

# **Yield, nutrient content and their uptake by groundnut (*Arachis hypogaea* L.) as affected by sulphur and planting methods in course textured soil of south-west Haryana**

## **Abstract**

The groundnut, scientifically known as *Arachis hypogaea* L., is a summer legume plant with rising importance in food, industry, and medicine. Sulphur is the master nutrient for oilseed crop production because it helps in the synthesis of cysteine, methionine, vitamins (B, biotin and thiamine), metabolism of carbohydrates, oil content, protein content and also associated with growth and metabolism. This study followed randomised block design conducted over a year (2021-2022) in Bawal utilizing three sulphur levels (0, 25, and 50 kg/ha) and three planting methods (flatbed, flatbed with earthing up, and ridge-furrow). The treatment with 50 kg/ha sulphur in the ridge-furrow method yielded the highest pod yield (2652 kg/ha) and superior nutrient content, including nitrogen, phosphorus, potassium, and sulphur, in both seeds and stover. This treatment also showed superior quality parameters such as oil and protein content and shelling percentage for groundnut. The treatment with 25 kg/ha of sulphur and the flatbed with earthing up method followed closely in performance.

## **INTRODUCTION**

Groundnut (*Arachis hypogaea* L.) is an important oil, food and feed crop of the world belongs to the leguminosae (Fabaceae) family (Variath and Janila, 2017). It is also known as 'King of oilseeds' (Priya *et al.*, 2013), peanuts, earthnuts, manila nuts, jack nuts and monkey nuts. In India groundnut was introduced in the middle of the nineteenth century on east coast of the South Arcot district in Tamil Nadu. Groundnut seed contain 43-55 % oil content (Din *et al.*, 2009), 24-26 % protein, 45-48 % fat, 3% fiber, and 15-18 % carbohydrate (Shokunbiet *al.*, 2012). It is also used as fodder, seeds, straw and hay (Smith, 2002). It is also known as wonder nut and poor men's cashew nut. Besides, the kernels are also rich in vitamin E, K and all B vitamins except B12 (Naiknaware *et al.*, 2015). It is the richest plant source of thiamine and is also rich in niacin, which is low in cereals. It can be used as food (cooking oil, raw, roasted), feed (green material, straw, seed pressings) and in industry for raw material (Onyeike and Oguike, 2003).

India is the second largest producer of groundnut in the world after China followed by USA and Nigeria. About 80 % of total area and 84 % of the total production in the country is

confined to the states of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra but also grown in the states of Rajasthan, Haryana and Punjab. In India during 2020-2021, the area under groundnut was 8528 thousand hectares with a production of 10244 thousand tonnes with productivity of 1703 kg ha<sup>-1</sup> (Anonymous 2020-21). Whereas in Haryana, area under groundnut was 9.25 thousand hectares and production was 9.44 thousand tonnes with an average productivity of 1020 kg ha<sup>-1</sup> during 2020-21 (Anonymous 2020-21). Balanced use of fertilizer is a key component of any oilseed production technology. Groundnut is an energy-rich crop therefore it requires the right quantity and right source of nutrients. Nutrients most often recommended for successful oilseed farming are nitrogen (N), phosphorus (P), potassium (K), sulphur (S), zinc (Zn) and boron (B).

Sulphur (S) is a secondary macronutrient recognized as the fourth major nutrient after nitrogen, phosphorus and potassium (Tandon and Messick, 2002) for plant growth and root development (Jamal *et al.*, 2010). It plays an important role in the catalytic and electrochemical functions of biomolecules in the plant cells. The overall requirement of sulphur for oil seed crops is as high as phosphorus. Sulphur is incredibly vital for the creation of amino acids with sulphur and oil production and also enhances yield as well as crop quality. Sulphur is the master nutrient for oilseed production because it helps in the synthesis of cysteine, methionine, vitamins (B, biotin and thiamine), metabolism of carbohydrates, oil content, protein content and also associated with growth and metabolism, especially by its effect on the proteolytic enzymes (Najar *et al.*, 2011). The application of sulphur improves nitrogenase activity, nitrogen fixation, plant dry matter and the quality of crops in sulphur-deficient soils (Kandpal and Chandel, 1993). It helps in the formation of plant proteins and is essential for chlorophyll formation, nodulation, microbial activity, improves root growth and increases the availability of other nutrients (Singh, 2007).

Groundnuts can be planted using a number of methods which include planting on flat ground (FG), earthing up after planting on flat ground (EFG), planting on raised bed (RB) and planting on ridge (R) (Olayinka *et al.*, 2015). The performance of crop management techniques like nutrient application, irrigation and weed control, among others, is highly dependent on the design of the land. Due to the groundnut's peculiar mechanism, geotropism, a loose and well-aerated soil surface has an advantageous effect on peg penetration and pod development. Earthing up is the raising of the soil around the plant in order to cover the pegs, depending on the cultivar (Mhungu and Chiteka, 2010). Jadhav *et al.* (2022) and found higher growth, yield and yield attributes parameters in ridge and furrow system over flat sowing.

## MATERIALS AND METHODS

The field experiment was conducted at the Regional Research Station, CCS HAU Bawal during *kharif* 2022 in district Rewari at 28.10° N latitude and 76.50° E longitude with 266 m above mean sea level in south-western area of Haryana, India. The climate of Bawal is semi-arid with average rainfall of 577 mm. The soil of experimental field had loamy sand texture with a pH of 8.17, electrical conductivity (EC) 0.18 dS/m, organic carbon (OC) 0.17 %, available nitrogen (113.10 kg/ha), available phosphorus (11.90 kg/ha) and available potassium (162.10 kg/ ha), respectively as micronutrients in 0-15 cm depth. The experiment was laid out in randomized complete block design in triplications on groundnut cultivar GNH 804. Nine treatments were assigned consisting of three sulphur application levels [0 (S<sub>0</sub>), 25 (S<sub>25</sub>), 50 (S<sub>50</sub>) kg S/ha] in plot and three planting methods. The recommended dose of fertilizer (RDF) was 15:50:25 kg for N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O /ha, respectively as par package and practices. The fertilizers (RDF, K<sub>2</sub>O and ZnSO<sub>4</sub>) were applied at the time of sowing through soil application. The soil samples were collected at random from the experiment area up to the depth of 0-15 cm from selected plots before overlaying the treatments and after harvesting the crop and analyzed for its various chemical properties. Soil pH and EC were determined in (1:2) soil:water suspension using digital pH meter and direct read type conductivity meter (Jackson 1973), respectively. Soil OC was determined by the Walkley and Black (1934) method. Available nitrogen was determined by alkaline permanganate method (Subbiah and Asija 1956), available P by spectrophotometer at 420 nm (Olsen et al. 1954), available K by ammonium acetate method using a flame photometer (Jackson 1973). Available sulphur was extracted using a calcium chloride solution at 420 nm (Chesnin and Yien, 1951).

### *Collection and Analysis of plant samples*

Samples of seed and straw were collected at the time of harvesting and dried (65±2 °C for 48 hr). The dried samples thus obtained were ground to a fine powder and processed further for estimation of various macronutrients (N, P, K and S). Total Nitrogen content in the digested plant material was determined by colorimetric method using Nessler's reagent as described by Lindner (1944). Total Phosphorus in plant sample was determined by Vanado-molybdophosphoric acid yellow colour method as proposed by Koenig and Johnson (1942). Potassium in the acid digest of plant samples was determined by using flame photometer. The data on concentration of NPKS, grain yield and straw yield was used to determine the uptake of Nitrogen (N), Phosphorus (P), Potassium (K), and Sulphur (S) using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration in grain/straw (\%)} \times \text{grain/straw yield (kg ha}^{-1}\text{)}}{100}$$

### ***Statistical analysis***

The data recorded during the experiment was subjected to statistical analysis by proper methods using online statistical package OPSTAT developed by Sheoran *et al.* (1998).

## **RESULTS AND DISCUSSION**

### **Effect of sulphur**

#### ***Pod and stover yield***

The pod yield was significantly increased due to application of sulphur up to S<sub>50</sub> treatment. Significantly, the highest pod yield (2652kg ha<sup>-1</sup>) was recorded with S<sub>50</sub> treatment, followed by (2372kg ha<sup>-1</sup>) with S<sub>25</sub> treatment. Both treatments were statistically differ with each other and significantly superior over control (S<sub>0</sub>). The increase in pod yield of groundnut was 6.84, 19.45 % due to application of S<sub>25</sub>, and S<sub>50</sub> treatment, respectively over control S<sub>0</sub> (Table 1).

The application of various levels of sulphur increased the stover yield of groundnut (Table 2). The stover yield of groundnut ranged from 2937 to 3483kg ha<sup>-1</sup>. The stover yield was significantly increased due to the application of sulphur up to S<sub>50</sub> treatment. Significantly, highest stover yield (3483kg ha<sup>-1</sup>) was recorded with S<sub>50</sub> treatment, followed by (3189kg ha<sup>-1</sup>) with S<sub>25</sub> treatment, both the treatments were statistically at par. The lowest stover yield (2937kg ha<sup>-1</sup>) was recorded with control (S<sub>0</sub>). The S<sub>50</sub> and S<sub>25</sub> treatments produced 18.59 and 8.58 % higher stover yield over control respectively.

Moreover, this could be the role of S in various metabolic and enzymatic processes including photosynthesis, respiration, legume-Rhizobium symbiotic N-fixation, protein synthesis and more over higher nutrients uptake resulted in higher plant height and number of branches per plant and ultimately helped in realization of higher crop yield. These results can also be ascribed to effect of sulphur application on cell division, enlargement and elongation resulting in overall improvement in plant organ associated with faster and uniform vegetative growth of the crop. The above results found are in conformity with the results of Banu *et al.* (2017), Patel *et al.* (2018) and Noman *et al.* (2021).

#### ***Nutrient content and uptake by seed and stover***

Sulphur application caused a significant increase in the nutrient content (N, P, K and S) in seed of groundnut. However, the content of nutrients increased with the highest level

i.e., 50 kg S ha<sup>-1</sup> and it significantly differed with 25 kg and 0 kg S ha<sup>-1</sup>. Results showed that total nitrogen, phosphorous, potassium, and sulphur uptake and content in seed were significantly influenced by different sulphur levels. Both S<sub>25</sub> and S<sub>50</sub> treatments recorded significantly higher N (3.43 and 3.56 %), P (0.31 and 0.32 %), K (1.09 and 1.18 %), and S (0.18 and 0.21 %) content and uptake of N (81.87 and 94.54 kg ha<sup>-1</sup>), P (7.40 and 8.61 kg ha<sup>-1</sup>), K (26.16 and 31.41 kg ha<sup>-1</sup>), and S (4.26 and 5.45 kg ha<sup>-1</sup>) in seed as compared to control.

In case of stover, S<sub>25</sub> and S<sub>50</sub> treatments recorded significantly higher N (1.22 and 1.41 %), P (0.17 and 0.20 %), K (0.88 and 0.92 %), and S (0.23 and 0.25 %) content and uptake of N (39.29 and 49.34 kg ha<sup>-1</sup>), P (5.59 and 7.16 kg ha<sup>-1</sup>), K (28.26 and 33.89 kg ha<sup>-1</sup>) and S (7.28 and 9.04 kg ha<sup>-1</sup>) in stover over the control.

Sulphur might have shown the synergistic effect in increasing the P and K uptake in crop. The probable reason for higher uptake of S under higher application of sulphur might have increased their concentration in soil solution, which increased the availability and uptake of sulphur by plant. Sulphur availability may influence photosynthetic rate since ferredoxin and acetyl-CoA contain S and play a significant role in the reduction of CO<sub>2</sub> and production of organic compounds. Also, sulphur is necessary for enzymatic reactions, chlorophyll formation, synthesis of certain amino acids and vitamins, hence, it helps to have a good vegetative growth leading to have a high yield. The results found are in confirmation with the results of Patel and Zinzala (2016), Longkumer *et al.* (2017), Yadav *et al.* (2020), Prusty *et al.* (2020) and Mehmood *et al.* (2021).

### **Effect of planting methods**

#### ***Pod and stover yield***

Application of different planting methods also significantly affected the pod yield of groundnut. Significantly, the highest pod yield (2775 kg ha<sup>-1</sup>) was recorded with **Ridge and Furrow** treatment followed by **Flat with earthing up** (2450 kg ha<sup>-1</sup>), both treatments were statistically different. The lowest pod yield (2019 kg ha<sup>-1</sup>) was recorded with control (**Flatbed**). The **Ridge and Furrow** and **Flat with earthing up** treatment produced 37.44 and 21.34 % higher pod yield over control. The interacting effect between sulphur and planting methods was found significant. (Table 4)

Similarly, in case of stover yield, significantly highest stover yield (3655 kg ha<sup>-1</sup>) was recorded with **Ridge and Furrow** treatment, followed by (3247 kg ha<sup>-1</sup>) with **Flat with earthing up** treatment. However, treatments **Ridge and Furrow** and **Flat with earthing up** were statistically at par with each other. The lowest stover yield (2707 kg ha<sup>-1</sup>) was recorded

with control (flat bed). The increased in stover yield was 35.02, 19.94 % due to application of **Ridge and Furrow and Flat with earthing up** treatments, respectively over control.

The increase in pod and stover yield might be due to ridges provide loose friable soil with and less mechanical compaction that permitted roots to grow profusely with more length compared to flat bed. This treatment offered more opportunity for peg proximity to the soil surface. For instance, it was observed that pegs produced at the upper parts of the branches had a shorter distance to travel and therefore end up in forming pods as a result of uniform distance that was maintained between the pegs and the soil surface as the branches extend outward from the main stem. It is also because excess rainfall is properly directed through furrows. It also increases water-use efficiency both under rainfed and irrigated scenarios because water moves laterally from furrows into beds thereby reducing evaporation losses. Similar results were found by Mathukia *et al.* (2014), Olayinka *et al.* (2015), Mvumiet *al.* (2018), Olayinka *et al.* (2021), and Chowdary *et al.* (2022).

#### ***Nutrient content and uptake by seed and stover***

Results showed that nutrient content was found to be influenced significantly by the planting methods and their uptakes were also influenced significantly. The application of **Ridge and Furrow method** showed significantly higher values of uptake of nitrogen (98.01 kg ha<sup>-1</sup> and 50.43 kg ha<sup>-1</sup>) by seed and stover in Table 2.

Ridge-furrow plays a vital role in enhancing growth, which may be attributed to more conducive soil condition like proper aeration and adequate availability of moisture essential for emergence that resulted in more crop productivity. Better nutrient uptake in raised bed planting might be due to the fact that ridge-furrow planting resulted in better utilization of available resources like water, nutrients and sunlight due to favorable microclimate. Similar findings were also illustrated by Singh *et al.* (2021), Dodwadiya and Sharma (2012).

From the findings, it can be concluded that both the seed and stover yield of groundnut significantly increased over the control with the application of S @ 50 kg ha<sup>-1</sup> and ridge-furrow method. Also, the application of sulphur @ 50 kg ha<sup>-1</sup> and ridge-furrow planting method significantly increases the nutrient content and uptake in seed and stover of groundnut in coarse-textured medium S status soil.

## **Quality Parameters**

### **Effect of sulphur**

The quality parameters such as protein content, oil content and shelling percentage are presented in Table 3. Application of sulphur significantly increased the protein, oil content and shelling %. Significantly, higher protein, oil content and shelling (22.26 ,47.80 and 67.85 %) was recorded with S<sub>50</sub> treatment, followed by (21.42, 45.65 and 66.08 %) with S<sub>25</sub> treatment respectively over control. These both the treatments were statistically differ with each other and significantly superior over control. The lowest protein, oil content and shelling (19.51, 43.36 and 64.70%) were recorded with control (S<sub>0</sub>), respectively. This might be due to the fact that sulphur application improved over all nutritional environment of the Rhizosphere as well as plant system which could be more advantageous for profused vegetative and root growth which activated higher absorption of nutrients from the soil and improved metabolic activities inside the plant. These results may be attributed to the sulphur plays an important role in synthesis of essential amino acids like cysteine, methionine and certain vitamin like biotin, thymine as well as the formation of ferredoxin (iron-containing plant protein) that act as an electron carrier in the photosynthetic process and chlorophyll which required for the production of oil. Sulphur besides being a structural component of protein is also directly involved in protein bio-synthesis This might be due to the synergistic effect of sulphur on nitrogen uptake which facilitates protein synthesis and activates different enzymes. The results are found to be similar with the results from Rao *et al.* (2013), Kannan *et al.* (2017), Patel *et al.* (2018) and Prusty *et al.* (2020).

#### **Effect of planting methods**

The quality parameters such as protein content, oil content and shelling percentage are presented in Table 3. Significant differences were observed among the different planting methods evaluated. The findings revealed that the application of ridge-furrow method significantly influences the protein, oil content and shelling of groundnut. Protein, oil content and shelling varied from 22.06, 46.25 and 67.85 percent under the treatment ridge-furrow followed by the treatment flat bed with earthing up (20.99, 45.75 and 66.27%) while, the minimum value of protein, oil content and shelling (20.14, 44.82 and 64.51%) were observed under control (flatbed) respectively. The results are in agreement with the findings of Olayinka *et al.* (2015).

**Table 1. Effect of S levels and planting method on yields and quality parameters of groundnut**

Treatment	Pod yield (q/ha)	Stover yield (qha)	Oil (%)	Protein (%)	Shelling (%)
<b>S levels (kg/ha)</b>					
0	22.20	29.37	45.36	19.51	64.70

25	23.72	31.89	45.65	21.42	66.08
50	26.52	34.83	47.80	22.26	67.85
CD (p=0.05)	1.25	3.27	1.51	0.63	1.55
<b>Planting Methods</b>					
Flat Bed	20.19	27.07	44.82	20.14	64.51
Flat bed with earthing up	24.50	32.47	45.75	20.99	66.27
Ridge and Furrow	27.75	36.55	46.25	22.06	67.85
CD (p=0.05)	1.25	3.27	NS	0.63	1.55
Interaction	2.16	NS	NS	NS	NS

**Table 2. Effect of S levels and planting method on nutrient content and their uptake in groundnut**

Treatment	Content in seed (%)				Uptake (kg/ha)			
	N	P	K	S	N	P	K	S
<b>S levels (kg/ha)</b>								
0	3.12	0.29	0.99	0.16	69.75	6.57	22.21	3.64
25	3.43	0.31	1.09	0.18	81.87	7.40	26.16	4.26
50	3.56	0.32	1.18	0.21	94.54	8.61	31.41	5.45
CD (p=0.05)	0.11	0.01	0.07	0.01	4.36	0.46	2.39	0.41
<b>Planting Methods</b>								
Flat Bed	3.20	0.29	0.96	0.17	65.56	5.94	19.52	3.52
Flat bed with earthing up	3.33	0.31	1.10	0.18	82.59	7.64	27.15	4.53
Ridge and Furrow	3.53	0.32	1.19	0.19	98.01	9.01	33.10	5.30
CD (p=0.05)	0.10	0.02	0.07	NS	4.35	0.46	2.39	0.41
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

**Table 3. Effect of S levels and planting methods on nutrient content and their uptake in groundnut**

Treatment	Content in stover (%)				Uptake (kg/ha)			
	N	P	K	S	N	P	K	S
<b>S levels (kg/ha)</b>								
0	1.12	0.16	0.85	0.20	33.65	4.75	25.09	5.97
25	1.22	0.17	0.88	0.23	39.29	5.59	28.26	7.28
50	1.41	0.20	0.92	0.25	49.34	7.16	33.89	9.04
CD (p=0.05)	0.18	0.02	NS	0.01	7.50	0.60	4.83	0.82
<b>Planting Methods</b>								
Flat Bed	1.11	0.17	0.79	0.19	30.17	4.49	21.46	5.18
Flat bed with earthing up	1.27	0.18	0.88	0.22	41.67	5.77	29.69	7.28

Ridge and Furrow	1.37	0.20	0.98	0.27	50.43	7.25	36.09	9.82
CD (p=0.05)	0.18	0.02	0.08	0.01	7.50	0.60	4.83	0.82
Interaction	NS	NS	NS	0.02	NS	NS	NS	1.23

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