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Interactive Effect of Nitrogen and Sulphur on Yield and Quality of Groundnut (*Arachis hypogea* L.)

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ABSTRACT : Randomized field experiments were conducted to study the interactive effect of sulphur (S) and nitrogen (N) on seed, oil and protein yield of two cultivars of groundnut {*Arachis hypogea*: cv Amber (V_1); cv Kaushal, (V_2)}. Two dosage levels of sulphur (0 and 20 kg ha^{-1}) and two dosage levels of N (23.5 and 43.5 kg ha^{-1}) in various combinations were tested as micronutrient treatments, T_1, T_2, and T_3. Results indicated significant enhancement of the yield components namely seed and oil yield as well as seed protein. Maximum response was observed with treatment T_3 (having 20 kg S and 43.5 kg N ha^{-1}). Increase in seed and oil yields of 90% and 103 % in V_1, and 79 and 90 % in V_2, respectively were recorded as compared to the control treatment T_1 (having 0 kg S and 23.5 kg N ha^{-1}). Effect of S and N interaction was observed on protein, N and S content in seeds. The results obtained by these experiments clearly suggest that judicious balanced application of N and S could improve the yield.

Keywords: groundnut, nitrogen, oil yield, protein yield, seed yield, sulphur

Sulphur (S) has long been known to play an important role in plant metabolism. Organic sulphate (SO_4^{2-}) is the most common form of S taken up by plant roots and is relatively abundant in the soil and environment. It is actively transported into roots by plasma membrane-localized H^+/SO_4^{2-} co-transporters. Reduction and most of the assimilation of sulphate takes place in plastids (Leusteck *et al.*, 2000). In addition, S forms part of the amino acids, cysteine and methionine and also participates in the synthesis of many secondary compounds in plants. The amount and kinds of these compounds, as well as proteins rich in S containing amino acids that a plant is able to synthesize and store can influence the quality of a crop and its nutritional value for humans and animals (Zhao *et al.*, 1999; Ahmad *et al.*, 2000).

S deficiencies in soil and plant are recognized as a wide spread problem through out the world (Messick & Debrey, 2001). These deficiencies are intensified by increased use of high analysis fertilizer and S free pesticide, increased crop production, and reduced industrial SO_2 emission into the atmosphere. Consequently, the yield and quality of oilseed crops have declined due to the S-deficiency, as it is required along with N for the synthesis of proteins and enzymes (Walker & Booth, 2003; Abdin *et al.*, 2003; Pasricha & Abrol, 2003). N and S are both involved in plant protein synthesis. The shortage in S supply to crops decreases the N use efficiency of the crop (Ceccoti, 1996). Consequently, the poor efficiency of N utilization caused by insufficient S needed to covert N into biomass production may increase N losses from cultivated soils (Schnug *et al.*, 1993). Several field studies have been conducted on S fertilization on groundnut (Lakkineni & Abrol, 1992; Singh & Chudhari, 1995; Chaubey *et al.*, 2000), but these data are insufficient to provide a basis for evolving S application management technology with appropriate amount of N to optimize N-assimilation efficiency, and seed as well as oil yield of groundnut. In this investigation, therefore, an attempt was made to evolve appropriate application/ management technology of S and N for optimum seed, oil and protein yield in groundnut crops.

MATERIALS AND METHODS

Field experiments, employing randomized block design, were conducted to study the interactive effect of S and N on seed and oil yield of groundnut (*Arachis hypogea* L.) cultivars. Two cultivars of groundnut namely Amber (V_1) spreading type and Kaushal (V_2) bunch type were selected for the experiment. The cultivars were grown on sandy loam soil at the experimental field of Hamdard University. The S and N content in the soil were 0.002 % and 0.07 %, respectively. The treatments consisted of two dosage levels of S (0 and 20 kg ha^{-1}) and two dosage levels of N (23.5 and 43.5 kg ha^{-1}) in different combinations: 0 S + 23.5 kg N ha^{-1} (T_1); 20 S + 23.5 kg N ha^{-1}(T_2) and 20 S + 23.5+20 kg N ha^{-1} (T_3). Each treatment had three replications. The plot size was 9 m^2 (3 x 3 m). Phosphorous (P) and potassium (K) were

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applied at the rate of 60 and 40 kg ha^{-1} each to all the plots as basal dressings. N was applied in split applications (first dose at the time of sowing and second at 35 days after sowing). S was applied as a single basal dose at the time of sowing. The sources of N, P, K and S were urea, diammonium phosphate, murate of potash and gypsum, respectively. Same concentrations of rhizobium cultured seed were used in all the treatments. Irrigation was applied as per requirement of the crop. The regular weeding operations, kept the crop free from weeds. At two weeks after sowing, seedlings were thinned to keep an intra row spacing of 45cm in V_1 and 30cm in V_2, and plant to plant distance of 15cm in V_1 and 10cm in V_2.

The yield components were determined at harvest from an area of 1 m^2 from each plot. Oil content was measured by rapid gravimetric method (Kartha & Sethi, 1957). Oil yield was calculated on the basis of oil percentage and seed yield. The crude protein content in seeds was estimated by applying the factor N x 6.25 to the seed N content and was expressed as a percentage of the dried seeds. Protein yield was calculated on the basis of protein percentage and seed yield. The concentrations of N and S in seeds were determined by micro-Kjeldahl and wet digestion in a 2:1 nitric-perchloric acid mixture followed by turbidity measurement, respectively (Linder, 1944; Chesnin & Yein, 1950). The statistical analysis was done following the method of Nageswar (1983). Harvest index was calculated according to Donald & Hamblin (1976).

RESULTS AND DISCUSSION

All yield parameters studied showed significant enhancement due to the combined application of S and N fertilizers. It is evident from table 1, 2 and 3 that treatment T_3 (20 S and 23.5+20 kg N ha^{-1}) proved optimal for most of the yield parameters, including seed and oil yield in both the cultivars. As compared with the treatment T_1 (having only 23.47 kg N ha^{-1}), seed yield was 90.04 % and 79.58 % higher, biological yield 67.04 % and 61.47 % higher and harvest index 20.39 % and 8.07 % higher in V_1 and V_2 respectively, with treatment T_3. Oil content showed increase of 7.21% and 5.91% in V_1 and V_2, Oil yield per hectare was accordingly increased by 103.87 % and 90.22 % in V_1 and V_2, respectively with this treatment (T_3) (Table 1 & 2). The major parameters contributing to enhancement of yield parameters were found to be increase in number of pods per plant (41.52% inV_1 and 42.86 % in V_2), number of seeds per pod (24.84% inV_1 and 25.22 % in V_2) and 100 seeds weight (9.15% inV_1 and 15.83 % in V_2) (Table 3).

S and N fertilization in various combinations increased protein concentration in the seeds of both cultivars significantly, as compared to application of N alone. The protein concentrations in the seed were almost equal in both the cultivars. The protein concentrations in the seed were observed to be 17.34% and 24.14% higher in V_1 and V_2 respectively, with treatment T_3. S and N fertilization in various combinations significantly improved the seed N concentration, suggesting a role for S in N transport in to seeds. The seed N concentration were observed to be 16.94% and 24.16% higher in V_1 and V_2 respectively, with treatment T_3. No significant differences were observed between the two cultivars

Table 1. Interactive effect of S and N on seed yield, biological yield and harvest index of groundnut cultivars.

Treatment	Seed yield (kg /ha)	Bilogical yield (kg/ha)	Harvest index (%)
Arachis hypogea L. cv. Amber (V_1)			
T_1	1647	5587	29.51
T_2	2383	7568	31.51
T_3	3130	9333	35.53
Arachis hypogea L. cv. Kaushal (V_2)			
T_1	2532	8174	30.96
T_2	3404	10209	33.34
T_3	4547	13199	33.46
L.S.D. (0.05)			
Cultivars (V)	11.08	37.65	0.93
Treatment (T)	13.57	46.12	1.14
V x T	19.2	65.22	NS

$T_1 = S_0 N_{23.5}$; $T_2 = S_{20} N_{23.5}$; $T_3 = S_{20} N_{23.5+20}$
LSD = Least singnificant differences

Table 2. Interactive effect of S and N on oil content, oil and protein yield of groundnut cultivars.

Treatment	Oil content (%)	Oil yield (kg /ha)	Protein yield (kg /ha)
Arachis hypogea L. cv. Amber (V_1)			
T_1	47.0	775	42.5
T_2	50.0	1191	69.7
T_3	50.5	1580	69.7
Arachis hypogea L. cv. Kaushal (V_2)			
T_1	47.3	1197	61.5
T_2	49.6	1689	101.2
T_3	50.1	2277	137.2
L.S.D. (0.05)			
Cultivars (V)	NS	5.33	2.38
Treatment (T)	0.343	6.53	3.56
V x T	0.485	9.24	7.14

$T_1 = S_0 N_{23.5}$; $T_2 = S_{20} N_{23.5}$; $T_3 = S_{20} N_{23.5+20}$
LSD = Least singnificant differences

Table 3. Interactive effect of S and N on number of pods per plant, number of seeds per pod and 100-seed weight of groundnut cultivars.

Treatment	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	100-Seed weight(g)
Arachis hypogea L. cv. Amber (V_1)			
T_1	25.67	1.57	35.82
T_2	33.33	1.70	37.10
T_3	36.33	1.96	39.10
Arachis hypogea L. cv. Kaushal (V_2)			
T_1	16.33	2.22	37.90
T_2	22.23	2.56	41.50
T_3	23.33	2.78	43.90
L.S.D. (0.05)			
Cultivars (V)	2.701	0.051	0.370
Treatment (T)	3.307	0.063	0.454
V x T	NS	0.089	0.641

$T_1 = S_0 N_{23.5}$; $T_2 = S_{20} N_{23.5}$; $T_3 = S_{20} N_{23.5+20}$
LSD = Least singnificant differences

Table 4. Interactive effect of S and N on protein content, seed-N content and seed-S content of groundnut cultivars.

Treatment	Protein content (%)	Seed-N content (%)	Seed-S content (%)
Arachis hypogea L. cv. Amber (V_1)			
T_1	25.83	4.13	0.15
T_2	29.25	4.82	0.23
T_3	30.31	4.83	0.25
Arachis hypogea L. cv. Kaushal (V_2)			
T_1	24.31	3.89	0.14
T_2	28.75	4.81	0.22
T_3	30.18	4.83	0.24
L.S.D. (0.05)			
Cultivars (V)	0.215	0.038	0.011
Treatment (T)	0.263	0.047	0.013
V x T	0.372	0.066	0.018

$T_1 = S_0 N_{23.5}$; $T_2 = S_{20} N_{23.5}$; $T_3 = S_{20} N_{23.5+20}$
LSD = Least singnificant differences

in terms of seed N concentration. However, significant differences were observed between two cultivars in terms of seeds S concentration. Application of S and N in various combinations resulted in significant increases in seed S concentration of both cultivars, when compared with the N alone (T_1). The seed S concentration were recorded to be 66.66% and 50.00% higher in V_1 and V_2 respectively, with treatment T_3 (Table 4).

The high response of groundnut cultivars to the treatment T_3 may be attributed to the balanced application of N and S. Since both these nutrients are involved in the biosynthesis of the protein and many other important biomolecules. The balanced application of S and N enhanced the efficiency of their utilization by plants. The maximum seed and oil yield were obtained, when S and N applications were balanced (Jamal *et al.*, 2005; Ahmad *et al.*, 1998). Similarly, a strong coupling between S and N has been established in many studies in terms of dry matter and seed as well as oil yield in several crops (Ahmad & Abdin, 2000; Zhao *et al.*, 1999). A shortage in the supply of S to the crops lowers the utilization efficiency of the available soil N, thereby increasing nitrate leaching (Lakkineni & Abrol, 1994). Large doses of gypsum reduced the yield of hay when N status in soil was unsatisfactory (O'Conner & Vartha, 1969). Likewise, large doses of N created S deficiency (Eppendorfer, 1971). Ensuring the N supply from deficient to adequate levels resulted in a 2.4-fold increase in seed number per plant and a 2-fold increase in single seed weight, so that seed yield per plant increased 5-fold in sunflower (Hocking *et al.*, 1987). It has been established that for every 15 part of N in protein there is 1 part of S, which implies that the N:S ratio is fixed within a narrow range of 15:1. The N:S ratio in the whole plant in general is 20:1 (Cram, 1990). The work on barley plants, demonstrated that the apparent matching of supply to demand is accompanied by an apparent linkage of SO_4^{-2} to NO_3^- uptake at the whole plant level (Clarkson *et al.*, 1989). The assimilatory pathways of these elements are considered functionally convergent (Filner, 1978). The role of S, as discussed by many researchers (Friedrich & Schrader, 1978; Reuveny *et al.*, 1980; Barney & Bush, 1985), is linked to the function of nitrate reductase, the enzyme responsible for conversion of NO_3^- -N taken up by the crop in to amino acid and subsequently in to protein. Further, S is a constituent of the initiation amino acid methionine, which is essential for protein synthesis in eukaryotes. Thus, an imbalance in S and N supply may have an adverse effect on protein metabolism (Beaton & Wagner, 1985).

Thus, the two nutrients interact at metabolic level in such a way that imbalance in their supply reduce the yield of crop. Hence, the inclusion of S in fertilizer recommendation for optimum seed, oil and protein yield in groundnut is necessary, and S and N should be given in balanced doses to obtain optimum yield.

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