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Effect of Application of Elemental Sulphur Incubated with Different Organic Amendments on Yield and Quality of Groundnut in Sulphur Deficient Inceptisol Soil

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: Under intensive farming system, use of high analysis fertilizers with rare use of organic manures, depleted the organic carbon status in the soil leads to decrease in productivity though applying improved technologies. After N, P, K fourth major nutrient now days considered as S (Sulphur) which play important role in oilseed and pulse crop productivity and its application with organics to soil found beneficial. Considering this, the proposed research as "Effect of Application of Elemental Sulphur Incubated with Different Organic Amendments on Yield and Quality of Groundnut in Sulphur Deficient Inceptisol Soil." was carried out with five organic amendments having different quality and maturity parameters which showed the significant results with yield and quality of Kharif groundnut.

Study Design: Randomized Block design with seven treatments and four replications.

Place and Duration of the Study: The field research trial was conducted during *Kharif* 2019 at Post Graduate Farm, College of Agriculture, Kolhapur, Maharashtra, India.

Methodology: As per the treatments details, the five organic amendments viz: FYM, Vermicompost, Press mud compost, Poultry manure, and City waste compost were incubated with 40 kg ha^{-1} elemental Sulphur for 30 days prior to application in field plots. The treatment wise incubated organic amendments and RDF applied to groundnut crop. The initial soil analysis, initial and after incubation, the characteristics and quality and maturity parameters of five organic amendments were analyzed by using standard methods. The growth observations and post-harvest observation of groundnut crop were recorded and data were analyzed statistically.

Results: The application of different organic amendments incubated with elemental Sulphur @ 40 kg ha^{-1} namely FYM, Vermicompost, Press mud compost, Poultry manure, and City waste compost along with RDF to *Kharif* groundnut in Sulphur Deficient Inceptisol soil, significantly improved yield contributing characters, dry pod, haulm yields, protein and oil content as compared to absolute control and RDF. Amongst the different organic amendments, application of good quality and maturity poultry manure and vermicompost found significantly superior over rest of organic amendments incubated with Sulphur for improving the growth, dry pod, haulm yields, protein and oil content as compared rest of organic amendments.

Keywords: Elemental sulphur; incubation; organic amendments; groundnut; yield; quality.

1. INTRODUCTION

Legumes are essential crops and need more interest to maximize their productivity [1]. In India, oilseed crops constitute the second largest agricultural produce next only to food grains and these are the important source of our economy contributing 5 per cent to Gross Net Profit (GNP). Groundnut (*Arachis hypogaea* L.) is a unique and important legume-oilseed crop of Indian agriculture system. Groundnut alone contributes 70 per cent of the total edible oil production [2]. It is a valuable crop for marginal farmers largely grown during summer and *kharif* season. The lower yield and productivity are attributed to several production constrains, which include poor and imbalanced nutrition and cultivation on marginal lands. It is therefore, necessary to improve the nutritional aspects so as to obtain better productivity. In groundnut production, appropriate nutrient management practices appear to be more important in rainfed situation because of low nutrient efficiency. The earlier studies were confined mainly to N, P, and K requirement to this important crop, however, due attention was not paid to Sulphur nutrition. Sulphur is an important secondary nutrient which helps in synthesis of amino acids like cysteine, methionine, chlorophyll, vitamins-B, (biotin and thiamine), metabolism of carbohydrates, oil, protein content and also associated with growth and metabolism, especially its effect on the protolytic enzymes [3,4]. Sulphur is increasingly being recognized as the fourth major plant nutrient after nitrogen, phosphorus and potassium [5]. Role of Sulphur in Indian agriculture is now gaining importance because of the recognition of its role in increasing crop production, not only of oil seeds, pulses, legumes and forages but also of many cereals [6]. Consequently, besides nitrogen (N), phosphorus (P), and potassium (K), the

deficiency of Sulphur (S) is frequently reported in indian soils [7,8,9,10]. Organic manures play a direct role in supplying macro and micronutrient and indirectly improve the physical, chemical and biological properties of soils [11]. Use of farmyard manure with other organic amendments like vermicompost, neem seed cake, phosphor-compost and poultry manure, etc., provide a safer and environment friendly way of applying nutrients to groundnut [12]. Integrated use of organic manure and chemical fertilizer would be quite promising not only in providing greater stability in production, but also in maintaining better soil fertility [13]. Considering the importance of Sulphur in oilseed research, the present investigation was conducted to study the effects of application of elemental Sulphur incubated with different organic amendments on yield and quality of *Kharif* groundnut grown in Sulphur Deficient Inceptisol soil.

2. MATERIALS AND METHODS

The field experiment was conducted at Post Graduate Research Farm, RCSM College of Agriculture, Kolhapur, (Maharashtra). Initial soil was analyzed for fertility status by following standard method of analysis [14]. The soil of the experimental site was slightly alkaline (pH: 7.8) with medium organic carbon (0.52%) content and calcareous (free $CaCO_3$ - 9.13 %) in nature. The available nitrogen (205 kg ha^{-1}) and phosphorus (12.4 kg ha^{-1}) content was low while, available potassium content (161 kg ha^{-1}) was medium. The bulk density of initial soil was 1.69 Mg m^{-3} with 40.5 % maximum water holding capacity. The available Sulphur status (7.6 mg kg^{-1}) showed that, the initial soil was Sulphur Deficient. However, DTPA extractable micronutrients content *viz.* Fe, Mn, Zn, Cu was 3.0, 1.2, 0.6 and 1.4 mg kg^{-1} soil respectively. The field experiment was laid out in a randomized block design (RBD) comprising seven treatments, mentioned below with four replications.

Table 1. Treatment details

Symbols	Treatments
T_1	Only RDF (25:50:00 N: P_2O_5: K_2O kg ha^{-1})
T_2	40 kg S ha^{-1}through elemental Sulphur + RDF
T_3	FYM @ 10 t ha^{-1}+ 40 kg S ha^{-1}through elemental Sulphur + RDF
T_4	VC @ 5 t ha^{-1} + 40 kg S ha^{-1}through elemental Sulphur + RDF
T_5	PMC @ 5 t ha^{-1} + 40 kg S ha^{-1}through elemental Sulphur + RDF
T_6	PM @ 5 t ha^{-1} + 40 kg S ha^{-1}through elemental Sulphur + RDF
T_7	CWC @ 5 t ha^{-1} + 40 kg S ha^{-1}through elemental Sulphur + RDF

Table 2. Initial characteristics of organic amendments

Sr. No.	Characteristics	Farm Yard Manure	Vermi-compost	Press Mud Cake	Poultry Manure	City waste compost
1	pH (1:10)	8.1	6.9	6.3	7.3	8.1
2	EC dSm^{-1} (1:10)	0.16	0.41	3.02	1.42	2.23
3	Total Organic Carbon (%)	15.7	24.3	21.3	29.8	30.2
4	Total N (%)	0.54	1.2	1.4	3.10	0.73
5	Total P (%)	0.29	0.71	0.81	2.8	0.52
6	Total K (%)	0.40	2.0	1.41	1.97	0.35
7	Total S (%)	0.23	0.37	0.40	0.32	0.22
8	C/N ratio	29.1	20.3	15.2	9.6	41.4
9	C/S ratio	68.3	65.7	53.3	93.1	137.3
10	C/P ratio	54.1	34.2	26.3	10.6	58.1

**Note. pH, EC, and C/N ratio considered as quality and maturity parameters of organic Amendments [15]*

Table 3. Characteristics of organic amendments after incubation with elemental Sulphur

Sr. No.	Characteristics	Farm Yard Manure	Vermi-compost	Press mud Cake	Poultry Manure	City waste compost
1	pH (1:10)*	7.9	7.3	6.3	6.5	8.2
2	EC dSm^{-1} (1:10)*	0.57	1.32	4.10	1.47	3.72
3	Total Organic Carbon (%)	14.3	22.8	19.7	25.2	28.1
4	Total N (%)	0.58	1.23	1.45	3.29	0.78
5	Total P (%)	0.32	0.78	0.85	2.8	0.54
6	Total K (%)	0.40	2.2	1.45	2.1	0.36
7	Total S (%)	1.03	1.18	1.22	1.15	1.02
8	C/N ratio*	24.7	18.5	13.6	7.7	36.0
9	C/S ratio	13.9	19.3	16.2	21.9	27.6
10	C/P ratio	44.7	29.2	23.2	9.0	52.0

**Note. pH, EC, and C/N ratio considered as quality and maturity parameters of organic amendments [15]*

Size of the plots and treatment wise estimated quantity of all organic amendments were incubated with elemental Sulphur @ 40 kgha^{-1} for 30 days before application to experimental plots. Similarly initial samples of organic amendments and organic amendments incubated with Sulphur were characterized for their properties and depicted in Tables 2 and 3 respectively, by using standard methods and considering pH, EC and C/N ratio as quality parameters for maturity and degree of humification [15]. The recommended dose of fertilizers (RDF) i.e. 25:50:00 kg N, P_2O_5 and K_2O per hectare was applied as basal dose through urea and single super phosphate to all the treatments. Groundnut seeds, variety Phule warna (KDG 128) were treated with thirum @ 2.5 g kg^{-1}, *Rhizobium* and PSB @ 250 g kg^{-1} seed before sowing. Two seeds per hill were dibbled with spacing 30 x 10 cm. Proper plant protection measures along with timely irrigation were followed. Growth contributing characteristics *viz*. days required for initial flowering, for 50% flowering, number of root nodules per plant at peg formation stage were recorded. At maturity plants were harvested treatment wise and plant height, dry pod and haulm yield were recorded. Quality parameters *viz.* protein and oil content of groundnut seed were estimated by using standard methods. The experimental data were analyzed statistically by applying the standard methods described by Panse and Sukhatme [16].

3. RESULTS AND DISCUSSION

3.1 Effect of Application of Organic Amendments Incubated with Elemental Sulphur on Growth Contributing Characters of *Kharif* Groundnut in Sulphur Deficient Inceptisol

Initial flowering in short time span (33 DAS) was observed under treatment T_6 (Table 4) which was significantly lower span of time over absolute control (40.1 DAS) but it was at par with all other organic amendment treatments ($T_3$to T_7). The treatments T_2 to T_7 indicated that the addition of Sulphur in Sulphur Deficient Inceptisol, undergoes the microbial transformation and mineralization released the available Sulphur in soil and utilized by the crop. For flower initiation, treatment T_6 recorded significantly lowest days for 50 % flowering (Table 4) over the treatments T_1, T_2 and T_7 while it was found at par with treatments T_3, T_4 and T_5. Amongst the different organic amendments poultry manure, vermicompost, FYM and press mud compost are equally effective and significantly superior over city waste compost, might be due to initial poor quality and maturity affected the S mineralization and release of available Sulphur to groundnut. In case of plant height and root nodule per plant, it was observed that the treatment T_6 registered significantly higher plant height (35.73 cm) and root nodule count (124.25) over the treatment T_1 and T_2 but found at par with treatment T_4 (Table 4). Regarding growth contributing characteristics, amongst the organic amendments the poultry manure, vermicompost and press mud compost were equally effective and significantly superior over FYM and city waste compost, might be because of good quality and maturity helped for Sulphur mineralization than immobilization of added Sulphur in early stage of incubation Rundal et al*.* [17] also reported that integrated nutrient management gave significant impact on all growth parameters.

3.2 Effect of Application of Organic Amendments Incubated with Elemental Sulphur on Yield of *Kharif* Groundnut in Sulphur Deficient Inceptisol

The significantly highest dry pod yield (20.18 q ha^{-1}) of ground nut (Table 5) was recorded due to application of poultry manure @ 5t ha^{-1} + 40 kg S ha^{-1}through elemental Sulphur + RDF (T_6) but it was at par with the treatment T_4 (19.29 q ha^{-1}) and T_5(18.57qha^{-1}) over the treatment T_1 (14.52 q ha^{-1}) and T_2 (15.31 qha^{-1}). The dry pod yields increased to the tune of 38.9%, 32.9% and 27.9% over control (T_1) and T_2 due to the application of good quality poultry manure, vermicompost, and press mud compost incubated with 40 kg elemental S ha^{-1} and RDF, indicated that application of organic amendments incubated with Sulphur found significantly superior over without organic amendment treatment, except treatment T_7 which might be due to poor quality and maturity of city waste compost, (CWC) immobilized added Sulphur and affect release of nutrients. Amongst the different amendments used, poultry manure, vermicompost and press mud compost were equally effective and significantly superior over FYM and city waste compost because of poor quality for maturity affected the mineralization and transformation of added Sulphur and other nutrients [15], while the matured organic manures enhanced the mineralization and microbial transformation of added Sulphur, released the available nutrients and Sulphur effected growth activity and higher uptake of

nutrients might have produced more photosynthates [18]. The results are in confirmation with the findings reported by Sahebagouda et al. [19], Ashoka et al. [20], Premanandarajah et al*. [21]*. The similar trend of observations also recorded for the haulm yield of ground nut (Table 5). The haulm yield increased to the tune of 43.8% and 34.9% due to the application of poultry manure and vermicompost incubated with 40kg elemental S ha^{-1} + RDF, respectively over the absolute control (T_1) and rest of the organic amendments treatments. The significant lowest haulm yield observed due to treatment T_1 (49.49 qha^{-1}) and found to be at par with treatment T_2 and T_7. Amongst the different organic amendments utilized, poultry manure and vermicompost found significantly superior over rest of the organic amendments Rundal et al*. [17]*, Kalaiyarasan et al. [22], Sahebagouda et al. [19] were also obtained similar results in case of haulm yield using Sulphur with and without organic manures.

Table 4. Effect of application of organic amendments incubated with elemental Sulphur on growth contributing characters of *Kharif* groundnut in sulphur deficient inceptisol

Tr. No.	Treatments	Initial flowering (DAS)	50% flowering (DAS)	Plant Height (cm)	Nodule count/ Plant
T_1	Absolute control, only RDF	40.1	44.0	25.75	84.75
T_2	40 kg S ha^{-1} through elemental Sulphur + RDF	36.5	41.1	28.88	91.00
T_3	FYM @ 5 t ha^{-1}+ 40 kg S ha^{-1} through elemental Sulphur + RDF	36.1	40.0	30.88	102.50
T_4	VC @ 5 t ha^{-1} + 40 kg S ha^{-1} through elemental Sulphur + RDF	35.0	38.2	34.20	114.25
T_5	PMC @ 5 t ha^{-1} + 40 kg S ha^{-1} through elemental Sulphur + RDF	36.0	39.8	31.95	107.50
T_6	PM @ 5 t ha^{-1} + 40 kg S ha^{-1} through elemental Sulphur + RDF	33.0	36.3	35.73	124.25
T_7	CWC @ 5 t ha^{-1} + 40 kg S ha^{-1}through elemental Sulphur + RDF	36.4	40.7	30.75	96.00
Mean		36.0	40.0	30.75	96.00
SEm		1.28	1.38	1.514	4.530
CD 5%		3.82	4.12	4.50	13.46

Table 5. Effect of application of organic amendments incubated with elemental Sulphur on yield and quality of *Kharif* groundnut in sulphur deficient inceptisol

Tr. No.	Treatments	Dry pod yield (q ha^{-1})	Haulm yield (q ha^{-1})	Protein Content (%)	Oil Content (%)
T_1	Absolute control, only RDF	14.52	49.49	16.49	37.03
T_2	40 kg S ha^{-1} through elemental sulphur + RDF	15.31	54.15	17.81	37.45
T_3	FYM @ 5 t ha^{-1}+ 40 kg S ha^{-1} through elemental sulphur + RDF	16.98	58.46	18.69	38.98
T_4	VM @ 5 t ha^{-1} + 40 kg S ha^{-1} through elemental sulphur + RDF	19.29	66.77	19.88	40.26
T_5	PMC @ 5 t ha^{-1} + 40 kg S ha^{-1} through elemental sulphur + RDF	18.57	56.25	19.22	39.44
T_6	PM @ 5 t ha^{-1} + 40 kg S ha^{-1} through elemental sulphur + RDF	20.18	71.15	20.54	42.45
T_7	CWC @ 5 t ha^{-1} + 40 kg S ha^{-1} through elemental sulphur + RDF	15.77	50.88	17.95	37.88
Mean		17.23	58.16	18.65	39.07
SEm+-		0.69	2.10	0.61	1.15
CD at 5%		2.06	6.26	1.84	3.42

3.3 Effect of Application of Organic Amendments Incubated with Elemental Sulphur on Quality (Protein and Oil content) of *Kharif* Groundnut in Sulphur Deficient Inceptisol

Use of different organic amendments incubated with elemental Sulphur significantly affected the quality of ground nut in forms of protein and oil content, as per the data shown in Table 5. The treatment T_6 significantly registered highest protein content (20.54 %) as compared to T_1 (16.49 %) and T_2 (17.81 %) but found at par with treatment T_3, T_4 and T_5. The trend of impact of different treatments on oil content was similar to that was observed in protein content. Significantly highest oil content (42.15 %) was recorded due to T_6 over the control T_1 (37.03 %) and T_2 (37.45 %) but found at par with T_3, T_4 and T_5. The organic amendments, viz; poultry manure, FYM, vermicompost and press mud compost were equally effective in increasing the protein and oil content and significantly superior over city waste compost might be due to maturity and humification enhanced microbial transformation and mineralization of added Sulphur and increased available nutrients with uptake and formation of more Sulphur containing amino acids. The higher content of protein and oil due to application of organic manures and Sulphur was also reported by Rao and Shaktawat [23] and Sahebgouda et al. [19].

4. CONCLUSION

The study concluded that amongst the different organic manures used, Poultry manure and Vermicompost were found to be mature and good quality than rest of organic manures used as organic amendment. The application of good quality poultry manure and vermicompost @5 t ha^{-1} and incubated with 40 kg S ha^{-1}through elemental Sulphur for 30 days prior to application + RDF to Sulphur Deficient Inceptisol soil, significantly increased the dry pod, haulm yield, improved the quality of kernel for protein and oil content of *kharif* groundnut.

5. FUTURE PERSPECTIVE OF THE STUDY

Present study was related with Integrated use of organic and inorganic sources of nutrients to maintain the soil productivity and soil fertility with effective use of organic amendments by studying the quality parameters for maturity and humification. In future, it must be considered whatever may be the organic material used as source of nutrient.

6. LIMITATIONS OF THIS STUDY

1. The quality and maturity parameter of selected Organic amendment is pre-requisite for taking it to incubation with Sulphur.
2. Organic amendment must follow the good quality for pH, EC and C/N ratio.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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