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RESEARCH ARTICLE

Effect of Sulphur on Yield and Biochemical Constituents in Groundnut (*Arachis hypogaea* L.) grown on Vertic Ustropept of Tamil Nadu

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ABSTRACT

A pot culture experiment was conducted with groundnut (CO 7) in a sulphur deficient (7.19 mg kg^{-1}) Inceptisol (Vertic Ustropept) at the Radioisotope (Tracer) Laboratory, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore during October 2016 to January 2017. The treatment structure comprised five levels of sulphur (0, 20, 40, 60, and 80 kg ha^{-1}) along with the recommended fertilizer dose. The variation in yield and the changes in starch, sugars, cysteine, methionine, protein, and oil content with kernel development as influenced by the sulphur application were studied. The yield attributes *viz*., number of pods pot^{-1}, pod and kernel yield pot^{-1} and shelling percentage, were remarkably influenced due to the application of sulphur up to 60 kg ha^{-1}, which was comparable with S @ 40 kg ha^{-1} and had an adverse effect with S @ 80 kg ha^{-1}. In all the stages of sampling (30 DAS, 15 DOP (75 DAS), 30 DOP (90 DAS) and at harvest stage), starch, total sugars, reducing and non-reducing sugars of groundnut were found to decrease with increasing S levels with control recording the highest value and S @ 60 kg ha^{-1} recording the lowest value. During crop growth, protein content and sulphur-containing amino acids *viz*., cysteine, and methionine showed an increasing trend up to 60 kg S ha^{-1} application and recorded comparable values with S @ 40 kg ha^{-1}. Similarly, oil content in the kernel steadily increased with stages of kernel development. The highest oil content at all stages of kernel development was recorded at 60 kg S ha^{-1}.

Keywords: *Sulphur, groundnut, yield, starch, sugars, cysteine, methionine*

INTRODUCTION

Groundnut (*Arachis hypogaea* L.), the king of oilseed crops, is the third most important oilseed crop of the world cultivated widely in 96 countries (Upadhaya *et al*., 2003). Though the share of groundnut to the total oilseed production in India has been falling since 1950, from 70 per cent to the present level of 33 per cent, groundnut is still the major oilseed crop in India which accounts for about 27 per cent of the global area and contributes 19 per cent to world groundnut production (Rai *et al*., 2016). Tamil Nadu ranks fourth in terms of groundnut area (4.419 lakh ha) and third in production (9.737 lakh tonnes, Singh, 2014).

Sulphur, the fourth major plant nutrient after nitrogen, phosphorus, and potassium, is indispensable for the appropriate plant growth and development (Anjum *et al.,* 2012). Sulphur is inevitable for oilseed crops as it is involved in the synthesis of essential amino acids and is a vital component of coenzymes involved in oil synthesis (Chaudhary, 2009). Sulphur has been reported to influence the productivity of oilseed crops and total oil content considerably (Jankowski *et al*., 2008; Egesel *et al*., 2009). It is rightly called as the master nutrient of all oilseed crops as each unit of fertilizer sulphur generates 3-5 units of edible oil (Ramdevputra *et al*., 2010). Their sulphur requirement for proper growth and yield is more than that of many other crops (Fahmina *et al*., 2013).

Areas of sulphur deficiency are becoming widespread throughout the world due to the use of high-analysis fertilizers with low S returns with farmyard manure, high yielding varieties, and intensive agriculture, declining use of sulphur -containing fungicides, and reduced atmospheric inputs caused by stringent emission regulations (Tandon, 1995; CeCeotti, 1996; Randhawa and Arora, 2000; Nader and Nadia, 2011). As the intensity of cropping is gradually increasing, the response of oilseeds to sulphur is also increasing

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(Ghosh *et al*., 2002) and the variable response of groundnut to sulphur has been reported by many workers (Kumar *et al*., 2008; Ramdevputra *et al*., 2010; Giri *et al*., 2011). Hence, this investigation was attempted to study the importance of sulphur in realizing yield and quality of groundnut crop and to study the role of sulphur in influencing the biochemical constituents of groundnut.

MATERIAL AND METHODS

Experimental description

A pot culture experiment was conducted at the Radioisotope Laboratory, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore during October 2016 and January 2017. The experimental soil was sandy loam in texture, non-calcareous, and taxonomically classified as an Inceptisol (Vertic Ustropept) and was slightly alkaline in soil reaction (pH 7.63), non-saline (EC 0.18 dS m^{-1}) with CEC of 13.09 cmol (p+) kg^{-1}. The soil was medium in available nitrogen (300 kg ha^{-1}), phosphorus (15.5 kg ha^{-1}), and high in available potassium (526 kg ha^{-1}) with an organic carbon content of 4.70 g kg^{-1}. The available sulphur status of the soil was deficient (7.19 mg kg^{-1}). The soil was sufficient with respect to available micronutrients like Zn, Fe, Mn, and Cu 2.57, 21.20, 8.80, and 2.15 mg $kg^{-1,}$ respectively. The soil was non-calcareous in nature with the calcium carbonate content of 4.30 per cent.

The groundnut variety CO 7 obtained from Department of Oilseeds, Centre for Plant Breeding and Genetics, TNAU was used in this study. Nutrients were applied to the pots on a soil weight basis. All the pots received uniform application of nitrogen @ 25 kg ha^{-1}, phosphorus @ 50 kg $ha^{-1,}$ and potassium @75 kg $ha^{-1,}$ which were applied through urea, diammonium phosphate, and muriate of potash (Crop Production Guide, 2012). Sulphur was applied basally @ 0, 20, 40, 60 and 80 kg ha^{-1} in the form of elemental sulphur along with *Thiobacillus* at 21 days before sowing. The crop was harvested at 105 days after sowing, and the yield was recorded.

Collection of samples

Plant samples were collected from the pots at vegetative (30 DAS), 15 days of podding (DOP) (75 DAS), 30 DOP (90 DAS), and at harvest stage. At 15 DOP, 30 DOP, and at maturity (45 DOP), kernels were separated from the plant for biochemical analysis (total sugars, reducing sugars, starch, cysteine, methionine, and protein) which was carried out in the fresh samples. The plants were uprooted at vegetative (30 DAS), 15 DOP, 30 DOP, and at harvest and separated into shoot and pod samples. The pod samples after using for biochemical analysis were oven-dried, and the yield was recorded.

Total sugars and starch was estimated by the Anthrone method (Hodge and Hoferiter, 1962), and reducing sugars by Nelson-Somogyi Method (Somogyi, 1952). Non reducing sugar content of the sample was computed by taking the difference between total sugars and reducing sugars. Protein content was estimated by Lowry's method (Lowry *et al.,* 1951). Cysteine and methionine were estimated by spectrophotometric method (Gaitonde, 1967; Horn *et al*., 1946). The oil content in the samples was estimated by the method of A.O.A.C. (1960).

Statistical analysis

The experimental data were statistically analyzed as suggested by Gomez and Gomez (1984). For significant results, the critical difference was worked out at 5 per cent level.

RESULTS AND DISCUSSION

Effect of sulphur levels on yield parameters and yield of groundnut

Pod yield

A significant variation in pod yield was recorded due to the application of sulphur (Table 1). The highest pod yield of 23.42 g pot^{-1} was recorded by S@ 60 kg ha^{-1} and was comparable with S@ 40 kg ha^{-1} (21.95 g pot^{-1}). The increase in pod yield was 54.69 and 44.98 per cent over control for the addition of S@60 and 40 kg $ha^{-1,}$ respectively.

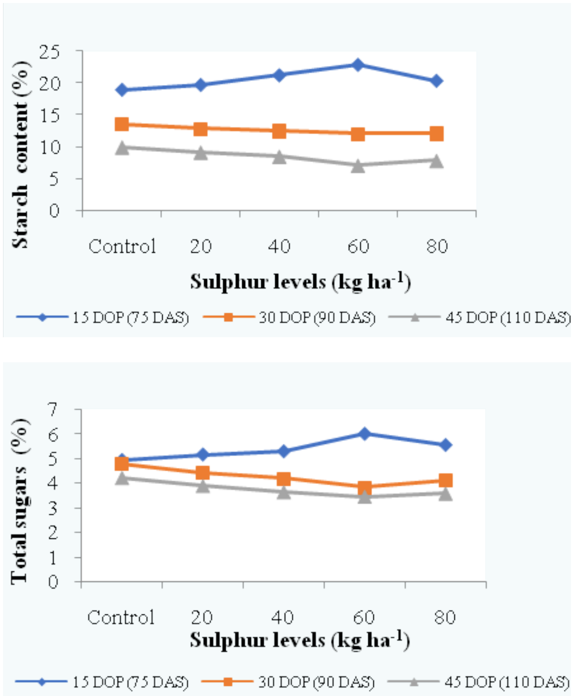

Figure 1. Effect of sulphur levels on starch and total sugars at different stages of kernel development in groundnut (var.CO 7)

Yield enhancement in groundnut with the addition of sulphur has been reported by many workers (Giri *et al.,* 2011; Dutta *et al.,* 2015; Saha *et al.,* 2015); Response to the increasing level of sulphur might be ascribed to an adequate supply of nutrients resulted in high production of photosynthates and their translocation to sink (Tomer *et al*., 1997; Patel *et al*., 2009).

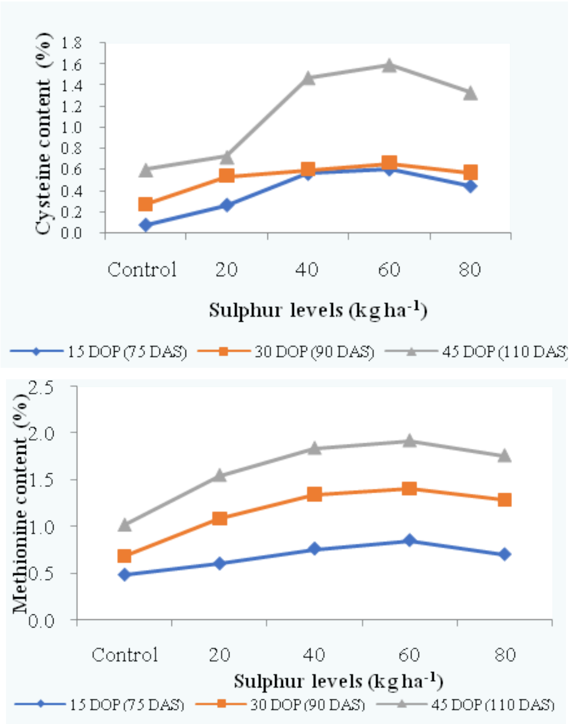

Figure 2. Effect of sulphur levels on cysteine and methionine at different stages of kernel development in groundnut (var.CO 7)

Kernel yield

The differential impact of treatments was quite clear on the kernel yield of groundnut and the highest kernel yield of 16.90 g pot^{-1} (Table 1) was recorded by the addition of S at 60 kg ha^{-1}.

Enhancing the dose of sulphur beyond 60 kg ha^{-1} did not produce any significant advantage rather than a decrease in seed yield. The higher dose of sulphur fertilizer beyond 80 kg ha^{-1} decreased the seed yield considerably, and the negative response to higher sulphur might be due to the imbalance and toxic effect caused by increasing sulphur level. This result showed that pod yield of groundnut was increased with the increase in sulphur application up to a certain limit, and similar results were reported in groundnut (Dutta *et al.,* 2015) and sunflower (Nasreen and Huq, 2002).

Shelling percentage

Imposed sulphur treatments had a significant influence on shelling percentage, which varied between 65.12 to 72.18 per cent (Table 1). The addition of S@ 60 kg ha^{-1} recorded significantly higher shelling percentage (72.18) and was found to be on par with 40 and 80 kg S ha^{-1}.

The increase in shelling percentage due to 60 kg S ha^{-1} was 10.84 per cent over control, and a similar increase in shelling percentage with sulphur application was reported by Singh and Singh (2016).

Starch

In the early stages of kernel development, sulphur application had a profound influence on starch content. Sulphur @ 60 kg ha^{-1} recorded significantly higher starch content (22.83 %). With development, the mean starch content decreased from 12.64 per cent at 30 DOP (90 DAS) to 8.45 per cent at maturity (Figure 1). Sulphur applied @ 60 kg ha^{-1} recorded the lowest starch content at 30 and 45 DOP (at maturity).

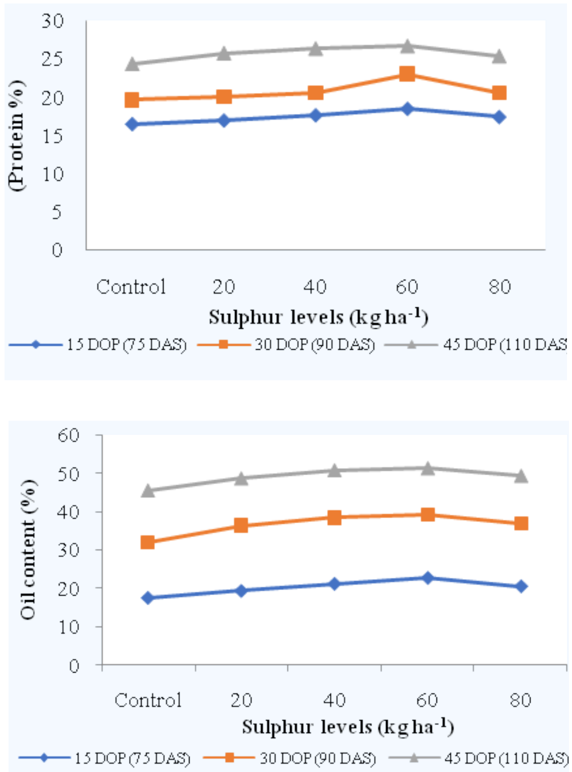

Figure 3. Effect of sulphur levels on protein and oil content at different stages of kernel development in groundnut (var.CO 7)

Starch may serve as a temporary reservoir of energy to be made available during the period of maximum oil synthesis (15 to 30 DOP) by its conversion to glucose and consequently providing various precursors for fatty acid synthesis. A decrease in starch content with the advancement in the kernel development stage was also reported by Sukhija *et al.*, (1987) in groundnut.

Application of sulphur affected adversely the starch content, which might be due to increased conversion of starch to oil in the grain of oil crops with increasing addition of sulphur. Starch is broken to produce glucose - 1 phosphate, which ultimately enters the glycolytic pathway, resulting in the formation of acetyl Co A. Sulphur being an essential component of enzymes helps in bringing about a higher turnover of starch to oil and protein leaving behind less starch in the grain. This confirms the findings of Yadav and Singh (1970).

Total, reducing and non reducing sugars

Total sugars varied from 4.94 per cent (control) to 5.92 per cent (S@ 60 kg ha^{-1}) at 15 DOP (Table 2 & Figure 1). The variation was between 3.97 (S@ 60 kg ha^{-1}) to 4.58 (control) per cent at 30 DOP and from 3.36 to 4.31 per cent at maturity. At all stages of sampling, S@80 kg ha^{-1} and S@ 40 kg ha^{-1} recorded comparable values. Sulphur applied treatments recorded lower reducing sugar content at 15 DOP, 30 DOP, and 45 DOP than control. At maturity, the lowest value was recorded by S@ 60 kg ha^{-1}(0.201 %) and was comparable with S@40 kg ha^{-1} (0.228%). Non reducing sugar content followed the same trend as that of reducing sugars and showed a reducing trend from 4.82 per cent to 3.49 per cent.

Table 1. Effect of sulphur levels on a number of pods, pod yield, kernel yield and shelling percentage in groundnut (var. CO 7)

Treatments	Pod yield (g pot^{-1})	Kernel yield (g pot^{-1})	Shelling percentage
Control (NPK alone)	15.14	9.86	65.12
S @ 20 kg ha^{-1}	19.34	13.04	67.42
S @ 40 kg ha^{-1}	21.95	15.77	71.86
S @ 60 kg ha^{-1}	23.42	16.90	72.18
S @ 80 kg ha^{-1}	20.24	14.35	70.89
Mean	**20.02**	**13.98**	**69.49**
SE_d	0.90	0.16	1.25
CD (P = 0.05)	1.91	0.34	2.67

An increase in the total, reducing and non reducing sugars with sulphur fertilization was observed in the early stage of kernel development (15 DOP). Fazli *et al.,* (2010) reported a significant increase in the total, reducing and non reducing sugar content of seeds at an early stage of development. The decrease in reducing, non reducing, and total sugars in sulphur applied treatments was observed at 30 DOP (75 DAS) and 45 DOP (105 DAS). This is in line with the findings of Sukhija *et al.*, (1987) in groundnut.

Table 2. Effect of sulphur levels on total sugar, reducing sugars and non-reducing sugars in groundnut (var. CO 7)

Treatments	Total sugar (%)			Reducing sugars (%)			Non-reducing sugars (%)		
	15 DOP	30 DOP	45 DOP	15 DOP	30 DOP	45 DOP	15 DOP	30 DOP	45 DOP
Control	4.94	4.58	4.31	0.512	0.456	0.384	4.43	4.12	3.93
S@20 kg ha^{-1}	5.15	4.43	3.98	0.549	0.424	0.359	4.60	4.01	3.62
S@40 kg ha^{-1}	5.65	4.09	3.68	0.601	0.383	0.228	5.05	3.71	3.45
S @ 60 kg ha^{-1}	5.92	3.97	3.36	0.626	0.352	0.201	5.29	3.62	3.23
S @ 80 kg ha^{-1}	5.31	4.23	3.56	0.570	0.404	0.252	4.74	3.83	3.31
Mean	**5.39**	**4.26**	**3.78**	**0.572**	**0.404**	**0.285**	**4.82**	**3.86**	**3.49**
SE_d	0.21	0.16	0.12	0.014	0.012	0.013	0.10	0.09	0.13
CD (P = 0.05)	0.44	0.34	0.26	0.029	0.026	0.026	0.22	0.21	0.28

Cysteine and methionine content

Sulphur application had a profound influence on cysteine and methionine content (Figure 2). Sulphur @ 60 kg ha^{-1} registered the highest cysteine content of 0.60 (15 DOP), 0.66 (30 DOP), and 1.59 per cent at maturity and was on par with sulphur @ 40 kg ha^{-1} at all stages of kernel development (Table 5). Sulphur applied @ 60 kg ha^{-1} recorded the highest methionine content of 0.85, 1.40 and 1.92 per cent at 15 DOP (75 DAS), 30 DOP (90 DAS) and at 45 DOP (maturity) respectively (Figure 2). Though at 15 DOP (75 DAS) all the treatments were significantly different from each other, S@ 60 kg ha^{-1} was comparable with S@40 kg $ha^{-1,}$ which recorded a methionine content of 1.34 per cent at 30 DOP (90 DAS) and 1.86 per cent at maturity.

Sulphur nutritional deficiency has previously been reported to have a strong negative effect on cysteine concentration (Macnicol, 1983). In the absence of sulphur, the content of sulphur-containing amino acids was affected, and the work of Vinod Kumar *et al.,*(1989) lends support to this. The increase in cysteine and methionine content with sulphur application corroborate with the findings of Dwivedi and Bapat (1998), who found that sulphur fertilization had increased the sulphur-containing amino acids in rapeseed and sunflower. Also, Jarvan *et al.*, (2008) reported an increase in cysteine and methionine content in wheat grain due to sulphur fertilization. The increased sulphur content in kernel was significantly correlated with cysteine (r = 0.840**) and methionine (r = 0.997**). This supports the findings of the present study.

Protein content

Sulphur application had a significant influence on protein content (Figure 3), and it showed an increase from control to S @ 60 kg ha^{-1}. Sulphur @ 60 kg ha^{-1} recorded comparable values with S@ 40 kg ha^{-1} at 30 DOP (90 DAS) and maturity. Protein content in the matured kernel ranged between 24.32 per cent (no sulphur) to 26.66 per cent in S@ 60 kg ha^{-1}.

Accumulation of soluble protein in developing seeds during the early stages of seed development is indicative of the synthesis of enzymes and membrane proteins required for the synthesis and accumulation of oil. Improvement in protein content is of paramount importance as it is considered as the building block of the living system. Sulphur is a constituent of the essential amino acid *viz*., methionine, cysteine, and cystine. It also helps in the conversion of these amino acids into high-quality protein. Sulphur application resulted in increased synthesis of methionine, cysteine, and resulted in increased protein content, which is in accordance with the findings of Tathe (2008). An appropriate structure is essential for protein formation, and sulphur provides disulfide chains and thus helps in increasing the protein content. These results are in support of the findings of Babhulkar *et al.,* (2000).

The results of the present study confirm the observations of Fazli *et al.,* (2010) that the supply of sulphur increased the soluble protein content during seed development. Application of sulphur increased the protein content of groundnut kernel by 36.90 per cent in S@60 kg ha^{-1} and 32.6 per cent in S @ 40 kg ha^{-1}.

Oil content

Oil content in the kernel steadily increased with stages of kernel development. The oil content of 20.46 per cent recorded at 15 DOP increased to 37.15 per cent at 30 DOP to 49.18 per cent in the matured kernel. The treatment which received S@ 60 kg ha^{-1} recorded the highest oil content at all stages of kernel development (Figure 3).

The maximum value of oil content in the kernel was observed with S@ 60 kg ha^{-1}. The increase in oil content due to sulphur fertilization might be the outcome of better availability of nutrients owing to the favourable environment created by sulphur application. As sulphur is an integral part of oil, the increased availability of sulphur might have favourably influenced the synthesis of essential metabolites responsible for higher oil content. Sulphur is also known to be involved in the increased conversion of primary fatty acids, several enzymes catalyzing metabolic process which promotes biosynthesis of lipids.

According to Kumar and Yadav (2007), the increase in oil content with an increase in sulphur dose might be due to the involvement of sulphur in the electron transport chain. The strong correlation between kernel sulphur content with oil content (r =0.959 **) draws support to the finding. An increase in oil content with sulphur application has earlier been reported by many workers (Mishra and Agarwal (1994); Jena (2006); Noman *et al.,* (2015)).

CONCLUSION

The study has brought out the response of groundnut (CO 7) to graded levels of sulphur on the yield variation and changes in starch, sugars, cysteine, methionine, protein and oil content with kernel development. Sulphur application at 60 kg ha^{-1} remained on par with S @ 40 kg ha^{-1} in all of the growth and biochemical parameters, which emphasizes that sulphur fertilization at 40 kg ha^{-1} would be adequate for improving the yield and quality of groundnut.

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