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Effect of sulphur and iron on nutrient content, uptake and quality of groundnut (*Arachis hypogaea* L.)

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Abstract
An experiment was conducted at Agronomy farm, S.K.N. College of Agriculture, Jobner during kharif season 2017. The treatments comprising four Sulphur levels (control, 20 kg S/ha, 40 kg S/ha and 60 kg S/ha) and four foliar spray of iron (control, foliar spray of 0.5% $FeSO_4$ at flowering, peg formation and flowering + peg formation) assigned to main and subplots of Randomized Block Design, respectively were replicated thrice. Groundnut variety RG-425(Raj Durga) was used as a test crop. The highest concentration of N, P, K, S and Fe in kernel and haulm and protein and oil content were obtained with 40 kg S/ha, however it was remained at par with 60 kg S/ha. The total uptake of N, P, K, S and Fe as well as oil yield were also obtained with application of 60 kg S/ha. The content of N, P, K, S and Fe in kernel and haulm, protein and oil content significantly increased with foliar application of 0.5% $FeSO_4$ at peg formation stage, which was remained at par with 0.5% at flowering + peg formation stage. The total uptake of N, P, K, S and Fe as well as oil yield were also obtained with foliar spray of 0.5% $FeSO_4$ at flowering + peg formation stage than rest of treatments.

Keywords: Groundnut, iron, nutrient content, sulphur, uptake, quality

Introduction
Groundnut (*Arachis hypogaea* L.) is a self-pollinated, annual, herbaceous, autotetraploid legume with 2n= 40 chromosomes belonging to the family Leguminosae (Fabaceae). It is a 4th most important oilseed crop of the world (Ramanathan, 2001) [16]. In India, it was cultivated on an area of 6.6 m ha with production of 4.7 MT and productivity of 1486 kg/ha during 2016-2017 (AICRPG, 2016). Groundnut is the principal *kharif* oil seed crop of the Rajasthan state. It was grown on 5.90 lakh hectare in the state with total production of 11.40 lakh tones and average productivity of 2051 kg/ha (Anonymous, 2017) [3].
Sulphur is one of the secondary plant nutrients play an important and specific role in the synthesis of sulphur containing amino acids like methionine (20%) and cysteine (27%) and synthesis of proteins, and oil content. Moreover, it is also associated with the synthesis of vitamins (biotin, thiamine), co-enzyme-A metabolism of carbohydrates, proteins and fats. Sulphur is a constituent of protein and play an important role in oil synthesis. Global reports of sulphur deficiency and consequent crop responses; particularly in oilseed crops like groundnut are quite ostensible (Singh and Bairathi, 1980) [21]. Iron is an essential micronutrient takes active part in the metabolic activities of the plant. It is an important part of the enzyme nitrogenase which is essential for nitrogen fixation bacteria. The ferredoxins are Fe-S proteins and are the first stable redox compound of the photosynthetic electron transport chain (Havlin *et al*., 1999) [8]. Application of iron also found to improve the protein content in groundnut kernels. Application of Fe successfully increases pod yield and micronutrient uptake (Rabari *et al*., 2018) [15].

Material and methods
The present study was conducted at Agronomy Farm field no. 3e of Department of Agronomy, S.K.N. College of Agriculture, Jobner (Rajasthan) during the *kharif* season, 2017 to evaluate the effect of sulphur and iron on groundnut crop. The soil of research site (before kharif 2017) was loamy sand in texture with pH 8.2 (slightly alkaline), organic carbon by Walkley-Black method (1.62 g/kg), low in nitrogen (131.10 kg/ha), medium in extractable P (14.9 kg/ha) and potassium (132.80 kg/ha), low in available sulphur (8.6 mg/kg) and iron (2.80 mg/kg). The field experiment was conducted for one season by taking groundnut crop in randomized block design.

Treatment consisted of four level of sulphur (0, 20, 40, 60 kg/ha) and four level of iron (control, 0.5% $FeSO_4$ at flowering stage, 0.5% $FeSO_4$ at peg formation, 0.5% $FeSO_4$ at flowering + peg formation stage to groundnut. The recommended dose of fertilizers amounting 20 kg N and 40 kg P_2O_5 /ha were applied to all the treatment as basal dose. Standard cultural practices were followed for all treatments which was recommended in groundnut crop. Five plants were randomly selected from each plot and used to calculate the nutrient content and uptake after drying and grinding these samples were analysed for nitrogen, phosphorus, potassium, sulphur and iron. Among quality parameters *viz.*, protein content of the seed was worked out by multiplying nitrogen content in the seed (per cent) with the factor 6.25 (A.O.A.C, 1960) [1]. Oil content in seed was determined by Soxhlet's Ether extraction method (A.O.A.C, 1960) [1]. All the data recorded were analysed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) [7] for Randomized block design. The least significant test was used to decipher the effect of treatments at 5% level of significance.

Results and discussion

Effect of sulphur and iron on nutrient content and total uptake by groundnut crop

Application of sulphur at 40 kg/ha significantly improved the N content by 8.50 and 16.35 percent in kernel and 21.42 and 47.82 percent in haulm over 20 kg S/ha and control, respectively, which was remained at par with 60 kg S/ha. The data revealed that improvement in N content was progressive and significant with spray of 0.5% $FeSO_4$ at flowering + peg formation stage over rest of treatments. The data given in (Table 1) show that highest uptake of 117.31 kg/ha was recorded with 60 kg S/ha that increased by 9.25, 43.11 and 119.92 percent over 40, 20 kg S/ha and control, respectively. The highest total uptake of N (117.17 kg/ha) was obtained with spray of 0.5% $FeSO_4$ at flowering + peg formation stage than rest of treatments.

Table 1: Effect of sulphur and iron on nitrogen content in kernel, haulm and total nitrogen uptake by groundnut

Treatments	N Content (%)		Total N uptake (kg ha^{-1})
	Kernel	Haulm	
Levels of sulphur (Gypsum)			
S_0 (Control)	3.18	1.38	53.34
S_{20} (20 kg S/ha)	3.41	1.68	81.97
S_{40} (40 kg S/ha)	3.70	2.04	107.37
S_{60} (60 kg S/ha)	3.82	2.06	117.31
SEm±	0.07	0.04	2.07
CD (P=0.05%)	0.21	0.12	5.97
Foliar spray of iron ($FeSO_4.7H_2O$)			
Fe_0 (Control)	3.16	1.32	53.62
Fe_1 (0.5% at flowering stage)	3.44	1.73	84.36
Fe_2 (0.5% at peg formation stage)	3.68	2.01	104.84
Fe_3 (0.5% at flowering + peg formation stage)	3.84	2.10	117.17
SEm±	0.07	0.04	2.07
CD (P=0.05%)	0.21	0.12	5.97

Data pertaining to increase in level of sulphur up to 40 kg/ha significantly enhanced the P content in kernel (.398%) and in haulm (.314%) than rest of treatment, which was at par with 60 kg S/ha. The data presented in the Table 2 showed that significant highest total P content was observed with foliar spray of 0.5% $FeSO_4$ at peg formation in kernel by 17.0 and 6.68 per cent and in haulm by 33.90 and 7.95 percent, over 0.5% at flowering and control, respectively. The application of 60 kg S/ha were increased the total P uptake (15.50 kg/ha) than other treatments. The maximum total uptake of P is noted with foliar application of 0.5% $FeSO_4$ at flowering + peg formation stage (15.33 Kg/ha).

Table 2: Effect of sulphur and iron on phosphorus content in kernel, haulm and total phosphorus uptake by groundnut

Treatments	Phosphorus content (%)		Total P uptake (kg ha^{-1})
	Kernel	Haulm	
Levels of sulphur (Gypsum)			
S_0 (Control)	0.344	0.236	7.41
S_{20} (20 kg S/ha)	0.375	0.283	11.26
S_{40} (40 kg S/ha)	0.398	0.314	13.99
S_{60} (60 kg S/ha)	0.413	0.325	15.50
SEm±	0.007	0.006	0.27
CD (P=0.05%)	0.021	0.017	0.78
Foliar spray of iron ($FeSO_4.7H_2O$)			
Fe_0 (Control)	0.341	0.233	7.56
Fe_1 (0.5% at flowering stage)	0.374	0.289	11.49
Fe_2 (0.5% at peg formation stage)	0.399	0.312	13.79
Fe_3 (0.5% at flowering + peg formation stage)	0.416	0.324	15.33
SEm±	0.007	0.006	0.27
CD (P=0.05%)	0.021	0.017	0.78

The application of 40 kg S/ha significantly increased the K content in kernel and haulm1.468 and 2.855% respectively. The foliar spray of 0.5% $FeSO_4$ at peg formation stage increase K content 1.473 and 2.850% respectively. The total uptake of K was obtained with 60 kg S/ha, however it was107.55 kg/ha. The foliar spray of 0.5% $FeSO_4$ at flowering + peg formation stage significantly increased the total uptake of K (106.18 kg/ha) than rest of treatments.

Table 3: Effect of sulphur and iron on potassium content in kernel, haulm and total potassium uptake by groundnut

Treatments	Potassium content (%)		Total K uptake (kg ha^{-1})
	Kernel	Haulm	
Levels of sulphur (Gypsum)			
S_0 (Control)	1.150	2.305	53.79
S_{20} (20 kg S/ha)	1.368	2.625	77.97
S_{40} (40 kg S/ha)	1.468	2.855	96.11
S_{60} (60 kg S/ha)	1.535	2.995	107.55
SEm±	0.027	0.053	1.85
CD (P=0.05%)	0.078	0.152	5.33
Foliar spray of iron ($FeSO_4.7H_2O$)			
Fe_0 (Control)	1.148	2.270	54.76
Fe_1 (0.5% at flowering stage)	1.360	2.670	79.27
Fe_2 (0.5% at peg formation stage)	1.473	2.850	95.22
Fe_3 (0.5% at flowering + peg formation stage)	1.540	2.990	106.18
SEm±	0.027	0.053	1.85
CD (P=0.05%)	0.078	0.152	5.33

The maximum S content was recorded with application of 40 kg S/ha in kernel (.215%) and haulm (.185%). The foliar spray of 0.5% at peg formation stage was significantly enhanced the S content in kernel by 16.75 and 34.16 per cent and in haulm by 6.47 and 16.02 per cent, over 0.5% at flowering and control. However, it was found at par with foliar spray of 0.5% $FeSO_4$ at flowering + peg formation stage. Application of 60 kg S/ha significantly increased the total S uptake which was 8.64 kg/ha. The foliar spray of 0.5% $FeSO_4$ at flowering + peg formation stage increased the total uptake of S (8.83 kg/ha) than rest of treatments.

Table 4: Effect of sulphur and iron on sulphur content in kernel, haulm and total sulphur uptake by groundnut

Treatments	Sulphur content (%)		Total S uptake (kg ha^{-1})
	Kernel	Haulm	
Levels of sulphur (Gypsum)			
S_0 (Control)	0.158	0.145	4.42
S_{20} (20 kg S/ha)	0.188	0.171	6.34
S_{40} (40 kg S/ha)	0.215	0.185	7.90
S_{60} (60 kg S/ha)	0.226	0.193	8.64
SEm±	0.004	0.003	0.15
CD (P=0.05%)	0.012	0.010	0.44
Foliar spray of iron ($FeSO_4.7H_2O$)			
Fe_0 (Control)	0.161	0.156	4.28
Fe_1 (0.5% at flowering stage)	0.185	0.170	6.32
Fe_2 (0.5% at peg formation stage)	0.216	0.181	7.88
Fe_3 (0.5% at flowering + peg formation stage)	0.225	0.187	8.83
SEm±	0.004	0.003	0.15
CD (P=0.05%)	0.012	0.010	0.44

The data in Table 5 showed that increasing level of sulphur significantly increased the Fe content in kernel and haulm, significantly maximum iron content in kernel (138.40%) and haulm (91.03%) were recorded with 40 kg S/ha, which was remained at par with 60 kg S/ha. The maximum Fe content in kernel (l132.8%) and haulm (87.30%) were recorded at foliar spray of 0.5% $FeSO_4$ at peg formation stage. The highest uptake of total iron (467.86 g/ha) that was recorded with 60 kg S/ha. The maximum total uptake of Fe (465.01 g/ha) was obtained with spray of 0.5% $FeSO_4$ at flowering + peg formation stage.

Table 5: Effect of sulphur and iron on iron content in kernel, haulm and total iron uptake by groundnut

Treatments	Iron content (%)		Total Fe uptake (g ha^{-1})
	Kernel	Haulm	
Levels of sulphur (Gypsum)			
S_0 (Control)	117.10	76.06	243.22
S_{20} (20 kg S/ha)	124.56	81.51	343.92
S_{40} (40 kg S/ha)	132.76	87.43	419.84
S_{60} (60 kg S/ha)	138.40	91.03	467.86
SEm±	2.23	1.62	8.02
CD (P=0.05%)	6.44	4.67	23.16
Foliar spray of iron ($FeSO_4.7H_2O$)			
Fe_0 (Control)	115.89	75.43	248.38
Fe_1 (0.5% at flowering stage)	125.10	81.36	347.27
Fe_2 (0.5% at peg formation stage)	132.86	87.30	414.18
Fe_3 (0.5% at flowering + peg formation stage)	138.97	91.95	465.01
SEm±	2.23	1.62	8.02
CD (P=0.05%)	6.44	4.67	23.16

The significant increase in N concentration in plants due to sulphur may be attributed to higher in Sulphur concentration, which in turn might have stimulated protein synthesis (Charliers and Carpentiers, 1956) [4]. Sulphur and nitrogen are said to increase the uptake and concentration of each other in groundnut. This accumulation of nutrients especially S in plant parts possibly with greater metabolism lead to greater translocation of these nutrients to reproductive parts of the crop which appears to be the most probable reason of higher nutrient concentration in kernel and haulm due to S fertilization. Sulphur synthesized some sulphur containing amino acids like cystine, cysteinin and methionine and resulted increase in protein content (Table 6) which is in accordance with the finding of Tathe (2008) [22]. Increased biomass production of the crop at harvest in terms of kernel and haulm yield together with higher nutrient concentration might have resulted in significantly higher uptake of N, P, and S by crop due to S fertilization up to 60 kg/ha (Table 1 to 5). These finding corroborate the result of Poonia *et al*. (2013) [14] in groundnut. Iron is also related to vitamins and certain enzymes which help in Cu, Zn and Mg metabolism. Therefore, its stimulatory effect on most of the physiological and metabolic process of plant might have helped in enhanced nutrient absorption from the soil and consequently better growth and development of plant. The results of present investigation are in agreement with those of Rao (1990) [17], Ravi *et al*. (2008) [18], Singh *et al*. (2013) [14] and Jokar, *et al*. (2015) [10]. Increased concentration of N, P, S and Fe with the application of iron fertilizer has also been reported by Kumawat *et al*. 2006 [12].

Effect of sulphur and iron on quality of groundnut

Results further indicate that application of 40 kg s/ha significantly increased protein content (23.14%). The foliar spray of 0.5% $feso_4$ at peg formation stage brought about significantly higher protein content (23.00%), however it was remained at par with 0.5% at flowering + peg formation stage.

Table 6: Effect of sulphur and iron on protein content, oil content and oil yield of groundnut.

Treatments	Protein content (%)	Oil content (%)	Oil yield (kg ha^{-1})
Levels of sulphur (Gypsum)			
S_0 (Control)	19.89	37.12	311.47
S_{20} (20 kg S/ha)	21.33	40.42	506.16
S_{40} (40 kg S/ha)	23.14	43.34	625.50
S_{60} (60 kg S/ha)	23.89	44.87	695.99
SEm±	0.46	0.87	12.88
CD (P=0.05%)	1.33	2.50	37.20
Foliar spray of iron ($FeSO_4.7H_2O$)			
Fe_0 (Control)	19.75	37.53	325.67
Fe_1 (0.5% at flowering stage)	21.50	40.23	515.40
Fe_2 (0.5% at peg formation stage)	23.00	43.69	618.80
Fe_3 (0.5% at flowering + peg formation stage)	24.00	44.30	679.24
SEm±	0.46	0.87	12.88
CD (P=0.05%)	1.33	2.50	37.20

The data presented in Table 6 showed that application of @ 40 kg S/ha significantly augmented the oil content (44.87%) over rest of treatment, however it was remained at par with 60 kg S/ha. The maximum oil content (44.30%) of groundnut significantly increases with the foliar spray of 0.5% $FeSO_4$ at flowering + peg formation stage. The application of 60 kg S/ha significantly increased the oil yield of 695.99 kg/ha than other treatments. The highest oil yield of 679.24 kg/ha was obtained with application of 0.5% $FeSO_4$ at flowering + peg formation stage than rest of treatments.

As sulphur is an integral part of oil, protein vitamins and favorable compound in plant. It is a constituent of three amino acids viz. methionine (21% S), cysteine (26% S) and cystine (27% S), which are building blocks of protein. It's also helps in conversion of these amino acids into high quality protein. Moreover, the increase in oil content might be due to increase in glucoside, which on hydrolysis produce higher amount of oil. The higher oil yield due to sulphur application is the outcome of higher oil content in kernel and significantly higher pod yield of groundnut. These results are in support with the finding of Tathe *et al*. (2008) [22], Jat and Ahlawat (2009) [9], Patra *et al*. (2012) [13], and Kader and Mona (2012) [11] in groundnut. The increase in protein content in kernel was due to higher N content in seed. The higher uptake of nutrients was a consequence of increased yield and their higher content in kernel and haulm under foliar application of iron. These results are in close conformity with findings of Ranugadevi *et al*. (2008) [19], Ravi *et al*. (2008) [18], Eisa *et al*. (2011) [6], Chaudhary (2013) [5] and Salih (2013) [20].

Conclusion

Based on one year experimentation, it may be concluded that sulphur fertilization at 40 kg/ha and foliar spray of 0.5% $FeSO_4$.$7H_2O$ at peg formation stage was found to be the most superior treatments for obtaining higher nutrient content in kernel and haulm as well as protein content and oil content, which was remained at par with 60 kg S/ha and 0.5% $FeSO_4$ at flowering and peg formation stage, respectively. The total nutrient uptake and oil yield were superior at 60 kg S/ha and 0.5% at flowering + peg formation stage than rest of treatments.

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