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# Effect of sulphur sources and levels on yield, quality and nutrient uptake by *kharif* groundnut (*Arachis hypogaea* L.) in loamy sand

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## Abstract
An experiment was conducted during *kharif* season of the year 2021 at Agronomy Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar to study the "Effect of sulphur sources and levels on yield, quality and nutrient uptake by *kharif* groundnut (*Arachis hypogaea* L.) in loamy sand". Nine treatment combinations comprising three sources of sulphur (Bentonite sulphur, liquid sulphur and gypsum) and three levels of sulphur (15, 30 and 45 kg $ha^{-1}$) were evaluated in randomized block design with four replication. An application of sulphur @ 45 kg S $ha^{-1}$ through gypsum recorded significantly higher pod yield, haulm yield; protein content, oil content in kernel; uptake of N, P, K and S by kernel and haulm of groundnut crop over rest of treatments. An application of sulphur improved the available sulphur status in soil.

**Keywords:** Sulphur, quality parameter, groundnut

## Introduction
Groundnut (*Arachis hypogaea* L.) is a self-pollinated, annual, herbaceous, autotetraploid legume belonging to the family leguminosae (Fabaceae) and popularly called as POOR MAN'S ALMOND.

India rank first in the world in respect of area and second in production after China. In India, total groundnut area was 49.14 lakh hectares and production of 82.03 lakh MT with productivity of 1669 kg $ha^{-1}$ during *kharif* 2021 (IOPEPC). In India, it is mainly grown in Gujarat, Andhra Pradesh, Maharashtra, Uttar Pradesh, Tamil Nadu and Punjab. Among the groundnut producing states, Gujarat is the topmost state both in area and production. In Gujarat, groundnut is cultivated during *kharif* as well as summer seasons. In Gujarat *kharif* groundnut area, production and productivity were 2070.05 thousand hectares, 5464.69 thousand tonnes and 2637.34 kg $ha^{-1}$, respectively during the year of 2020-21 (Anonymous, 2020-21). In Gujarat, largely cultivated districts are Junagadh, Rajkot, Dwarka, Banaskantha, Amreli, Jamnagar, Bhavnagar, Gir Somnath and Kutch. Within Gujarat, the Saurashtra region is considered as "bowl of groundnut". It has been witnessed that the area under groundnut is also increasing in potato growing areas of North Gujarat considerably because of suitable agro climatic conditions and coarse texture soil.

Sulphur is now widely accepted as fourth major plant nutrient along with N, P and K. It involves in the synthesis of essential amino acids and oil in oilseed crops, being vital component of co-enzyme involved in oil synthesis. It also involves in various metabolic and enzymatic processes including photosynthesis, respiration and legume rhizobium symbiotic nitrogen fixation. The role of sulphur in plant make it of fundamental importance in increasing the productivity of crops especially legume oilseeds in India, where more than 50% of soils have been reported to be deficient in sulphur (Tewatia, *et al*. 2006) [27].

Sulphur is a constituent of protein and plays an important role in oil synthesis. The groundnut is rich both in oil and protein; requirement of sulphur for this crop is substantial. Sulphur is identified as a key element for increasing the production of oilseeds by increasing the uptake of various macro and micro nutrients in groundnut (Singh, 1999) [24]. In addition, application of sulphur in soil also regulates the pH and increase the availability of other nutrients. It improves nodulation, pod yield and reduces the incidence of diseases. Sulphur increases chlorophyll and decreases chlorosis. In India, sulphur deficiency occur in a scattered manner in about 180 districts and yield response of about 40 crops were observed to sulphur application (Tandon, 1991) [26].

Bentonite sulphur is one of the concentrated source of sulphur. Bentonite sulphur is straight sulphatic fertilizer containing sulphur and bentonite clay. The Sulphur present is 90% in this fertilizer and the highest among other categories of sulphatic fertilizer. This makes bentonite sulphur more effective in terms of supplying sulphur to crop.

Liquid sulphur is one of the concentrated source of sulphur in liquid form. Liquid sulphur is easy to apply with other nutrients or crop protection products. Liquid sulphur easy to apply at planting or throughout the growing season.

Gypsum is another material huge deposits of which are found in the state of Rajasthan and being excavated at large scale. It acts as a source of two main plant nutrients i.e calcium and sulphur. Basically gypsum is used for soil amendments to improve chemical and physical properties of soil. It is commonly used as amendment for sodic soil reclamation.

Information are lacking on the effect of sulphur sources and levels on yield, quality and nutrient uptake by *kharif* groundnut, the present study was planned to assess the effect sulphur sources and levels on yield, quality and nutrient uptake by *kharif* groundnut.

## Materials and Methods

The field experiment was conducted during *kharif* season of 2021 to find out the effect of sulphur sources and levels on growth and yield of groundnut at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha (Gujarat).

Nine treatment combinations comprising three sources of sulphur (Bentonite sulphur, liquid sulphur and gypsum) and three levels of sulphur (15, 30 and 45 kg ha$^{-1}$) were evaluated in randomized block design with four replication. Groundnut variety Gujarat Groundut 20 was used as a test crop. The soil of experimental field was loamy sand in texture with slightly alkaline in reaction and electrical conductivity within safe limit. The soil was low in organic carbon and available nitrogen, medium in available $P_2O_5$ and $K_2O$ and deficient in available S.

A common dose of nitrogen and phosphorus @ 12.5 kg ha$^{-1}$ and 25 kg ha$^{-1}$ were applied for all treatments. The common dose of FYM (5 t ha$^{-1}$) was applied on total experimental area before a week of sowing Sulphur was applied in the form of Bentonite sulphur, Liquid sulphur, and Gypsum as per the treatments on the basis of content of sulphur. Other agronomic management practices were followed as per standard recommendations.

The data on pod and haulm yield were recorded from net plot and converted on hectare basis. The representative dry sample of pod and haulm were analyzed for quality parameter and nutrient content. The oil content was determined as per the method suggested by Tiwari *et al*. (1974) [28]. The N, P and K content were analyzed by micro Kjeldhal, vanado-molybdate phosphoric yellow color and flame photometric method, respectively (Jackson, 1973) [15]. The protein content in kernel was computed by multiplying the nitrogen content with 6.25 for each treatment (Gupta *et al.*, 1973) [12]. The sulphur content was estimated by turbidimetric method suggested by Chaudhary & Cornfield (1966) [6]. Uptake of each nutrient was computed on the basis of content of nutrient and yield of kernel and haulm.

The representative soil sample from 0-15 cm depth were collected from each net plot after harvest of groundnut crop. These sample were then grind using wooden mortar and pestle and passed through 2 mm sieve and analyzed for available N, $P_2O_5$, $K_2O$ and S in soil as per standard analytical methods. Data was statistically analyzed by the procedure described by the Panse and Sukhatme (1985) [19].

## Results and Discussion

### Effect on yield

Application of 45 kg S ha$^{-1}$ through gypsum ($T_9$) recorded significantly the highest pod yield (2442 kg ha$^{-1}$) but remained statistically at par with treatments $T_3$ (45 kg S ha$^{-1}$ through bentonite sulphur), $T_6$ (45 kg S ha$^{-1}$ liquid sulphur) and $T_8$ (30 kg S ha$^{-1}$ through gypsum). Whereas, significantly the lowest pod yield (1922 kg ha$^{-1}$) was noted under treatment $T_4$ (15 kg S ha$^{-1}$ through liquid sulphur). Gypsum also provides Ca and mobilization of Ca from soil to the pod in groundnut crop takes place through the gynophores so the amount of Ca transported decides the pod yield. It also emphasized that Ca application also reduce the ovule abortion and enhanced pod development, thus, result in higher pod yields.

Maximum availability of sulphur helps in stimulating photosynthesis and seed formation as well as synthesis of sulphur containing amino acids, proteins, chlorophyll, and promoting nodulation may be assigned to increase total biomass production which was finally reflected in increment in pod yield of groundnut. Similar results were also found by Chaubey *et al.* (2000) [5], Vaghasia *et al.* (2007) [29], Rao *et al.* (2013) [22], Naiknaware *et al*. (2015) [18], Banu *et al.* (2017) [4], Yadav *et al.* (2017) [30] and Dudekula *et al.* (2021) [9].

The results recorded in Table 1 indicated that the haulm yield of groundnut differed significantly due to different sources and levels of sulphur. Significantly the maximum haulm yield (3443 kg ha$^{-1}$) was recorded under the treatment $T_9$ (45 kg S ha$^{-1}$ through gypsum), but remained statistically at par with treatments $T_3$ (45 kg S ha$^{-1}$ through bentonite sulphur), $T_6$ (45 kg S ha$^{-1}$ liquid sulphur) and $T_8$ (30 kg S ha$^{-1}$ through gypsum). These results can 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 results were in line of results of those reported by Rao *et al.* (2013) [22], Naiknaware *et al*. (2015) [18], Banu *et al.* (2017) [4], Yadav *et al.* (2017) [30] and Aier and Nongmaithem (2020) [1].

### Effect on quality parameter

The results recorded in Table 1 indicated that the effect of sources and levels of sulphur on oil content was differed significantly. Significantly the maximum oil content (49.96%) was recorded under the treatment $T_9$ (45 kg S ha$^{-1}$ through gypsum), but remained statistically at par with treatments $T_3$ (45 kg S ha$^{-1}$ through bentonite sulphur), $T_6$ (45 kg S ha$^{-1}$ liquid sulphur) and $T_8$ (30 kg S ha$^{-1}$ through gypsum). Whereas, significantly the lowest oil content (46.17%) was noted under treatment $T_4$ (15 kg S ha$^{-1}$ through liquid sulphur).

This might be attributed to sulphur plays an important role in synthesis of S-containing 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.

The increased oil content and subsequently its yield might be attributed to the greater uptake of sulphur by plants through gypsum which is necessarily required in the formation of S-containing fatty acids responsible for oil synthesis. Higher oil yield under gypsum source is also the outcome of higher kernel yield under this treatment. Results of the present investigation are in agreement with the findings of Poonia *et al.* (2013) [21], Sisodiya *et al*. (2016) [25], Banu *et al.* (2017) [4], Elakiya *et al.* (2020) [10] and Yadav *et al.* (2020) [31] in groundnut.

The analysis data presented in Table 1 indicated that sources and levels of sulphur evolved their significant influence on protein content. Significantly the maximum protein content (22.79%) was recorded under the treatment $T_9$ (45 kg S $ha^{-1}$ through gypsum), but remained statistically at par with treatments $T_3$ (45 kg S $ha^{-1}$ through bentonite sulphur), $T_6$ (45 kg S $ha^{-1}$ liquid sulphur) and $T_8$ (30 kg S $ha^{-1}$ through gypsum). Whereas, significantly the lowest protein content (20.15%) was noted under treatment $T_4$ (15 kg S $ha^{-1}$ through liquid sulphur).

Sulphur, besides a structural component of protein, is also directly involved in protein bio-synthesis. The results are in conformity with the findings of Sisodiya *et al*. (2016) [25], Yadav *et al.* (2017) [30] and Yadav *et al.* (2020) [31] in groundnut.

**Effect on nutrient uptake**

The data presented in Table 2 indicated that varying sources and levels of sulphur significantly influenced the uptake of nitrogen by kernel and haulm of groundnut. Among different treatments, treatment $T_9$ (45 kg S $ha^{-1}$ through gypsum) gave significantly the highest uptake of nitrogen by kernel (63.58 kg $ha^{-1}$) and haulm (54.79 kg $ha^{-1}$) which was at par with treatments $T_3$ (45 kg S $ha^{-1}$ through bentonite sulphur), $T_6$ (45 kg S $ha^{-1}$ liquid sulphur) and $T_8$ (30 kg S $ha^{-1}$ through gypsum). While, significantly the lowest nitrogen uptake by kernel (40.22 kg $ha^{-1}$) and haulm (37.83 kg $ha^{-1}$) was recorded under treatment $T_4$ (15 kg S $ha^{-1}$ through liquid sulphur).

The increased uptake of nitrogen by groundnut due to increase levels of sulphur might be attributed to favorable effect of sulphur application on growth and yield attributes which resulted in to higher pod and haulm yield. The added nutrients and synergetic effect N and S might have enhanced the microbial activities resulting in higher nitrogen fixation, profuse plant and root growth which ultimately increased total uptake of nitrogen. The results are in close agreement with the findings reported by Kalaiyarasan *et al.* (2007) [16], Giri *et al*. (2014) [11], Patel and Zinzala (2018) [20] and Ravikumar *et al*. (2020) [23] in groundnut.

The data presented in Table 2 indicated that varying sources and levels of sulphur significantly influenced the uptake of phosphorus by kernel and haulm of groundnut. Among different treatments, treatment $T_9$ (45 kg S $ha^{-1}$ through gypsum) gave significantly the highest uptake of phosphorus by kernel (7.72 kg $ha^{-1}$) and haulm (6.48 kg $ha^{-1}$) which was at par with treatments $T_3$ (45 kg S $ha^{-1}$ through bentonite sulphur), $T_6$ (45 kg S $ha^{-1}$ liquid sulphur) and $T_8$ (30 kg S $ha^{-1}$ through gypsum). While, significantly the lowest phosphorus uptake by kernel (4.91 kg $ha^{-1}$) and haulm (4.41 kg $ha^{-1}$) was recorded under treatment $T_4$ (15 kg S $ha^{-1}$ through liquid sulphur).

Sulphur might have shown the synergistic effect in increasing the P uptake by kernel and haulm. This may be ascribed to increase in pod and haulm yield of groundnut in present investigation. The findings are in close agreement with those obtained Kalaiyarasan *et al.* (2007) [16], Patel and Zinzala (2018) [20] and Ravikumar *et al*. (2020) [23] in groundnut.

The data presented in Table 2 indicated that varying sources and levels of sulphur significantly influenced the uptake of potassium by kernel and haulm of groundnut. Among different treatments, treatment $T_9$ (45 kg S $ha^{-1}$ through gypsum) gave significantly the highest uptake of potassium by kernel (9.76 kg $ha^{-1}$) and haulm (27.52 kg $ha^{-1}$) which was at par with treatments $T_3$ (45 kg S $ha^{-1}$ through bentonite sulphur), $T_6$ (45 kg S $ha^{-1}$ liquid sulphur) and $T_8$ (30 kg S $ha^{-1}$ through gypsum). While, significantly the lowest potassium uptake by kernel (6.38 kg $ha^{-1}$) and haulm (19.85 kg $ha^{-1}$) was recorded under treatment $T_4$ (15 kg S $ha^{-1}$ through liquid sulphur).

Sulphur might have shown the positive effect on increasing the K uptake by plant. This may be ascribed to increase in pod and haulm yield of groundnut in present investigation. The findings are in close agreement with those obtained by Kalaiyarasan *et al.* (2007) [16], Patel and Zinzala (2018) [20] and Ravikumar *et al*. (2020) [23] in groundnut.

The data presented in Table 2 indicated that varying sources and levels of sulphur significantly influenced the uptake of sulphur by kernel and haulm of groundnut. Among different treatments, treatment $T_9$ (45 kg S $ha^{-1}$ through gypsum) gave significantly the highest uptake of sulphur by kernel (6.35 kg $ha^{-1}$) and haulm (18.29 kg $ha^{-1}$) which was at par with treatments $T_3$ (45 kg S $ha^{-1}$ through bentonite sulphur), $T_6$ (45 kg S $ha^{-1}$ liquid sulphur) and $T_8$ (30 kg S $ha^{-1}$ through gypsum). While, significantly the lowest sulphur uptake by kernel (3.97 kg $ha^{-1}$) and haulm (12.76 kg $ha^{-1}$) was recorded under treatment $T_4$ (15 kg S $ha^{-1}$ through liquid sulphur).

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. More over increasing trend of pod and haulm yield as well as S content in kernel and haulm by sulphur application. The findings are in close agreement with those obtained by Kalaiyarasan *et al.* (2007) [16], Patel and Zinzala (2018) [20] and Ravikumar *et al*. (2020) [23] in groundnut.

**Effect on available nutrients content in soil**

An appraisal of data given in Table 1 indicated that different sources and levels of sulphur did not exert its significant effect on available nitrogen, phosphorus and potash content in soil after harvest of crop.

Application of different sources and levels of sulphur significantly increased its availability in soil after harvest of crop. An increasing trend in sulphur content in soil was observed with increased in rate of sulphur application. Significantly the highest available sulphur (10.85 mg $kg^{-1}$) was recorded under the treatment $T_9$ (45 kg S $ha^{-1}$ through gypsum) as compared to other treatments. The lowest available sulphur (9.06 mg $kg^{-1}$) was noted with treatment $T_4$ (15 kg S $ha^{-1}$ through liquid sulphur).

This increased might be due to amelioration effect of sulphur and improved physic-chemical properties of soil and due to addition of sulphur in soil resulted in residual availability of sulphur in soil after harvest of groundnut. Similar results were also reported by Jat and Ahlawat (2009) [13] in groundnut, Chattopaddhyay *et al.* (2012) [8], Kumar *et al.* (2018) and Chauhan *et al*. (2020) [7] in mustard and Jat *et al.* (2017) [14] in sesame.

**Table 1:** Effect of sulphur sources and levels on growth parameter and yield attributes of *kharif* groundnut

| Treatments | Pod yield (kg ha$^{-1}$) | Haulm yield (kg ha$^{-1}$) | Oil content (%) | Protein content (%) | Available nutrients in soil (kg ha$^{-1}$) | | | Sulphur (mg kg$^{-1}$) |
|---|---|---|---|---|---|---|---|---|
| | | | | | N | $P_2O_5$ | $K_2O$ | |
| $T_1$ : 15 kg S ha$^{-1}$ through Bentonite sulphur | 1940 | 2748 | 46.53 | 20.32 | 139.24 | 28.25 | 207.97 | 9.21 |
| $T_2$ : 30 kg S ha$^{-1}$ through Bentonite sulphur | 2145 | 3035 | 47.00 | 20.80 | 143.78 | 30.13 | 209.73 | 9.99 |
| $T_3$ : 45 kg S ha$^{-1}$ through Bentonite sulphur | 2400 | 3384 | 49.86 | 22.40 | 148.50 | 31.83 | 213.19 | 10.75 |
| $T_4$ : 15 kg S ha$^{-1}$ through Liquid sulphur | 1922 | 2709 | 46.17 | 20.15 | 138.75 | 27.79 | 207.14 | 9.06 |
| $T_5$ : 30 kg S ha$^{-1}$ through Liquid sulphur | 2097 | 2955 | 46.93 | 20.65 | 143.09 | 29.54 | 209.10 | 9.81 |
| $T_6$ : 45 kg S ha$^{-1}$ through Liquid sulphur | 2389 | 3367 | 49.77 | 22.05 | 147.55 | 31.06 | 212.06 | 10.60 |
| $T_7$ : 15 kg S ha$^{-1}$ through Gypsum | 2041 | 2918 | 46.64 | 20.53 | 144.46 | 28.94 | 208.54 | 9.38 |
| $T_8$ : 30 kg S ha$^{-1}$ through Gypsum | 2353 | 3342 | 48.94 | 22.00 | 143.98 | 30.53 | 210.78 | 10.12 |
| $T_9$ : 45 kg S ha$^{-1}$ through Gypsum | 2442 | 3443 | 49.96 | 22.79 | 149.22 | 32.34 | 213.97 | 10.85 |
| S. Em. ± | 101 | 139 | 1.01 | 0.64 | 5.24 | 1.20 | 6.93 | 0.28 |
| C.D. (P=0.05) | 294.64 | 406.26 | 2.95 | 1.86 | NS | NS | NS | 0.82 |
| C.V. (%) | 9.21 | 8.98 | 4.21 | 6.00 | 7.26 | 8.00 | 6.59 | 5.63 |

**Table 2:** Effect of different sources and levels of sulphur on nutrient uptake by kernel and haulm of *kharif* groundnut

| Treatments | Nutrient uptake (kg ha$^{-1}$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Nitrogen | | Phosphorus | | Potassium | | Sulphur | |
| | Kernel | Haulm | Kernel | Haulm | Kernel | Haulm | Kernel | Haulm |
| $T_1$ : 15 kg S ha$^{-1}$ through Bentonite sulphur | 41.05 | 38.37 | 5.20 | 4.59 | 6.51 | 20.53 | 4.07 | 13.00 |
| $T_2$ : 30 kg S ha$^{-1}$ through Bentonite sulphur | 47.32 | 43.88 | 6.16 | 5.30 | 7.64 | 23.68 | 4.77 | 14.87 |
| $T_3$ : 45 kg S ha$^{-1}$ through Bentonite sulphur | 60.90 | 52.94 | 7.31 | 6.26 | 9.41 | 26.85 | 6.11 | 17.57 |
| $T_4$ : 15 kg S ha$^{-1}$ through Liquid sulphur | 40.22 | 37.83 | 4.91 | 4.41 | 6.38 | 19.85 | 3.97 | 12.76 |
| $T_5$ : 30 kg S ha$^{-1}$ through Liquid sulphur | 45.15 | 42.49 | 5.84 | 5.07 | 7.27 | 22.67 | 4.56 | 14.28 |
| $T_6$ : 45 kg S ha$^{-1}$ through Liquid sulphur | 59.16 | 51.52 | 7.44 | 6.14 | 9.12 | 26.64 | 5.98 | 17.10 |
| $T_7$ : 15 kg S ha$^{-1}$ through Gypsum | 44.26 | 41.66 | 5.70 | 4.96 | 7.10 | 22.15 | 4.39 | 13.99 |
| $T_8$ : 30 kg S ha$^{-1}$ through Gypsum | 56.82 | 50.44 | 7.06 | 6.03 | 8.72 | 26.30 | 5.67 | 16.66 |
| $T_9$ : 45 kg S ha$^{-1}$ through Gypsum | 63.58 | 54.79 | 7.72 | 6.48 | 9.76 | 27.52 | 6.35 | 18.29 |
| S. Em. ± | 3.48 | 2.33 | 0.38 | 0.33 | 0.44 | 1.52 | 0.26 | 0.86 |
| C.D. (P=0.05) | 10.17 | 6.81 | 1.11 | 0.96 | 1.28 | 4.42 | 0.75 | 2.50 |
| C.V. (%) | 13.68 | 10.14 | 11.95 | 12.05 | 11.01 | 12.62 | 10.09 | 11.12 |

## Conclusion
Based on one year investigation, it can be concluded that for getting higher yield as well as for improving quality of *kharif* groundnut the crop should be fertilized with 30 kg S ha$^{-1}$ through gypsum along with recommended dose of nitrogen and phosphorus (12.5:25 N:$P_2O_5$ Kg ha$^{-1}$**)** in loamy sand.

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