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Sulphur Solubilizes on Various Soil Properties at Growth Stages of Groundnut under Vertisol

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Abstract

Effect of sulphur solubilizing bacteria on sulphur fraction at critical growth stage of groundnut crop showed significant and highest values while pH, EC, $CaCO_3$ content of soil does not change significantly. It had statistically non-significant responses with treatment administered, while organic carbon content increased significantly. The available NPKS status of soil increased significantly and recorded maximum 270, 255 and 251 kg ha^{-1} of available N 14.23,18.63,20.48 kg ha^{-1} of available P and 754,726 and 723 kg ha^{-1} of available K during 40,80 DAS and harvest stage of groundnut respectively with use of T_7 (100% RDF + FYM @10 Mg ha^{-1} + 10 kg E.S. ha^{-1}+S.S. B). The experiment was conducted with eight treatments which include 100% RDF, 75% RDF, elemental sulphur @10 and 20Kg ha^{-1} FYM @5 and 10 Mg ha-1 and sulphur solubilizing bacteria. The experiment was laid out in complete randomized design (CRD) and replicated thrice. *Thiobacillus thiooxidants* used as sulphur oxidizing bioinoculants. The sowing was done by dibbling method on monsoon crop season and fertilizer in calculated amount was given at the time of sowing, while sulphur oxidizing bioinoculants also applied at the same time and soil samples were collected at 40,80 DAS and at harvest stage of crop. Collected soil sample were dried, well ground and sieved through 2mm sieves and stored in polyethylene bags. Soil samples were analyzed for pH, EC, $CaCO_3$, organic carbon, available NPK and sulphur. Plant samples were collected during 40, 80 DAS and at harvest stages of crop and analyzed. The results emerged out in this experiment indicated that the pH, EC, CaCO3were non-significant, while there was significant increase in available NPKS, in treatment T_7 (100% RDF + FYM @10 Mg ha^{-1} +10 kg E.S. ha^{-1} + S.S.B) Similarly, kernel yield of groundnut was also significantly increased with inoculation of sulphur oxidizing bacteria along with elemental sulphur and FYM 10 t ha-1. Significant highest values were recorded in treatment T_7 with liquid inoculants and found to be at par with T_6 and T_8 treatments. Further, content and uptake of major (NPK) and secondary (S) nutrient improved with sulphur oxidizing bacteria showing better results in inoculation with 100% RDF+FYM @10 Mg ha^{-1} +10Kg ha^{-1} elemental sulphur.

Keywords: *Sulphur, SOB (Thiobacillus thiooxidants), Sulphur fraction, Groundnut etc.*

Introduction

Groundnut is important crop 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 an excellent health food and contains 40% quality protein, 23% carbohydrates and 20% cholesterol free oil. Groundnut protein is rich in valuable amino acid viz., lysine (5%) which is deficient in most of the cereals. It also contains 60% poly unsaturated fatty acid (52.8% linoleic acid +7.2% linolenic acid). It has high calorific value releasing 432 calories from 100 gm edible protein as compared to 350 calories from cereal of same quantity (Sreemannarayana *et al.,* 2018).

A large part of sulfur is biologically oxidized in the soil (Tabatabai,1986). Parameters affecting the P availability of rock phosphate when used in combination with elemental sulfur include the type of rock phosphate, the ratio of rock phosphate to elemental sulfur and crop and soil conditions.

Elemental sulfur must be inoculated with Thiobacillus to enhance the P solubility of apatite and hence plant biomass (Rasool, 2021). Sulphur is now being recognized as the fourth major nutrient in addition to nitrogen, phosphorus, potassium and sulphur. The deficiency of sulphur in soil and plant is being reported from several parts of the country and also in Maharashtra on Marathwada regions. Crop generally requires as much sulphur as they need phosphorus.

Groundnut (*Arachis hypogaea* L.) is one of the most important oilseed crops in India, known as the "King of Oilseeds". It is a major source of edible oil and protein for human nutrition and its haulms serve as valuable fodder. Groundnut is particularly sensitive to sulphur nutrition because sulphur is a constituent of essential amino acids like cysteine, cystine and methionine, and plays a vital role in oil synthesis, chlorophyll formation and nitrogen fixation through enhanced nodule formation. In India, especially in Maharashtra, a large area of groundnut is grown on Vertisols, which are clayey, swell-shrink soils characterized by high cation exchange capacity, calcareous nature and often low to medium availability of sulphur due to continuous cropping without sulphur replenishment. Vertisols present unique soil chemical dynamics where sulphur availability is highly influenced by pH, calcium carbonate content, organic matter and microbial activity. Application of sulphur through different sources like Gypsum, Elemental Sulphur, and Bentonite Sulphur solubilizes at different rates and consequently alters various soil properties such as soil pH, EC, organic carbon, available N, P, K, S and micronutrient status at different critical growth stages of groundnut viz., flowering, pegging and pod development. Understanding the pattern of sulphur solubilization and its interaction with soil properties during these stages is essential for optimizing fertilizer scheduling, improving nutrient use efficiency and sustaining soil health. Hence, the present investigation on "Effect of Sulphur Solubilization on Various Soil Properties at Growth Stages of Groundnut under Vertisol" was undertaken to assess the dynamics of soil fertility in relation to sulphur sources and groundnut growth (Singh *et al.,* 2019 & Sawarkar *et al.,* 2017).

MATERIAL AND METHODS

A pot culture experiment was conducted in monsoon crop season. This pot culture experiment was laid out by using completely randomized design (CRD) with three replications with eight treatments. The Groundnut was sown by dibbling method with two or five seed per pots. Organic manures *i.e.* FYM was applied at the rate of FYM @ 10 Mg ha^{-1}; N, P, K @ 25:50:0 kg ha^{-1} were applied through urea (46%), Di-ammonium phosphate (18%) and MOP (60%) as per treatment. Soil samples were collected from each pot at the time of sowing after 40 days of at pod formation stage on at the time of harvesting. The collected soil samples were thoroughly mixed and brought to the laboratory, air dried, ground with wooden mortar and pestle and sieved through 2 mm sieve, for analyzing. (Soil pH, Soil EC (dSm1), Organic carbon, Calcium carbonate, Available Nitrogen, Available Phosphorus, Available Potassium, Available Sulphur).

RESULT AND DISCUSSION

Effect of Sulphur Solubilizers on Different Soil Properties at Various Growth Stages of Groundnut Grown Under Vertisol.

Soil pH

The data pertaining to soil pH at different growth stages of groundnut as influenced by Sulphur solubilizing bacteria with and without FYM presented in Table 1. The data reveals that soil pH was varied, at 40,80 DAS and at harvest stage of the crop growth. However, these values at all the growth stages were found statistically, non-significant with administration of different treatment.

Soil EC (dSm-1)

Electrical conductivity of soil was found to be in normal range at 40, 80 DAS and at harvest stage of crop growth, in Table1. The response of electrical conductivity was found non-significant at all stages of crop growth.

Organic carbon (%) content in Soil

The data presented in Table 1 revealed that the organic carbon (OC) values of soil at different stages were significantly influenced with application of various treatments. The value of organic carbon content varied from 0.22-0.57, 0.25-0.55 and 0.27-0.53 % at 40, 80 DAS and at harvest stage respectively. The significant and highest value of organic carbon 0.57 and 0.55 and 0.53% was recorded at 40, 80 DAS and at harvest stage respectively with use of 100% RDF + FYM @ 10Mg ha^{-1} +10kg E.S. ha^{-1} + S.S.B. (T_7) treatment which was followed by T8 (100% RDF + FYM @ 5Mg ha^{-1} +10kg E.S. ha^{-1} + S.S.B.) The lowest value was found with application of T_1 treatment. The organic carbon content of soil increased significantly and attended maximum value in the treatment that received 100% NPK along with FYM, which was due to increased contribution from the biomass added; it is also observed that with increased level of fertilizer application the crop yield was increased. Hence lowest value of organic carbon 0.22,

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0.25, and 0.27, during 40,80 DAS at harvest stage respectively was recorded with use of T_1 (100% RDF) Similar findings were reported by (Das *et al.,* 2021) in rapeseed and (Ibrahim *et al.,* 2023) in pepper plant, they reported that with addition of biomass through FYM and plant debris increased the content of organic carbon in soil.

Calcium carbonate in soil

The data pertaining to soil $CaCO_3$ influenced by sulphur solubilizing bacteria on sulphur fraction with and without FYM is presented in Table 1. The data showed that $CaCO_3$ values recorded at 40, 80 DAS and at harvest stage were statistically non-significant.

Available N content in soil

The data narrated in Table 2 revealed that sulphur solubilizing bacteria on sulphur fraction with and without FYM had significant influence on available nitrogen content of soil. Available N content in soil at various crop growth stage showed that the N content was significantly influenced with use of various treatments. The available N content was ranged from 217-270, 203-255 and 198-251 kg ha^{-1} during 40,80 DAS at harvest stage of groundnut crop respectively. Available nitrogen content of soil at 40,80 DAS and harvest stage of groundnut crop was noticed significantly highest in treatment T_7 (100% RDF + FYM @10 Mg ha^{-1} +10 kg E.S. ha^{-1} + S.S.B) which was found at par with treatment T_8 (100% RDF + FYM@5 Mg ha^{-1} +10 kg E.S. ha^{-1} +S.S.B.) and T_6 (100% RDF + FYM@5 Mg ha^{-1} +S.S.B.) respectively, however lowest value 217, 203 and 198 kg ha^{-1} was noticed in absolute control treatment T_1 (100% RDF), at above growth stages respectively. Integrated use of sulphur and FYM significantly influenced the available N status of soil. The availability of N might be increased due to enhancement of the process of mineralization and nitrification with addition of FYM and sulphur solubilizing bacteria, more over sulphur had synergetic relation with available N in soil (Jamal *et al.,* 2019). This interrelated process had complementary effect on availability of N. These results are in continuity with the finding of (Hussain *et al.,* 1999). Combined application of 45/60 kg sulphur either along with 1.5 - 3.0 t FYM ha^{-1} recorded the highest content of available nitrogen and sulphur in soil and resulted an improvement of 13 to 16 kg of available N and 16.6 to 19.9 kg of available sulphur over initial level this improvement might be due to the direct addition of N through FYM and chemical fertilizer reported by (Singh *et al.,* 2006) and it is accredited to the findings of (Amit, *et al.,* 2022) in Soybean, (Anwar, *et al.,* 2022) and (Alam, *et al.,* 2021). The process of mineralization and nitrification with the addition of FYM and Sulphur oxidizing bacteria.

Available phosphorus content in soil

The data presented in Table 2 revealed that the available phosphorus content was significant influenced with application of FYM, elemental sulphur and sulphur solubilizing bacteria in groundnut crop. Available phosphorus status ranges from 10.61 - 14.23, 11.35 - 18.63 and 12.58 - 20.48 kg ha^{-1} of soil at 40, 80 DAS and at harvest stage of groundnut crop respectively. The significant highest values were recorded in treatment T_7 (100% RDF + FYM @10 Mg ha^{-1} + 10 kg E.S. ha^{-1} + S.S.B) the value were 14.23, 18.63 and 20.48 kg ha^{-1} at 40,80 DAS and at harvest stage of groundnut crop. While the lowest value was observed at T_1 (100% RDF), and then values were recorded as 10.61, 11.35 and 12.58 Kg ha^{-1} at 40, 80 DAS and at harvest stage respectively. FYM + Thiobacillus had complementary effect on availability of P in the soil. There effect clearly exhibit in availability and uptake of P. (Geetha, *et al.,* 2020) Similarly (Balloei, *et al.,* 2023) reported that Thiobacillus increased oxidation of sulphur and decreased soil pH and increases solubility of fixed P in soil further (Patgiri and Baruah, 1993), observed the availability of P is increased up to 30 Kg sulphur ha^{-1} beyond which its availability decreased indicating that P exhibits a advances effect on availability might be ascribed to the negative interaction between the elements. Similar observation was reported by (Heydarnehad, *et al.,* 2020) in calcareous soil sulphur oxidizing bacteria increased the availability of P, Fe and Zn. FYM and Sulphur oxidizing bacteria effect of phosphorus in soil, Sulphur oxidizing bacteria use that time are increased sulphur and decreased with soil pH that time increased in soil phosphorus.

Available potassium content in soil

The data on available potassium content in soil was significant influenced was the use of FYM, elemental sulphur and sulphur solubilizing bacteria revealed in Table 2. The data revealed that content of available potassium were ranged between 526-754, 532-726 and 523-723 kg ha^{-1} during 40, 80 DAS and at harvest stage of groundnut crop. Significant and maximum available potassium was 754, 726, 723 kg ha^{-1} noticed at 40, 80DAS and harvest stage with the use of T_7 (100% RDF + FYM @10 Mg ha^{-1} + 10 kg E.S. ha^{-1} + S.S.B) treatment. Which was followed by

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T_6 (100% RDF + FYM@5 Mg ha^{-1} + S.S.B.) respectively, however lowest content of available K noticed in absolute control treatment T_1 (100% RDF). Available K content in soil was increased with addition of FYM + Thiobacillus in all stage of crop growth. Combination with 10 kg elemental sulphur per hectare further enhancement in available K. This result was because of complementary effect of FYM + Thiobacillus on sulphur and other nutrient availability (Geeta, *et al.,* 2009). Available potassium a declining trend (173 to 179 kg ha^{-1}) from improvement of 4 and 5 kg ha^{-1} over initial value was recorded with 45 kg sulphur application of along with FYM either 1.5 to 3.0 t ha^{-1}. Similarly, a slight improvement of 1 and 2 kg ha^{-1} was also recorded with combined application of 30 kg sulphur along with FYM either 1.5-3.0 t ha^{-1}. This improvement might be due to the beneficial effect of application of FYM along with inorganic fertilizer, Similar finding was reported by (Thakur, *et al.,* 2011; Rasool, 2021) in *Raphanus sativa*. Available potassium content in soil was increased with addition of FYM and sulphur oxidizing bacteria all stages of crop growth.

Available sulphur (ppm) in soil

The data Table 2 showed that the available sulphur of soil was affected with administration of various treatments of elemental sulphur and sulphur solubilizers with and without FYM. The values of available sulphur content varied from 10.56 - 20.90, 10.27 - 15.10 and 10.09 - 14.83 ppm at 40, 80 DAS and at harvest stage of groundnut crop. available sulphur content of soil at 40,80 DAS and harvest of groundnut crop was noticed significantly highest and that values were 20.90, 15.10 and 14.83 ppm respectively in treatment T_7 (100% RDF + FYM @10 Mg ha^{-1} +10 kg E.S. ha^{-1} + S.S.B) was found at par with treatment T_8 (100% RDF + FYM@5 Mg ha^{-1} +10 kg E.S. ha^{-1} +S.S.B.) and T_6 (100% RDF + FYM@5 Mg ha^{-1} +S.S.B.) respectively. Whereas lowest value was noticed in absolute control treatment T_1 (100% RDF). No regular trend, soil may be of leaching upon rainfall/irrigation and 10ppm critical limit in soil.

Conclusion

Sulphur solubilization improves sulphur availability and nutrient dynamics in Vertisol under groundnut cultivation. Soil properties such as pH, electrical conductivity, organic carbon and available sulphur influence sulphur availability. Sulphur availability and soil nutrient status vary at different growth stages of groundnut. Improved sulphur availability supports better plant growth, nodulation, pod development and yield.

Therefore, effective sulphur management is essential for improving soil fertility and groundnut productivity in Vertisols.

Table No 1. Effect of Sulphur Solubilizers on Various Soil Properties at Growth Stages of Groundnut Under Vertisol

Tr. No.	Treatments	P^H			EC (dSm^{-1})			Organic Carbon (%)			Free Calcium Carbonate (%)		
		Sampling period (DAS)			Sampling period (DAS)			Sampling period (DAS)			Sampling period (DAS)		
		40	80	At Harvest	40	80	At Harvest	40	80	At Harvest	40	80	At Harvest
T_1	100% RDF	7.32	7.01	7.03	0.25	0.2	0.21	0.22	0.25	0.27	6.7	6.97	4.33
T_2	100% RDF + S.S.B.	7.59	7.36	7.33	0.28	0.22	0.22	0.22	0.27	0.27	7.23	5.87	6.1
T_3	100 % RDF + 20 kg E.S. ha^{-1}+ S.S.B.	7.61	7.36	7.23	0.26	0.22	0.22	0.27	0.22	0.36	5.47	5.1	5.27
T_4	100 % RDF + 10 kg E.S. ha^{-1}+S.S.B.	7.66	7.43	7.36	0.26	0.24	0.25	0.35	0.36	0.41	7.57	6.33	5.17
T_5	75 % RDF + FYM @10 Mg ha^{-1}+S.S.B.	7.57	7.37	7.31	0.27	0.25	0.25	0.47	0.45	0.44	6.7	5.83	4.07

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T_6	100 %RDF + FYM @10 Mg ha^{-1}+ S.S.B	7.6	7.35	7.35	0.25	0.24	0.24	0.52	0.49	0.48	5.57	7	6.93
T_7	100% RDF + FYM @10 Mg ha^{-1}+10 kg E.S. ha^{-1}+S.S.B.	7.98	7.46	7.41	0.28	0.27	0.28	0.57	0.55	0.53	6.37	6.3	2.77
T_8	100% RDF + FYM@5 Mg ha^{-1}+10 kg E.S. ha^{-1}+S.S.B.	7.97	7.25	7.25	0.27	0.26	0.26	0.55	0.52	0.51	5.93	7.33	4.27
	SE(m)	**0.35**	**0.25**	**0.24**	**0.018**	**0.015**	**0.014**	**0.013**	**0.012**	**0.11**	**0.98**	**0.47**	**1.31**
	CD @ 1%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.039**	**0.037**	**0.035**	**NS**	**NS**	**NS**

Table No 2. Effect of Sulphur Solubilizers on Various Soil Properties at Growth Stages of Groundnut Under Vertisol

Tr. No.	Treatments	Available Nitrogen (kg ha^{-1})			Available Phosphorus (kg ha^{-1})			Available Potassium (kg ha^{-1})			Available Sulphur (ppm)		
		Sampling period (DAS)			Sampling period (DAS)			Sampling period (DAS)			Sampling period (DAS)		
		40	**80**	**At Harvest**	**40**	**80**	**At Harvest**	**40**	**80**	**At Harvest**	**40**	**80**	**At Harvest**
T_1	100% RDF	217.4	203.8	198.6	10.61	11.35	12.58	526.9	532.5	523.1	10	10	10
T_2	100% RDF + S.S.B.	228.9	214.2	210.1	10.5	11.47	12.58	584.7	579	569.9	12	11	10
T_3	100 % RDF + 20 kg E.S. ha^{-1}+ S.S.B.	234.1	228.9	211.1	10.36	12.53	13.59	622.1	524	514.2	11	11	10
T_4	100 % RDF + 10 kg E.S. ha^{-1}+ S.S.B.	243.5	220.5	222.6	11.74	14.53	15.47	537.9	616.8	599.4	12	12	11
T_5	75 % RDF + FYM @10 Mg ha^{-1} + S.S.B.	247.7	218.4	233.1	12.93	14.91	16.06	674.1	668.9	655.6	15	12	12
T_6	100 %RDF + FYM @10 Mg ha^{-1} + S.S.B.	255	238.9	240.4	13.75	15.59	17.73	740.5	715.2	707.3	19	13	13
T_7	100% RDF + FYM @10 Mg ha^{-1} +10 kg E.S. ha^{-1}+S.S.B.	270.7	255	251.9	14.23	18.63	20.48	754.9	726.8	723	20	15	14
T_8	100% RDF + FYM@5 Mg ha^{-1} +10 kg E.S. ha^{-1} + S.S.B.	265.5	242.3	245.6	14.08	17.77	18.89	743.6	720.3	715.7	18	14	13
	SE(m)	**4.07**	**4.44**	**3.36**	**0.22**	**0.56**	**0.52**	**5.45**	**5.65**	**6.1**	**1.12**	**0.6**	**0.54**
	CD @ 1%	**16.8**	**18.3**	**13.9**	**0.93**	**2.33**	**2.15**	**16.2**	**16.82**	**17.95**	**3.3**	**1.8**	**1.6**

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