.23
CD at 5%	6.89	3.09	6.45	0.47	0.34	0.75	1.62	3.30	3.79	0.39	0.63	0.69
Gibberellic acid												
No spray	95.9	54.6	150.5	8.59	4.91	13.86	22.1	64.6	86.6	6.48	8.91	14.75
GA_3 @ 75 ppm	112.0	58.5	170.6	10.72	5.24	15.96	25.5	66.7	92.0	7.01	9.38	17.12
SEm±	2.08	1.13	2.07	0.17	0.11	0.21	0.47	1.51	1.90	0.13	0.17	0.26
CD at 5%	6.08	3.31	6.04	0.51	0.33	0.61	1.38	4.40	6.55	0.38	0.49	0.78

Effect of sulphur on nutrient content and uptake

A perusal of data presented in Table 1 further indicated that the significantly higher nitrogen, phosphorus and sulphur content (6.44, 0.599 and 0.45 per cent) were recorded with the application of 45 kg sulphur ha^{-1} over application of 15 kg sulphur ha^{-1} (5.98, 0.568 and 0.33 per cent). However, it was found at par with 30 kg sulphur ha^{-1} (6.24,0.590 and 0.41 per cent) in soybean seed. The maximum phosphorus and sulphur content (0.178 and 0.35 per cent) was found with application of 45 kg sulphur ha^{-1}, which was closely followed by 30 kg sulphur ha^{-1} (0.173 and 0.31 per cent). However, it was found significantly superior over application of 15 kg sulphur ha^{-1} (0.159 and 0.24 per cent) in soybean straw. Under application of sulphur fertilizer was observed non-significant difference of potassium content in seed and nitrogen and potassium content in straw of soybean. The nitrogen and potassium content in straw numerically increases with increasing levels of sulphur fertilizer but did not show any significant difference.

Significantly highest nitrogen, phosphorus, potassium and sulphur uptake by soybean seed (114,10.65, 24.5 and 7.98 kg ha^{-1}) was recorded with the application of 45 kg sulphur ha^{-1}, which was found at par with 30 kg sulphur ha^{-1} (107.3, 10.11, 23.3 and 7.16 kg ha^{-1}) over application of 15 kg sulphur ha^{-1} (90.5, 8.72, 20.8 and 5.17 kg ha^{-1}). The maximum nitrogen, phosphorus, potassium and sulphur uptake by straw of soybean (60.5, 5.58, 69.1 and 10.96 kg ha^{-1}) was recorded with application of 45 kg sulphur ha^{-1}, which was found at par with 30 kg sulphur ha^{-1} (57.7, 5.23, 66.8 and 9.65 kg ha^{-1}) over 15 kg sulphur ha^{-1} (51.6, 4.42, 61.1 and 6.86 kg ha^{-1}). Significantly higher total nitrogen, phosphorus, potassium and sulphur uptake (174.6,16.23, 93.2 and 18.95 kg ha^{-1}) with application of 45 kg sulphur ha^{-1} over 15 kg sulphur ha^{-1} (141.2, 13.15, 81.9 and 12.03 kg ha^{-1}). However, it was found at par nitrogen uptake by total (165.0,15.35, 89.9 and 16.82 kg ha^{-1}) with 30 kg sulphur ha^{-1} by soybean crop (Table 2).

Sulphur plays a vital role in improving vegetative structure for nutrient absorption, strong sink strength through development of reproductive structures and production of assimilates to fill economically important sink (Sharma and Singh, 2005). The above results revealed that sulphur dose increases its uptake due to high sulphur content and high seed yield. These results are in agreement with (Ravi *et al.,* (2017), who reported that sulphur significantly increased the nutrients uptake by soybean crop. The above results revealed that sulphur dose increases its uptake due to high sulphur content and high seed yield. These results are in agreement with those of Layek and Shiva Kumar (2009), who reported that sulphur significantly increased the nutrients uptake by soybean crop.

Effect of gibberellic acid on nutrient content and uptake

It is obvious from data Table 1 further indicated that nitrogen, potassium content in seed and straw of soybean failed to bring any significant variation with foliar spray of gibberellic acid @ 75 ppm. The phosphorus and sulphur content was recorded significantly higher with foliar spray of gibberellic acid @ 75 ppm (0.594 and 0.41 per cent) over no spray (0.577 and 0.38 per cnet). The maximum phosphorus and sulphur content (0.172 and 0.31%) in soybean straw recorded with foliar spray of gibberellic acid @ 75 ppm over no spray (0.168 and 0.29 per cent) in soybean straw.

Significantly higher uptake of nitrogen, phosphorus, potassium and sulphur uptake by seed (112, 10.72, 25.5 and 7.54 kg ha^{-1}) with foliar spray of gibberellic acid @ 75 ppm over no spray (95.9, 8.59, 22.1 and 6.48 kg ha^{-1}). Results showed that the maximum nitrogen, phosphorus, potassium and sulphur uptake (58.5, 5.24, 66.7 and 9.38 kg ha^{-1}) by straw of soybean was recorded with foliar spray of gibberellic acid @ 75 ppm over no spray (54.6, 4.91,64.6 and 8.91 kg ha^{-1}). The maximum total uptake of nitrogen, phosphorus, potassium and sulphur by crop (170.6, 15.96, 92.0 and 17.12 kg ha^{-1}) was recorded with foliar spray of gibberellic acid @ 75 ppm as compared to no spray (150.5, 13.86, 86.6 and 14.75 kg ha^{-1}) Table 2.0.The nitrogen and potassium content in seed and straw of soybean failed to bring any significant variation with foliar spray of GA_3 @ 75 ppm and no spray.While, markedly higher values uptake of nitrogen, phosphorus, potash and sulphur was recorded due to the enhanced plant growth and yield attributes only. This is consistent with findings of (Pal *et al*., 2016) who reported increased nitrogen, phosphorus, potash and sulphur uptake compared with the control in black fennel (*Nigella sativa* L.) and cucumber, respectively Similar observation was reported by Jayapaul *et al*. (1987) in the treatment foliar spray of GA_3 @ 125 ppm increased nutrient content in soybean seed.

Effect of phosphorus on available soil nutrients

A perusal of data presented in Table 1 that the available nitrogen, phosphorus, potassium and sulphur (290, 34.45, 443 and 22.77 kg ha^{-1}) was recorded with application of 60 kg P_2O_5 ha^{-1} over application of 20 kg P_2O_5 ha^{-1} (281, 25.07, 430 and 19.51 kg ha^{-1}) and control (270, 16.86, 416 and 16.09 kg ha^{-1}). However, it was found at par with 40 kg P_2O_5 ha^{-1} (285, 33.28, 438 and 21.97 kg ha^{-1}) in soil after harvest of crop. The phosphorus application may be helpful in improving the soil health in terms of available nutrients. Similar findings have been also reported by (Taliman *et al*., 2019). The nitrogen, phosphorus and potassium uptake improved remarkably by application of phosphorus. Available phosphorus status of soil after crop harvest also improved with the use of phosphorus. Hence, application of 50 kg phosphorus ha^{-1} and phosphorus solubilizing bacteria culture are recommended for better yield of green gram in Nagaland. (Nusakho *et al*., 2015).

Effect of sulphur on soil nutrient status

The maximum available nitrogen, phosphorus, potassium and sulphur (285, 29.50, 433 and 23.05 kg ha^{-1}) was recorded with application of 45 kg sulphur ha^{-1} over application of 15 kg sulphur ha^{-1} (279, 24.43, 426 and 16.66

kg ha^{-1}) in soil after crop harvest (Table 1.0).However, it was found at par with application of 30 kg sulphur ha^{-1} (282, 28.32, 429 and 20.56 kg ha^{-1}). These results are conformity with the findings of Meena *et al*. (2011). The above results revealed that sulphur doses increased sulphur availability in soil after harvest of soybean. Similar findings are also reported by (Asisan *et al*., 2017), who reported that application of sulphur significantly increased the sulphur availability in soil after the harvest of soybean.

Effect of gibberellic acid on available soil nutrients

A reference data revealed that foliar spray of GA_3 @ 75 ppm was did not significantly influence available nitrogen, phosphorus, potassium and sulphur in soil after crop harvest. The available nitrogen, phosphorus, potassium and sulphur (kg ha^{-1}) in soil after crop harvest was found numerically higher with application of foliar spray of GA_3 @ 75 ppm over control. The increase available nutrient content in soil due to gibberellic acid is attributed due to addition of more organic matter in soil in the form of litter fall and fine root biomass as well as the fixing atmospheric nitrogen by soybean reported by Sharma *et al*. (2009). As the organic anion exudation and acidic phosphatase activity of soybean roots was found mobilization of phosphorus by foliar spray of GA_3 (Sharma *et al*., 2009).

CONCLUSION

It is concluded that the application of 40 kg phosphorus ha^{-1} and 30 kg sulphur ha^{-1} is suitable dose for obtaining higher nutrient content and uptake of soybean crop. Hence this dose of phosphorus and sulphur is proved as beneficial for enhancing the sustainable production of soyabean. The foliar spray of gibberellic acid @ 75 ppm is also beneficial for soybean crop.

REFERENCES

Aftab, T., Khan, M., Idrees, M., Naeem, M. and Moinuddin. (2010). Salicylic acid acts as potent enhancer of growth, photosynthesis and artemisinin production in *Artemisia annua* L. Journal of Crop Science and Biotechnology. 13: 183-188.

Amba, A.A., Agbo, E.B., Voncir, N. and Oyawoye, M.O. (2011). Effect of phosphorus fertilizer on some soil chemical properties and nitrogen fixation in legumes. Contemptory Journal of Agriculture Science. 5: 39-44.

Anonymous, (2020). Directorate of Economics and Statistics, Govt. of India, New Delhi.pp.75.

Asisan, M., Kuldeep, K. and Shashi, B.K. (2017). Effect of sulphur on growth, yield, nutrient content, uptake and oil content in linseed. Bulletin of Environment Pharmacolation Life Science. 6: 274-277.

Black, C.A. (1965). Methods of Soil Analysis. American Society of Agronomy, Madison, Wisconsin, USA.

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* (L.) Merrill] under upland conditions. Journal of Agriculture Science. 4: 1-10.

Dhage, S.J., Patil, V.D. and Patange, M.J. (2014). Effect of various level of phosphorus and Sulphur on yield, plant nutrient content, uptake and availability of nutrient at harvest stages of soybean. International Journal of Current Microbiology and Applied Science. 3: 833-844.

Fazli, I.S., Abdin, M.Z., Jamal, A. and Ahmad, S. (2005). Interactive effect of sulphur and nitrogen on lipid accumulation, acetyl-CoA concentration and acetyl-CoA carboxylase activity in developing seeds of oilseed crops (*Brassica campestris* L. and *Eruca sativa* Mill.). Plant Science. 168: 29-36.

Gomez, K.A. and Gomez, V.A. (1984). Statistical Procedure for Agriculture Research. John Wiley and Sons Inc., New York, USA.

Gonyane, M.B. and Sebetha, E.T. (2022). The effect of plant density, zinc added to phosphorus fertilizer sources and location on selected yield parameters of soybean. Legume Research-An International Journal. 45: 196-202.

Jadon, C.K., Dashora, L.N., Meena, S.N. and Singh, P. (2019). Growth, yield and quality of soybean [*Glycine max* (L.) Merr.] as influenced by weed management and fertility levels in vertisols of SE Rajasthan. International Journal of Bio-resource and Stress Management. 10: 177-180.

Jayapaul, P.K., Vairaran, P.S. and Ramiah, S. (1987). Effect of *Azospirillum,* boron and Gibberellic acid on seed yield and quantities of sun flower under grade level of nitrogen. Seed and Fram. 13: 33-35

Kanwar, J.S. and Mudahar, M.S. (1986). Fertilizer sulphur and food production. MartinusNijhoff/Dr W. Junk Publisher, Dordrecht pp.247.

Layek, J. and Shivakumar, B.G. (2009). Effect of sulphur and boron nutrition on nutrient uptake and quality of soybean [*Glycine max* (L.) Merrill]. Journal of Oilgrains Research. 26: 369-371.

Meena, D.S., Ram, B. and Tetarwal, J.P. (2011). Productivity, quality and profitability of soybean (*Glycine max* L.) as influenced by sulphur and boron nutrition. Soybean Research. 9: 103-108.

Meseret, T. and Amin, M. (2014). Effect of different phosphorus fertilizer rates on growth, dry matter yield and yield components of common bean (*Phaseolus vulgaris* L.). World Journal of Agriculture Research. 2: 88-92.

Mugendi, D., Mucheru, M., Pypers, P., Mugwe, J., Kungu, J., Vanlauwe, B. and Roel, M. (2010). Maize Productivity as Influenced by Organic Inputs and Mineral Fertilizer in a Nitisol Soil in Meru South District. 19th World Congress of Soil Science, Soil Solutions for a Changing World. 1-6 August, 2010, Brisbane, Australia.

Nusakho, N., Sharma, Y.K., Sharma, S.K. and Gupta, R.C. (2015). Influence of phosphorus and phosphorus solubilizing bacteria on performance of green gram and soil properties. Annals of Plant and Soil Research. 17: 323-325.

Olsen, S.R., Cole, C.V., Watanable, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. United State Department of Agriculture, cir. No. 939, Washington 19-33.

Pal, P., Yadav, K., Kumar, K. and Singh, N. (2016). Effect of gibberellic acid and potassium foliar spray on productivity and physiological and biochemical parameters of parthenocarpic cucumber cv. 'seven star F_1'. Journal of Horticulture Research. 24: 93-100.

Piper, C.S. (1950). Soil and Plant Analysis, New York, Academic Press.

Ravi, S., Jadhav, R.L. and Sidramappa (2017). Response of soybean to sulphur and boron nutrition in Northern Karnataka. International Journal of Current Microbiology and Applied Science. 6: 3426-3432.

Sharma, O.P. and Singh, G.D. (2005). Effect of sulphur in conjunction with growth substances on productivity of cluster bean and their residual effect on barley. Indian Journal of Agronomy. 50: 16-28.

Sharma, K.L., Ramachandra, R.K., Das, S.K., Prasad, R.B.R.C., Kulkarni, B.S., Srinivas, K., Kusuma, G.J., Madhavi, M. and Gajbhiye, P.N. (2009). Soil fertility and quality assessment under tree-crop and pasture-based land-use systems in a rainfed environment. Communication in Soil Science and Plant Analysis. 40: 1436-1461.

Solomani, A., Sivakumar, C., Anbumani, S., Suresh, T. and Arumugam, K. (2001). Role of plant growth regulators on rice production: A review. Agriculture Review. 23: 33-40.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for determination of available nitrogen in soils. Current Science. 25: 259-260.

Suman, J., Uhlik, O., Viktorova, J. and Macek, T. (2018). Phytoextraction of heavy metals: A promising tool for clean-up of polluted environment. Frontiers in Plant Science. 9: 1476. https://doi.org/10.3389/fpls.2018.01476.

Taliman, N.A., Dong, Q., Echigo, K., Raboy, V. and Saneoka, H. (2019). Effect of phosphorus fertilization on the growth, photosynthesis, nitrogen fixation, mineral accumulation, seed yield and seed quality of a soybean low-phytate line. Plants. 8: 1-13.

Thakur, H.S., Raghuwanshi, S.R.H. and Raghuwanshi, O.P.S. (2009). Integrated nutrient management in soybean [*Glycine max* (L) Merrill]. Soybean Research. 7: 16-20.