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Effect of nitrogen and sulphur on yield, quality, nutrient uptake and post harvest nutrient status of groundnut (*Arachis hypogaea* L.)

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Abstract

Field investigations were carried out during 2022 and 2023 (*Kharif* season) at Experimental farm, Annamalai University to investigate the effect of nitrogen (N) and sulphur (S) on yield, quality, nutrient uptake and post-harvest nutrient status of groundnut. The experiment was laid out in factorial randomized block design (FRBD) with 4 nitrogen levels (0, 17, 25 and 34 kg/ha) and 4 sulphur levels (0, 20, 40 and 60 kg/ ha) which are replicated thrice. The results revealed that the different nitrogen and sulphur levels notably influenced the yield parameters, quality characters, uptake and post harvest soil available nutrients of groundnut. Among the various nitrogen levels tested, 34 kg N/ha (N_4) registered maximum pod yield (2579 kg/ha), kernel yield (1835 kg/ha) and haulm yield (3761 kg/ha), oil content (49.10 per cent), oil yield (902.66 kg/ha) and crude protein content (26.31 per cent). Regarding sulphur levels, pod yield (2573 kg/ha), kernel yield (1837 kg/ha) and haulm yield (3727 kg/ha), oil content (49.12 per cent), oil yield (906.31 kg/ha) and crude protein content (26.33 per cent) by groundnut was influenced by sulphur application at 60 kg/ha (S_4). With respect to various interaction effects, application of 34 kg N/ha along with 60 kg S/ha (N_4S_4) has a significant effect on the yield, quality characters and increased nutrient uptake which ultimately results in maximum yield of groundnut.

Key words : groundnut, nitrogen, sulphur, yield, quality, and uptake.

In India's agricultural economy, oilseeds are ranked second in terms of area, production, and value next to food grains. Groundnut is one among the most essential oilseed crop and it is widely cultivated as rainfed crop in India. Groundnut is the "King

of Oilseeds" and belongs to Leguminosae family. Groundnut is a leading oilseed crop in India, primarily grown for the consumption purpose for humans and also for animal feed[20]. The domestic production of vegetable oil and fats are rising at only about 2 percent per year while the domestic demand is increasing rapidly at a rate of 6 percent per year. Furthermore, the average yield of most oilseeds in India is significantly lower compared to other countries worldwide. Among nine major oilseeds crops, groundnut (*Arachis hypogaea* L.) occupies a preeminent position in the national edible oil economy. Primary macronutrients namely nitrogen, phosphorus, and potassium (N, P, and K) are crucial for enhancing both the productivity and quality of the crops. Among all essential elements, nitrogen is a crucial and limiting factor for the growth and development of most plants. Additionally, nitrogen plays a role in chlorophyll, the component responsible for absorbing light energy essential for photosynthesis. It enhances the rate of photosynthesis, helps in the synthesis of metabolites and its transportation to the seeds[18]. Sulphur is the fourth major plant nutrient followed by N, P and K. It is a crucial component of three amino acids - cystine, cysteine, and methionine - that are essential for protein synthesis[26]. It is an important prerequisite which enhances the groundnut productivity and quality characters. Sulphur is becoming increasingly important as a plant nutrient in dry land agriculture as it is the key nutrient of all oilseed crops[27]. The combined use of nitrogen and sulphur had significantly greater impact on both the concentration and uptake of these essential nutrients, influencing growth parameters and nutrient absorption.

The investigation was carried out during *kharif* season (July – November) of 2022 and 2023 at Experimental farm, Faculty of Agriculture, Annamalai University. The maximum temperature during the cropping period ranges from 36.11 to 28.57^{o} C with a mean of 33.16^{o} C and the minimum temperature fluctuates between 25.42 and 22.14 ^{o}C with a mean of 23.67 ^{o}C. During crop period, 65.10 mm of rainfall was recorded with 25 number of rainy days. The experimental soil was classified as sandy loam in texture with low available N_2, medium available P_2O_5 and K_2O and low available S. The VRI 8 groundnut variety was chosen for this study. The study was laid out in factorial randomized block design (FRBD) and replicated thrice. The treatment consisted of two factors *viz.,* nitrogen levels (0, 17, 25 and 34 Kg N/ha) and sulphur levels (0, 20, 40 and 60 Kg S/ha). The requirement of nitrogen, phosphorous, potassium and sulphur were met through urea, DAP, MOP and gypsum. The crop harvested from each plot was bundled up and the pods were stripped off. The pods were dried in sunlight to bring the moisture content to 10 % and individual plot yield were recorded. The pods are then shelled to obtain the kernel yield. The estimated data were analyzed by the outlined procedure of Panse and Sukhatme[15]. The critical difference were worked out at five per cent (P=0.05) probability level for significant result.

Pod yield :

Data presented in table 1 indicated that the groundnut pod yield was notably affected by varying nitrogen levels during 2022 and 2023. On pooled basis, higher pod yield (2579 kg/ha) was recorded under N_4 over other levels of nitrogen. Nitrogen is a vital source for the chlorophyll and amino acids formations, which enhances nutrient translocation to

reproductive parts which ultimately results in a higher yield. This outcome was supported by the conclusions of Waghmode *et al.*,[29] and Saryam *et al.,*[22]. Based on the pooled data, S at 60 kg/ha (S_4) registered higher values of pod yield (2573 kg/ha) in groundnut. Sulphur is involved in the production of acids and vitamins that directly contribute to root growth and developmental processes ultimately leading to higher pod yields. A higher yield could be attributed to a well-balanced nutritional environment, more efficient and enhanced distribution of metabolites, and effective nutrient allocation to the reproductive sites[2]. Regarding interaction effect, fertilization of 34 kg N/ha with 60 kg S/ha significantly registered higher pod yield of groundnut. The improved growth and enhanced nutrient uptake, which likely led to greater photosynthesis and the production of more metabolites essential for yield attributes, ultimately resulting in higher pod yield. Similar findings were observed by Yadav *et al.,*[30], Devi *et al.,*[7] and Suryavanshi *et al.,*[7].

Kernel yield :

Application of 34 kg N/ha (N_4) led to significant increase in kernel yield (1835 kg/ha). With each successive increment of nitrogen up to 34 kg/ha, resulted in significant increase in kernel yield in pooled values. The increase in seed yield is likely due to a higher number of branches per plant, pods per plant and 100-seed weight with nitrogen application. This effect can be attributed to nitrogen's role in promoting cell division and expansion, improving sink capacity, and enhancing the accumulation of photosynthates[23]. Increased doses of sulphur from 0 to 60 kg S/ha resulted in improvement of kernel yield (1837 kg/ha) of groundnut in these two years. Application of 60 kg S/ha substantially enhanced the kernel yield over control. The enhancement in kernel yield can be ascribed to the stimulating effect of sulphur fertilization on protein synthesis. This enhancement in protein synthesis likely accelerated photosynthesis and improved various yield-contributing characters, leading to a significant increase in kernel yield which was noted by Abilash *et al.,*[2].

Haulm yield :

In both the years, haulm yield of groundnut was significantly affected by different nitrogen and sulphur levels. The nitrogen ferilization of 34 kg N/ha (N_4) helped in attaining higher haulm yield (3761 kg/ha). This improvement in haulm yield is most likely due to effective nitrogen fertilization, which enhanced net photosynthesis and increased the mobilization of photosynthates towards reproductive structures, thereby boosting haulm yield[16]. Regarding various levels of sulphur, higher haulm yield (3727 kg/ha) was recorded under S at 60 kg/ha. The outcomes can be credited to the influence of sulphur fertilization on cell division, growth and elongation, which results in an enhancement of plant structures and encouraging more consistent vegetative growth of the crop. The findings aligned with those previously reported by Aier and Nongmaithem[1] and Bhadiyatar *et al.,*[3]. Regarding interactions, combination N_4S_4 registered higher haulm yield on mean basis. This might be attributed to the availability of essential nutrients that could have contributed to a consistent nutrient supply as favorable soil conditions were maintained during the entire growth phase of

the crop. Similar findings was supported by Suryavanshi *et al.,*[28].

Oil content :

With respect to different levels of nitrogen tried, fertilization with 34 kg N/ha (N_4) registered higher oil content of 49.10 per cent in groundnut (Table-1) during 2022 and 2023. Nitrogen increases the vegetative growth of plant and the synthesis of carbohydrate which later transfer to seeds results in increased oil content of groundnut[30]. Application of 60 kg S/ha results in higher oil content (49.12 per cent). The rise in oil content was mainly due to sulphur's role in the synthesis of sulphur containing amino acids (cysteine, methionine) and certain vitamins (biotin and thymine). Additionally, sulphur assists in the ferredoxin formation which is a Fe containing plant protein that serves as an electron carrier in both photosynthesis and chlorophyll process which are necessary for oil production. Regarding interaction, the highest oil content was obtained during both years from the plots applied with N_4S_4. Nitrogen and sulphur are crucial structural elements essential for protein and fat synthesis. Their presence creates a favorable environment for the production of metabolites necessary for oil biosynthesis in plants. Enhancement of oil content with increasing level of sulphur may be due to the effective sulphur utilization in electron transport system. Similar results was observed by Pandey *et al.,*[14].

Oil yield :

Among the different levels of nitrogen tried, 34 kg N/ha (N_4) facilitated higher oil yield (902.66 kg/ha) in groundnut during both the seasons (Table-1). This increase in oil yield could be related to increased kernel yield. Based on the pooled data, sulphur at 60 kg/ha (S_4) registered higher values of oil yield (906.31 kg/ha). This elevated oil levels could be linked to the rise in sulphur absorption by plants via gypsum, which is important for oil production through the creation of sulphur containing fatty acids which subsequently increases the oil yield. These conclusions align with the findings reported by Nayee *et al.,*[22]. Regarding interaction, combination N_4S_4 results in higher oil yield. The treatment N_1S_1 registered lower oil yield.

Protein content :

Among the various nitrogen levels tested, fertilization with 34 kg N/ha (N_4) recorded the higher protein content (26.31 per cent) in groundnut (Table-1). The improved nitrogen supply could have increased the better uptake and utilization of all plant nutrients and a higher proportion of photo synthetases might have been shifted to protein synthesis[5]. Sulphur application at 60 kg/ha (S_4) significantly recorded maximum crude protein content (26.33 per cent) in groundnut crop during both the years. Sulphur is referred to as building blocks of protein because it is the constituent of three amino acids. It is also responsible for converting these amino acids into good quality protein. Proper arrangement is the basics for the proteins function and sulphur- plays a key role by providing disulfide (S-S) bonds that link two polypeptide chains, thereby facilitating protein synthesis. Sulphur is directly involved in the process of protein bio-synthesis and it also acts as the structural component of protein. Comparable results were previously discussed by Yadav *et al.,*[30]. Regarding interactions, combination N_4S_4 imparted significant impact on the crude protein content of groundnut. The increase is probably due to the effect of greater

nutrient concentration and mobility and their better absorption by plants. Role of nitrogen and sulphur for protein synthesis are profoundly inter-related. These findings are in concordance with the study done by Bhadiyatar *et al.,*[3] and Singh *et al.,*[24] in groundnut.

Nutrient uptake :

With different nitrogen levels, applying 34 kg N/ha (N_4) significantly enhanced the nutrient uptake of N (106.32 kg/ha), P (29.03 kg/ha), K (65.64 kg/ha) and S (15.98 kg/ha) in both the cropping seasons (Table-2). This notable increase could be attributed to the higher levels of nitrogen applied. The nitrogen concentration and DMP increases with increased nitrogen application, nutrient uptake also increases. The higher nitrogen content found in the seeds is likely due to nitrogen's tendency to concentrate in reproductive organs. Additionally, the beneficial impact of nitrogen on phosphorus uptake may be linked to improved photosynthesis, leading to greater carbohydrate accumulation in the plant's vegetative parts, which in turn enhances nutrient uptake. Increased potassium and sulphur uptake at higher nitrogen levels contributes to a more favorable environment for growth and yield. Nitrogen promotes the development of a robust root system, which enhances the plant's ability to utilize and absorb nutrients, leading to greater overall nutrient uptake[16].

Table-1. Effect of nitrogen and sulphur on yield and quality of groundnut
(Pooled data of two years)

Treatments	Pod yield (kg/ha)	Kernel yield (kg/ha)	Haulm yield (kg/ha)	Oil content	Oil yield (kg/ha)	Protein content
Factor A-Nitrogen levels						
N_1	1683	1120	2707	47.01	526.64	22.97
N_2	2274	1579	3409	48.15	762.46	25.15
N_3	2504	1771	3678	48.90	867.64	26.02
N_4	2579	1835	3761	49.10	902.66	26.31
C.D	**43.30**	**36.16**	**55.67**	**0.13**	**17.82**	**0.20**
S.Ed	**20.42**	**17.05**	**28.62**	**0.06**	**08.40**	**0.09**
Factor B-Sulphur levels						
S_1	1892	1281	2998	47.47	608.21	23.76
S_2	2195	1517	3316	48.01	731.02	24.83
S_3	2380	1669	3513	48.56	813.87	25.53
S_4	2573	1837	3727	49.12	906.31	26.33
C.D	**43.31**	**36.16**	**55.67**	**0.14**	**17.82**	**0.20**
S.Ed	**20.43**	**17.05**	**28.62**	**0.07**	**08.40**	**0.09**

Factor A: N_1-0kg/ha, N_2-17kg/ha, N_3-25kg/ha, N_4-34kg/ha

Factor B: S_1-0kg/ha, S_2-20kg/ha, S_3-40kg/ha, S_4-60kg/ha

Table-2. Effect of nitrogen and sulphur on nutrient uptake and post harvest nutrient status of groundnut (Pooled data of two years)

Treatments	Nutrient uptake (kg/ha)				Post harvest nutrient status (kg/ha)			
	N	P	K	S	N	P	K	S
Factor A-Nitrogen levels								
N_1	68.78	19.41	41.07	8.01	178.06	6.19	215.65	15.22
N_2	92.76	25.49	56.73	12.97	208.51	8.05	233.69	24.97
N_3	103.14	28.05	63.49	15.33	234.56	9.73	249.67	34.84
N_4	106.32	29.03	65.64	15.98	222.81	8.94	241.72	30.47
C.D	**1.68**	**0.58**	**1.26**	**0.31**	**2.42**	**0.27**	**1.93**	**1.19**
S.Ed	**0.79**	**0.27**	**0.59**	**0.15**	**1.14**	**0.13**	**0.91**	**0.56**
Factor B-Sulphur levels								
S_1	77.43	21.79	46.56	9.92	191.11	6.91	222.37	18.61
S_2	89.18	24.59	54.91	12.15	211.40	8.17	235.01	26.42
S_3	97.11	26.46	59.53	13.98	223.03	9.11	243.34	31.05
S_4	107.31	29.14	65.92	16.25	218.41	8.73	240.02	29.41
C.D	**1.71**	**0.60**	**1.26**	**0.30**	**2.40**	**0.26**	**1.90**	**1.16**
S.Ed	**0.81**	**0.28**	**0.59**	**0.15**	**1.13**	**0.12**	**0.90**	**0.55**

Factor A: N_1-0kg/ha, N_2-17kg/ha, N_3-25kg/ha, N_4-34kg/ha

Factor B: S_1-0kg/ha, S_2-20kg/ha, S_3-40kg/ha, S_4-60kg/ha

Significantly higher uptake of N (107.31 kg/ha), P (29.14 kg/ha), K (65.92 kg/ha) and S (16.25 kg/ha) were recorded under the application of sulphur at 60 kg/ha (S_4) (Table-2). This substantial increase might be attributed to the extensive vegetative and root growth, along with the enhanced availability of nutrients at higher sulphur doses. This combination leads to increased nutrient concentration due to greater absorption by the plant[11]. Sulphur application had a synergistic effect on boosting total phosphorus uptake and may have also enhanced potassium absorption by the plant. The increased sulphur uptake can be linked to higher yield parameters and greater nutrient concentrations in the kernels, shells, and haulms of groundnut observed in this study. These results align with findings from Rajput *et al.*,[19]. The lower nutrient uptake was recorded under the treatment S_1.

The interaction between varying doses of N and S levels greatly affected the uptake of nutrients in groundnut. Among the different combinations tested, maximum uptake of nutrients was recorded under N_4S_4 over other combinations in 2022 and 2023. The increased availability of essential nutrients led to greater dry matter yield and improved nutrient absorption in groundnut. The combined effect of nitrogen and sulphur likely boosted microbial activity, leading to enhanced N fixation, vigorous plant and root development, and ultimately greater nutrient uptake by the plants. These

findings are consistent with those reported by Dubey *et al.,*[8]. The treatment combination N_1S_1 registered lower uptake of nutrients in groundnut.

Post harvest soil available nutrients :

From the pooled data, nitrogen fertilization of 25 kg N/ha (N_3) registered higher values for post-harvest available nutrient status of soil (Table-2). Increased available N in soil might be assign due to additional nitrogen application in soil and its non-significant effect on both phosphorus and sulphur. Increased soil nutrient status of nitrogen might be due to availability of applied nitrogen in soil[6]. This effect is caused by the dilution of nutrients caused by higher rates of nitrogen application. Overall, higher nutrient concentrations were observed in the soil. Applying nitrogen at elevated levels ensured better availability of nutrients in sufficient quantities for the plants. The increased nutrient availability observed in this study suggests improved soil fertility and health. The higher levels of NPK in the soil are likely due to the synergistic effects of the applied nutrients, which enhanced the NPK content[10].

Among the various sulphur levels tested, applying 40 kg S/ha (S_3) resulted in the higher post-harvest nutrient levels in the soil. The improved soil nutrient status from sulphur fertilization could be the result of enhanced adsorption capacity and increased microbial activity, which likely accelerated mineralization during the crop growth period, leading to higher nutrient accumulation in the soil. Notably, the highest available sulphur was found with the 45 kg S/ha, while the lowest was observed under no sulphur application (S_1). This increase is likely because of the ameliorative effects of sulfur and improvements in soil physicochemical properties, as well as the residual sulfur left in the soil after crop harvest. These findings are similar with those reported by Jat *et al.,*[9], Sahoo *et al.,*[21] and Chauhan *et al.,*[6].

The interaction effect between varying levels of nitrogen and sulphur was significant on post harvest soil nutrient status of groundnut. The higher values of post-harvest soil fertility was registered with 25 kg N/ha and 40 kg S/ha (N_3S_3). This may be because the crop utilized the nutrients more efficiently and consistently. The increase in soil availability with nitrogen and sulphur application could be attributed to the positive impact of sulphur on nutrient mineralization in the soil creating favorable conditions for microbial and chemical activity. This in turn led to increased nutrient availability, in the soil. Similar trends was noticed by Chauhan *et al.,*[6] and Sukirtee *et al.*[25].

Based on the above discussed points, it could be concluded that combination N_4S_4 (34 N + 60 S kg/ha) was found significantly superior for over other treatments. Hence, it is a fitting practice for obtaining higher yield and good quality oil of groundnut in red laterite soil.

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