E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2024; SP-7(8): 166-168
Received: 14-06-2024
Accepted: 19-07-2024

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Effect of sulphur and sulphur solubilizing bacteria on yield, yield attributes and quality of *Kharif* groundnut

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DOI: https://doi.org/10.33545/2618060X.2024.v7.i8Sc.1247

Abstract
In order to evaluate the effects of different combinations of sulphur and sulphur solubilizing bacteria on yield and yield attributes, quality of *Kharif* groundnut (var. GJG 22), a field experiment was conducted on medium black calcareous soil at Cotton Research Station, Junagadh Agricultural University, Junagadh during *Kharif* seasons of 2019. The results revealed that the application of S @ 30 kg ha^{-1} significantly increased the plant height, number of branches, number of nodules, number of pegs, number of mature pods, number of total pods, shelling percentage, test weight, oil percentage, pod and haulm yield over the control plot treatment. The application of 1.5 lit SSB ha^{-1} produced significantly favourable effect on plant height, number of branches, number of nodules, number of pegs, number of mature pods, pod and haulm yield over the control. However, shelling percentage, test weight, oil and protein percentage did not influence by SSB application.

Keywords: Groundnut, sulphur, SSB, yield and quality

Introduction
Groundnut (*Arachis hypogaea* L.) is native of Brazil in South America. Groundnut is an important oilseed crop and is a rich source of edible oil and vegetable protein. The area under groundnut grown in India is 39 M ha and production is 68 million MT with the average productivity of 1745 kg/ha (Anon., 2019) [1]. Sulphur is considering fourth major essential plant nutrient after nitrogen, phosphorus and potassium. The transfer of sulphur between the inorganic and organic pool is entirely caused by the activity of the soil biota particularly the soil microbial biomass, which has the greatest potential for both mineralization and also for subsequent transformation of the oxidation state of sulphur. *Thiobacillus* play an important role in sulphur oxidation in soil. Sulphur oxidation is the most important step of sulphur cycle, which can be used by the plants, while the acidity produced by oxidation helps in solubilizing plant nutrients and improves alkali soils (Vidyalakshmi *et al*., 2009) [8]. No work has so far been done on effect of sulphur and sulphur solubilizing bacteria on yield of groundnut particularly in this region. Keeping this in view, this study was taken to know the effect of sulphur and sulphur solubilizing bacteria on yield, yield attributes and quality of groundnut.

Materials and Methods
A field experiment was conducted on medium black soil at Cotton Research Station, Junagadh Agricultural University, Junagadh, during *Kharif* 2019 with groundnut (*Arachis hypogaea* L. var. GJG-22). The soil had pH 7.8 and $EC_{2.5}$ 0.33 dSm^{-1}, available N (237.0 kg ha^{-1}), P_2O_5 (36.2 kg ha^{-1}) and S (17.5 ppm). The treatments consisted four levels of S (0, 10, 20 and 30 kg ha^{-1}) and three levels of SSB (0, 1.5 and 3 lit ha^{-1}) in Factorial Randomized Block Design with triplicate replications. Sulphur in the form of gypsum was applied as basal and SSB was applied by drenching at the time of sowing. Recommended dose of N, P_2O_5 and K_2O applied in the form of urea, DAP and KCl, respectively as basal. The groundnut var.GJG-22 was sown by drilling at row spacing of 60 cm. At maturity, pod and haulm yield data were recorded. The oil content of kernels was determined by non-destructive method using Nuclear Magnetic Resonance

Spectrophotometer as suggested by Tiwari *et al.* (1974) [7]. The protein content of kernels was worked out by multiplying nitrogen content in seeds with the factor of 6.25 as reported by A.O.A.C (1965) [2].

Results and Discussion

The results obtained from the present investigation are presented in Table 1 and 2.

Effect of sulphur

The data presented in Table 1 indicated that pod and haulm yield of groundnut were significantly influenced by various levels of sulphur. The higher pod (2213 kg ha^{-1}) and haulm (2832 kg ha^{-1}) yields were recorded with treatment of 30 kg S ha^{-1}, which was 13.7 and 16.4 per cent higher, respectively over control (S_1). Yield attributes were also significantly influenced by sulphur application. Among the different levels of sulphur, application of sulphur @ 30 kg ha^{-1} gave significantly the highest plant height (41.37 cm), number of branches (6.92), number of nodules (79.09), number of pegs (30.77), number of mature pods (13.44), number of total pods (17.59), shelling percentage (71.82%) and test weight (47.98 g). The response of crop to applied sulphur might be attributed to metabolic processes enhancement in the plant cell, resulted increased meristamatic activities causing more apical growth and plays vital and important role in energy storage and transformation, carbohydrate metabolism and activation of enzymes also increase the photosynthetic activity of plant and enhances nodulation and nitrogen fixation in groundnut and also sulphur is involved in the formation of sulphur containing amino acids, vitamins and has direct role in root growth and nodulation. Similar results were also observed by Rao *et al.* (2013) [4] and Pancholi *et al.* (2017) [3] in case of groundnut. However, oil percentage and protein content did not influence by sulphur application.

Table 1: Effect of sulphur and sulphur solubilizing bacteria on yield, yield attributes and quality parameters of *Kharif* groundnut

Treatments	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Plant height (cm)	No. of branches per plant	No. of nodules/ plant at 45 DAS	No. of pegs/ plant at 75 DAS	No. of mature pods/plant	No. of immature pods/plant	Total pods/plant	Shelling (%)	Test weight (g)	Oil content (%)	Protein content (%)
Sulphur levels (kg S ha^{-1})													
S_1 -0	1946	2434	35.94	6.01	68.98	24.78	11.10	2.37	13.46	67.66	43.97	49.23	25.18
S_2 -10	2029	2559	37.14	6.24	75.16	25.70	12.02	3.29	15.31	70.71	44.16	50.14	26.66
S_3 -20	2208	2805	39.61	6.70	78.48	30.07	13.14	4.19	17.32	71.42	45.73	50.30	27.61
S_4 - 30	2213	2832	41.37	6.92	79.09	30.77	13.44	4.14	17.59	71.82	47.98	50.81	27.83
S.Em.±	64.0	70.53	0.77	0.21	1.60	0.83	0.264	0.083	0.407	1.01	0.99	0.87	0.77
C.D. at 5%	188	207	2.28	0.63	4.70	2.58	0.775	0.243	1.193	2.95	2.92	NS	NS
SSB levels (lit SSB ha^{-1})													
SSB_1 - 0	1981	2529	36.87	6.06	70.22	26.18	11.91	3.35	14.21	70.33	45.26	49.89	26.53
SSB_2 - 1.5	2173	2746	39.56	6.72	78.41	28.93	12.76	3.62	16.76	70.52	45.63	50.10	26.98
SSB_3 - 3	2143	2698	39.10	6.63	78.33	28.38	12.62	3.53	16.79	70.35	45.49	50.38	26.95
S.Em.±	55.5	61.1	0.67	0.19	1.39	0.76	0.23	0.07	0.35	0.87	0.86	0.76	0.67
C.D. at 5%	163	179	1.97	0.55	4.07	2.24	0.67	0.21	1.03	NS	NS	NS	NS
Interaction (S x SSB)													
S.Em.±	111	122	1.34	0.37	2.77	1.52	0.457	0.144	0.705	1.745	1.722	1.51	0.341
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Effect of sulphur and SSB levels on soil available nutrients at different stages of groundnut

Treatment	Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})		Available S (ppm)	
	45 DAS	At harvest	45 DAS	At harvest	45 DAS	At harvest	45 DAS	At harvest
Sulphur levels (kg S ha^{-1})								
S_1 – 0	239	216	33.70	27.43	278	262	17.11	15.94
S_2– 10	251	224	34.49	29.77	281	266	17.99	16.82
S_3 – 20	263	233	37.78	31.29	287	269	19.95	17.85
S_4 – 30	266	239	39.94	33.39	289	269	20.49	18.38
S.Em.±	7.55	10.65	1.73	1.51	5.00	7.34	0.60	0.55
C.D. at 5%	NS	NS	NS	NS	NS	NS	1.77	1.61
SSB levels (lit SSB ha^{-1})								
SSB_1 – 0	244	224	34.43	29.35	280	266	17.23	15.68
SSB_2 – 1.5	252	229	37.04	31.32	286	267	19.99	18.07
SSB_3 – 3	267	231	37.97	30.74	286	267	19.44	18.00
S.Em.±	6.54	9.23	1.50	1.30	4.33	6.35	0.52	0.47
C.D. at 5%	NS	NS	NS	NS	NS	NS	1.53	1.39
Interaction (S x SSB)								
S.Em.±	13.07	18.45	2.99	2.61	8.67	12.71	1.05	0.95
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS

NS=Non –significant

Effect of Sulphur Solubilizing Bacteria

The yield and yield attributes of groundnut were significantly influenced by application of sulphur solubilizing bacteria (Table-1). Among the different levels of SSB, yields (pod and haulm), yield attributes (plant height, number of branches, number of nodules, number of pegs and number of mature pods) of groundnut were associated higher with application of SSB @ 1.5 li ha^{-1}. However, the shelling per cent and test weight in

kernel did not affect significantly by SSB application. Significantly higher pod (2173 kg ha^{-1}) and haulm (2746 kg ha^{-1}) yield was recorded with 1.5 l ha^{-1} SSB. The magnitude of increase in pod and haulm yield was 9.69 and 8.58 per cent, respectively which compared to control (SSB_1). The response of crop to applied SSB in the present study may be attributed to the fact that sulphur oxidizing bacteria enhanced the rate of natural oxidation of sulphur and production of sulphates and makes them available to plants at their critical stages of growth, resulting in increasing plant yield. These results are in accordance with the findings of Shinde and Jadav (2002) [6] in case of groundnut and Shinde *et al.* (2000) [5] in case of cotton. However, oil and protein content did not influence by SSB application.

Available nutrients status in soil

The available sulphur content in soil increased significantly with increasing levels of sulphur and SSB application at 45 DAS and harvest of groundnut (Table 2). The highest soil available sulphur was found with 30 kg S ha^{-1} and SSB 1.5 lit ha^{-1} application at 45 DAS and harvest of groundnut, respectively. The application of S and SSB was not found significant in case of soil available N, P_2O_5 and K_2O.

Conclusion

In conclusion, the study demonstrates that both sulphur (S) and sulphur solubilizing bacteria (SSB) significantly impact the yield and growth attributes of groundnut (*Arachis hypogaea* L. var. GJG-22). Application of 30 kg S ha^{-1} notably enhanced pod and haulm yields, as well as key yield attributes like plant height and number of pods. Similarly, SSB at 1.5 l ha^{-1} improved pod and haulm yields, likely by boosting the availability of sulphates through enhanced natural oxidation. Although sulphur and SSB treatments did not significantly affect oil or protein content, they substantially increased soil available sulphur, optimizing nutrient availability for groundnut cultivation.

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