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SULPHUR FERTILIZATION IN GROUNDNUT (*ARACHIS HYPOGAEA* L.) UNDER CALCAREOUS SOIL CONDITIONS: EFFECTS ON NUTRIENT UPTAKE, CONTENT AND YIELD

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ABSTRACT

A pot experiment was carried out to examine the effects of different sources of sulphur (cosawet, gypsum, bentonite and elemental sulphur) on nutrient uptake and yield of *kharif* groundnut variety GG-7. The groundnut plants were grown in 15 kg capacity of pots filled with medium black calcareous soil (pH 7.8 and EC 0.58 dSm^{-1}). Before sowing, pot soil was fertilized with different sources of sulphur at five diferent levels *viz*.0, 5, 10, 15, and 20 mg sulphur kg^{-1} of soil. The required NPK was applied at recommended dose. The pots without suphur treatment were considered as control. The experiment was laid out in factorial completely randomized design. The results indicated that application of elemental sulphur @ 20 mg kg^{-1} recorded the highest uptake and leaf content of phosphorous (0.113 % and 43.29 mg plant^{-1}) and potassium (0.558 % and 213.79 mg plant^{-1}) in plant at harvesting. The same treatment also produced the highest yield (14.95 g plant^{-1}) of groundnut. The Magnesium content and uptake by the plants were found non-significant. Thus, it can be suggested that under calcerous soil condition. Application of elemental sulphur @ 20 mg kg^{-1} would be beneficial for improving nutrient content and yield of groundnut.

INTRODUCTION

Lack of sulphur in soils is reported from oil seeds growing belts of India. This situation is also prevalent in Gujarat state of India. The deficiency of sulphur in Gujarat soils varies from 15-25 per cent (Patel *et al*., 1996). Sulphur is known to play an inevitable and imperative role in the synthesis of oil and a constituent of sulphur containing amino acids like cysteine, cystine and methionine. It also promotes nodulation in legumes and produces heavier grains of oilseeds (Tandon, 1986). On other hand, sulphur deficiency may be responsible for poor flowering, fruiting, cupping of leaves, reddening of stem and petiole and stunted growth of plant. Therefore, sulphur is becoming a critical element not only for improving quality but also to achieve economic yield. Groundnut is a major oil seed crop grown in Gujarat (Vijayapriya *et al*., 2005). However, less use of sulphur fertilizers and intensive cultivation oil seeds, the status of available sulphur in soils of groundnut growing area in Gujarat is depleted in considerable amount (Patel *et al*., 2013). This condition leads lesser yield with low oil content in seeds of high yielding varieties of groundnut. Sulphur fertilization may improve the quality and yield of groundnut by either involving in oil synthesis or helping the uptake of other essential nutrient (Gosh *et al*., 2000). So many sources of sulphur are available in market at affordable price. However, their comparative effectiveness under calcareous soil condition has not been studied earlier in case of groundnut. Therefore, an investigation has been carried out to access the effectiveness of different sulphur sources on nutrient uptake, content and yield of groundnut under calcareous soil condition.

MATERIALS AND METHODS

This experiment was conducted at Department of Agricultural Chemistry and Soil Science, College of Agriculture, Junagadh Agricultural University, Junagadh during *kharif* 2012. Four sulphur sources were applied S_1: Cosawet sulphur (90 %S), S_2: Gypsum (20 %S), S_3: Bentonite sulphur (90 %S) and S_4: Elemental sulphur (100 %S) at 5 levels (L_1:0, L_2:5, L_3:10, L_4:15, L_5:20 mg kg^{-1}) in 15 kg capacity earthen pots filled with medium black calcareous soil (pH 7.8 and EC 0.58 dSm^{-1}). Each treatment was replicated thrice. Thus there were 60 pots in the whole experiment. Ten groundnut seeds were planted during *Kharif* in each pot. The plant samples were collected randomly at 60 DAS and at harvest. The plant samples oven dried at 55 to 65 ºC for nutrient analysis till a constant weight was obtained. The plant samples were grounded followed by digested in Diacid mixture as per method described by Jonson and Ulrich (1969). The phosphorus, potassium and magnesium content were determined by as described by Jackson (1974). The nutrient uptake was calculated by multiplying the concentration values with the respective total biological values of plant (Chaudhary and Cornfield, 1966). Yield was calculated after the harvesting of fully mature pods by weighing the grains in electronic balance.

RESULTS AND DISCUSSION

Effect of sulphur sources

Significantly the highest pod yield (13.14 g plant^{-1}) was registered with application of elemental sulphur (S_4) as compared to other sources. The application of sulphur might have helped in the release of available nutrients from soil and thus higher uptake by the crop was noticed, higher nutrients uptake increased vegetative growth of the plant that is ultimately increased photosynthesis and yield of the plant. The results obtained correspond with the finding of Dungarwala *et al.* (2006) observed positive effect of elemental sulphur on unshelled nuts yield of groundnut. Singh *et al.* (2001) reported gradual increase in pod yield under 20 kg S ha $^{-1}$ as elemental sulphur. Manohar and Rathore (1989) also reported that the highest pod yield with elemental S @ 50 and 250 kg /ha. The effect of different sources on P content in plant at 60 DAS and at harvest was found significant. Among the various sources of sulphur under investigation application of elemental sulphur (S_4) resulted significantly the highest P content (0.127 %) at 60 DAS and (0.113 %) at harvest. Hilal (1990) showed that elemental sulfur has a potential role in correcting many of the soil and plant nutrition problems. It has proved an important role of fine S particles in improving certain soil physical and biological properties, reducing pH, increasing the availability of plant nutrients and increasing fertilizer application efficiency. Phosphorus is also important during growth stage of the crop because it is a constituent of nucleic acid, phytin and phospholipids. It helps in fixing more nitrogen in root nodules and also stimulates flowering. The similar findings were also reported by Mishra *et al.* (1990). The higher K content (0.546 %) in plant as compared to other sources was registered with application of bentonite sulphur (S_3) at 60 DAS and non significant at harvest. Bentonite sulfur is the most famous chemo-additive for soil buffering from high pH values it is exposed in soils, to a variety of chemical and biological transformations (Dutta and Patra 2005).The results are in accordance with the results reported by Marok and singh (1976). The effect of sulphur sources on Mg content in plant at 60 was non significant. The significantly highest Mg content (0.60 %) was registered with application of elemental sulphur (S_4) at harvest. Application of elemental sulphur significantly increased the uptake of P (26.2 mg plant^{-1}and 41.1 mg plant^{-1}), K (109.4 mg plant^{-1} and 196.7 mg plant^{-1}) and Mg uptake (111.7 mg plant^{-1} and 222.3 mg plant^{-1}) at 60 DAS and atharvest respectively as compared to remaining sources. This effect of elemental sulfur was expected and might be due to the direct effect of sulfur on increasing the solubility of others nutrients in soil, the present findings are in agreement with the results of Singh *et al.* (1990).

Effect of sulphur levels

Application of 20 mg kg^{-1} (L_5) sulphur level produced significantly the highest pod yield (13.56 g plant^{-1}). Application of sulphur produced synergistic effect on macro and micro nutrient and ultimately increased growth and yield. The results obtained correspond with the finding of Chopra and Kanwar (1986). Dube and Misra (1990), Yadav and Singh (1996) observed positive effect of sulphur application on pod yield of groundnut. Phosphorus concentration in plant is maximum during initial growing stage and then it was decreasing by increasing age Sivakumar *et al.* (2014). The P content was increase with increasing levels of sulphur up to 20 mg kg^{-1}. Significantly the highest P content (0.126 %) was found under application of 20 mg kg^{-1} sulphur (L_5) at 60 DAS and (0.113 %) at harvest as compared to remaining doses of sulphur. The application of sulphur in the soil having produced synergistic effect on P concentration in haulm. Rayan and strochlen (1979) conducted an experiment to determine the effect of sulphur application on P deficient calcareous soils in which the treatment was found to increase significantly the water soluble P and P supplying power of the soil and also it has been found to be help in increasing the P fractions. S application increased the plant P content at all growth stages reported by Khandkar and Shinde (1991). Patel *et al.* (2009) revealed that application of elemental sulphur @ 50 ppm significantly increased the phosphorus content in groundnut grown on the medium black calcareous clayey soil. Significantly the highest k content at 60 DAS (0.550 %) was found under application of sulphur @ 20 mg kg^{-1} (L_5) and (0.558 %) at harvest. Yadav and Singh (1970) reported that with increase in the level of S, there was an increase in the content of K in groundnut grown on black cotton soils under potted condition. The potassium is needed by the groundnut crop from early stage of its growth to maturity stage. It helps in formation of proteins and chlorophyll. The results of the present investigation also are in conformity with the Singh and Chaudhari (1997). The Mg content was increase with increasing levels of sulphur up to 15 mg kg^{-1} then further applying sulphur it was decrease to some extent. The significantly highest Mg content (0.55 %) was observed with application of 15 mg kg^{-1} sulphur (L_4) at 60 DAS. The maximum Mg content (0.56 %) was found under application of 20 mg kg^{-1} sulphur (L_5) level at harvesting stage. Higher Mg content

Table1: Interaction effect of sulphur sources and levels on pod yield (g/plant) of groundnut.

Treatment	S_1 (Cosawet)	S_2 (Gypsum)	S_3 (Bentonite)	S_4 (E.sulphur)	Mean of levels
L_1-0 mg kg^{-1}	9.87	9.58	10.90	10.40	10.19
L_2-5 mg kg^{-1}	10.71	9.94	10.98	12.35	11.00
L_3-10 mg kg^{-1}	11.39	10.96	11.99	13.79	12.03
L_4-15 mg kg^{-1}	11.62	11.59	11.90	14.20	12.33
L_5-20 mg kg^{-1}	12.68	13.81	12.78	14.95	13.56
Mean of sources	11.25	11.18	11.71	13.14	
Treatment	Levels (L)	Sources (S)		L X S	
S.Em. +	0.11	0.10		0.22	
C.D. ($P < 0.05$)	0.32	0.29		0.64	
C.V.%	3.28				

Table 2: Effect of sulphur sources and levels on phosphorus and potassium content (%) of groundnut

Treatment	P content (%)										K content (%)									
	60 DAS					At harvest					60 DAS					At harvest				
Levels (mg/kg)/sources	S_1	S_2	S_3	S_4	Mean Levels (L)	S_1	S_2	S_3	S_4	Mean levels (L)	S_1	S_2	S_3	S_4	Mean levels (L)	S_1	S_2	S_3	S_4	Mean levels (L)
L_0(Control)	0.109	0.108	0.108	0.112	0.109	0.100	0.098	0.098	0.104	0.100	0.507	0.510	0.563	0.503	0.521	0.513	0.523	0.518	0.513	0.517
L_5(5 mg/kg)	0.107	0.106	0.104	0.122	0.110	0.105	0.099	0.099	0.107	0.102	0.524	0.521	0.528	0.522	0.524	0.528	0.533	0.534	0.532	0.532
L_{10}(10mg/kg)	0.108	0.108	0.106	0.128	0.113	0.102	0.102	0.102	0.112	0.105	0.530	0.527	0.533	0.529	0.530	0.533	0.538	0.539	0.537	0.537
L_{15}(15 mg/kg)	0.110	0.111	0.109	0.133	0.116	0.103	0.102	0.104	0.118	0.107	0.539	0.534	0.540	0.537	0.538	0.547	0.549	0.551	0.555	0.550
L_{20}(20 mg/kg)	0.131	0.118	0.112	0.142	0.126	0.104	0.110	0.114	0.123	0.113	0.548	0.542	0.568	0.543	0.550	0.561	0.543	0.562	0.565	0.558
Mean sources (S)	0.113	0.110	0.108	0.127		0.103	0.102	0.103	0.113		0.530	0.527	0.546	0.527		0.536	0.537	0.541	0.540	
	L		S		LxS		L		S		LxS		L	S		LxS		L	S	LxS
C.D.(P < 0.05)	0.004		0.003		0.008		0.002		0.002		0.005		0.011	0.010		0.022		0.006	NS	0.011

Note: S_1 = Cosawet, S_2 = Gypsum, S_3 = Bentonite, S_4 = Elemental sulphur, NS = Non significant

Table 3: Effect of sulphur sources and levels on phosphorus and potassium uptake (mg/plant) of groundnut

Treatment	P uptake (mg/plant)										K uptake (mg/plant)									
	60 DAS					At harvest					60 DAS					At harvest				
Levels (mg/kg)/sources	S_1	S_2	S_3	S_4	Mean levels (L)	S_1	S_2	S_3	S_4	Mean Levels (L)	S_1	S_2	S_3	S_4	Mean levels (L)	S_1	S_2	S_3	S_4	Mean levels (L)
L_0(Control)	16.6	16.2	16.8	17.3	16.7	31.0	30.1	32.0	32.7	31.50	78.0	76.6	87.1	77.3	79.7	164.3	161.0	169.3	161.5	164.0
L_5(5 mg/kg)	17.1	17.9	20.9	24.9	20.2	34.6	32.0	34.3	37.5	34.66	83.1	87.9	106.6	106.2	96.0	174.2	172.6	185.2	186.7	179.7
L_{10}(10 mg/kg)	17.4	21.3	21.6	27.4	21.9	34.8	34.4	36.0	40.7	36.53	85.8	104.7	108.2	113.5	103.1	181.2	181.8	190.2	195.4	187.2
L_{15}(15 mg/kg)	18.0	22.3	22.6	29.9	23.2	36.4	34.8	37.9	44.6	38.47	88.6	106.6	112.1	121.7	107.3	193.4	187.7	201.1	209.9	198.0
L_{20}(20 mg/kg)	21.9	25.1	23.8	33.6	26.1	39.0	38.9	45.1	50.7	43.29	91.9	114.9	121.5	128.0	114.1	210.3	192.2	222.5	230.1	213.7
Mean for sources (S)	18.2	20.5	21.1	26.6		35.1	34.1	37.0	41.1		85.5	98.2	107.1	109.4		184.7	179.1	193.7	196.7	
	L		S		LxS		L		S		LxS		L		S		LxS	L	S	LxS
C.D.(P < 0.05)	0.45		0.40		0.90		1.10		0.99		2.21		3.26		2.91		6.52	4.19	3.74	8.38

Note: S_1 = Cosawet, S_2 = Gypsum, S_3 = Bentonite, S_4 = Elemental sulphur, NS = Non significant

Table 4: Effect of sulphur sources and levels on Mg content (%) and their uptake (mg/plant) of groundnut

Treatment	Mg content (%) 60 DAS					At harvest				
Levels(mg/kg)/sources	S_1	S_2	S_3	S_4	Mean levels (L)	S_1	S_2	S_3	S_4	Mean levels (L)
L_0(Control)	0.53	0.52	0.51	0.50	0.51	0.50	0.51	0.52	0.51	0.51
L_5(5 mg/kg)	0.52	0.53	0.52	0.52	0.52	0.52	0.51	0.52	0.60	0.53
L_{10}(10 mg/kg)	0.53	0.52	0.53	0.54	0.53	0.53	0.52	0.52	0.63	0.55
L_{15}(15 mg/kg)	0.53	0.54	0.57	0.58	0.55	0.54	0.53	0.53	0.64	0.56
L_{20}(20 mg/kg)	0.47	0.52	0.52	0.53	0.51	0.55	0.54	0.53	0.65	0.56
Mean for sources(S)	0.51	0.52	0.53	0.53		0.52	0.52	0.52	0.60	
	L		S		L x S		L		S	
C.D.(P < 0.05)	0.023		NS		NS		0.023		0.020	

Treatment	Mg uptake (mg/plant) 60 DAS					At harvest				
Levels(mg/kg)/sources	S_1	S_2	S_3	S_4	Mean Levels (L)	S_1	S_2	S_3	S_4	Mean levels (L)
L_0(Control)	81.0	78.6	80.4	77.8	79.4	155.0	157.0	170.4	162.8	161.2
L_5(5 mg/kg)	83.1	89.6	105.2	106.9	96.2	171.6	165.2	180.4	213.0	182.5
L_{10}(10 mg/kg)	85.8	102.8	108.2	116.3	103.3	180.2	175.7	183.5	229.3	192.2
L_{15}(15 mg/kg)	87.5	109.3	119.0	131.4	111.8	190.9	181.2	193.4	242.0	201.9
L_{20}(20 mg/kg)	79.0	110.6	110.9	126.4	106.7	206.2	191.1	212.6	264.6	218.6
Mean for sources(S)	83.3	98.2	104.7	111.7		180.8	174.0	188.0	222.3	
	L x S		L		S		L x S	L	S	L x S
C.D.(P < 0.05)	NS		1.84		1.65		3.68	3.19	2.85	6.38

Note: S_1 = Cosawet, S_2 = Gypsum, S_3 = Bentonite, S_4 = Elemental sulphur, NS = Non significant

and uptake were recorded with increasing S levels indicating beneficial effect. Singh and Ram (1992) observed positive effect of sulphur application on Mg concentration of sunflower plant. Application of 20 mg kg^{-1} sulphur produced significant effect on uptake of P (26.14 mg $plant^{-1}$and 43.29 mg $plant^{-1}$), K (114.43 mg $plant^{-1}$ and 213.79 mg $plant^{-1}$) 60 DAS and at harvest respectively over control, whereas significantly highest Mg uptake (111.82 mg $plant^{-1}$ and 218.67 mg $plant^{-1}$) was obtained under application of sulphur @ 15 mg kg^{-1} and 20 mg kg^{-1} at 60 DAS and at harvest respectively over control. The high root CEC and high S requirement of legume crops and their ability to utilize P from relatively insoluble compound therefore ultimately increased the content and uptake P by groundnut crop. The results of the present investigation also are in conformity with the earlier workers Mishra and Gupta (2004).

Interaction effect of sulphur sources and levels

Interaction effects between sources and levels of sulphur for yield indicated that increase level of sulphur through elemental sulphur more yield (14.95 g $plant^{-1}$) obtained over use of other remained sources. Interaction effect of sulphur sources and levels on P content in plant (0.142 %) at 60 DAS and (0.123 %) at harvest was found significant with the application of elemental sulphur (S_4) @ 20 mg kg^{-1} (L_5). Shukla and Prasad (1979) reported that phosphorus concentration in groundnut tissues were increased with applications of sulphur, decreased with enhanced maturity. Application of bentonite sulphur (S_3) at 20 mg kg^{-1} (L_5) level produced significantly the highest K content (0.568 %) at 60 DAS as compared to remaining doses of sulphur. The application of elemental sulphur (S_4) at 20 mg kg^{-1} (L_5) level produced significantly higher K content (0.565 %) at harvesting stage. The similar results were also reported by Singh *et al*. (1990). The interaction effect was absent in case of Mg content in plant at both the stages of plant. Application of elemental sulphur @ 20 mg kg^{-1} produced significant effect on uptake of P (33.68 mg $plant^{-1}$ and 50.7 mg $plant^{-1}$) and K (128 mg $plant^{-1}$ and 230.1 mg $plant^{-1}$) by plant at both the stages respectively. Significantly highest Mg (131.4 mg $plant^{-1}$) uptake at 60 DAS was found under bentonite sulphur application at 15 mg kg^{-1}, whereas the application of elemental sulphur @ 20 mg kg^{-1} produced significant effect on uptake of Mg (264.6 mg $plant^{-1}$) at harvest. The results obtained correspond with the finding of Gupta *et al*. (1994) concluded that soil application of elemental S to calcareous soil increases availability of most of the macronutrients and their absorption by groundnut. Addition of any chemical may increase N, P, K, Ca and Mg content and their uptake by crop. The application of sulphur resulting in the increased root biomass and thereby the increased P absorption and accumulation reported by Reddy *et al*. (1992).

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