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Effect of potassium and sulphur on yield, quality and nutrient uptake by summer groundnut in loamy sand

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Abstract
An experiment was conducted during summer season of the year 2020 at Agronomy Instructional Farm, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar to study the "Effect of potassium and sulphur on yield, quality and nutrient uptake by summer groundnut (*Arachis hypogeal* L.) In loamy sand". Nine treatment combinations comprising three levels of potassium (0, 25 and 50 kg ha^{-1}) and three levels of sulphur (15, 30 and 45 kg ha^{-1}) were evaluated in randomized block design with factorial concept with three replications. An application of potassium @ 50 kg K_2O ha^{-1} recorded significantly higher pod yield, haulm yield protein content, oil content in kernel; oil yield, total uptake of N, P, K and S by groundnut crop as compared to 0 kg K_2O ha^{-1}. Potassium availability was significantly increased with increasing levels of potassium. Among different sulphur levels, application of 45 kg S ha^{-1} recorded significantly higher pod yield, haulm yield, protein content, oil content in kernel; oil yield, total uptake of N, P, K and S by groundnut crop as compared to 15 kg S ha^{-1}. An application of sulphur improved the available sulphur status in soil.

Keywords: Potassium, sulphur, quality parameter, groundnut

Introduction
Groundnut (*Arachis hypogaea* L.) is an important summer oil seed crop and food grain legume. Groundnut cultivation occurs in 108 countries around the world, which is grown in all tropical and subtropical countries. It is a valuable cash crop planted by millions of small farmers because of its economic and nutritional value. About two thirds of world production is crushed for oil and remaining one third is consumed as food. Groundnut (*Arachis hypogaea* L.) is important oilseed crop belong to family *Leguminosae* and popularly called as Poor Man's Almond.

Groundnut (*Arachis hypogaea* L.) contains high quality edible oil (48 per cent), easily digestible protein (26 per cent) and carbohydrates (20 per cent) therefore considered as "king of oilseed" among the oilseed crops and botanically classified in family Fabaceae India ranks first in the world in respect of area and second in production after China. In India, total groundnut area was 39.31 lakh hectares and production of 68.62 lakh MT with productivity of 1745 kg ha^{-1} during the year of 2019 (IOPEPC). In Gujarat, summer and *kharif* groundnut area, production and productivity were 33,920 and 15.52 lakh hectares, 84,000 MT and 29.38 lakh MT and 2476 kg ha^{-1} and 1893 kg ha^{-1}, respectively during the year of 2019 (Anonymous, 2019-20) [1].

Potassium is one of the major essential nutrient elements required by plants. Among the three major nutrients, Potassium (K) has a special position as evident by its role in increasing the crop yield (Yadav, *et al*., 2003) [42] by adding tolerance to various biotic and abiotic stresses. Potassium plays a major role in improving growth and yield of crop as it is involved in assimilation, transport and storage tissue development (Cakmak, 2005) [11]. Potassium is the second most absorbed nutrient by the peanut crop (Tasso *et al*., 2004) [39]. Though potassium is not a constituent of any compound or structurally bound in groundnut, it is required for translocation of assimilates and involved in maintenance of water status of plant especially the turgor pressure of cells and opening and closing of stomata and increase the availability of metabolic energy for the synthesis of starch and proteins. Besides, it increased peg formation, nodulation, synthesis of sugar and starch and help in pod growth and development.

Sulphur is the fourth major nutrient and plays an important role in the nutrition of oil-seed crop and as a constituent of sulphur containing amino acids cystine, cysteine and methionine. (Gangadhara *et al*., 1990) [18]. They considered that the oil-seeds require more sulphur than other crops; its concentration and uptake vary with the availability of sulphur in soil.

The overall requirement of sulphur for oil seed crops is as high as phosphorus (Aulakh *et al*. 1988) [2]. In oil seed crops, it is also involved in the formation of glucocides or glucosinolates which on hydrolysis increase the oil content. One of the main functions of sulphur in proteins or polypeptides is the formation of disulphide bonds between polypeptide chains. The application of sulphur increased the uptake of various macro and micro nutrients in groundnut (Singh, 1999) [36]. Information are lacking on the effect of potassium and sulphur on yield, quality and nutrient uptake by summer groundnut, the present study was planned to assess the effect of potassium and sulphur on yield, quality and nutrient uptake by summer groundnut.

Materials and Methods

The field experiment was conducted during summer season of 2020 to find out the effect of potassium and sulphur on yield, quality and nutrient uptake by summer 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 levels of potassium (0, 25 and 50 kg K_2O ha^{-1}) and three levels of sulphur (15, 30 and 45 kg S ha^{-1}) were tried in factorial randomized block design with three replications. Groundnut variety Gujarat Groundnut 2 was used as a test crop. The soil of experimental field was loamy sand in texture, slightly alkaline in nature, low in organic carbon, available Zn and Cu; medium in available P_2O_5, available S, Fe and Mn and high in available K_2O, available nitrogen.

A common dose of nitrogen and phosphorus @ 25 kg ha^{-1} and 50 kg ha^{-1} were applied for all treatments. Potassium and sulphur were applied in form of murite of potash and bentonite sulphur, respectively as per treatments. Other agronomic management practices were followed as per standard recommendation.

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) [38]. The N, P and K content were analyzed by micro Kjeldhal, Vanado-Molybdate phosphoric yellow color and flame photometric method, respectively (Jackson, 1973) [22]. The protein content in kernel was computed by multiplying the nitrogen content with 6.25 for each treatment (Bhuija and Chaowdhary, 1974) [6]. The sulphur content was estimated by turbidimetric method suggested by Chowdhary & Cornfield (1966) [8]. The total uptake of each nutrient was computed on the basis of content of nutrient and yield of pod and haulm.

The representative soil sample from 0-15 cm depth was collected from each net plot after harvest of groundnut crop. These samples were then grind using wooden mortar and pestle and passed through 2.00 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 Suktane (1985) [27].

Results and Discussion

Pod yield

Application of potassium @ 50 kg K_2O ha^{-1} recorded significantly higher pod yield (2281 kg ha^{-1}) as compared to 0 kg K_2O ha^{-1}, but it was at par with application of potassium @ 25 kg K_2O ha^{-1} (Table 1). The lowest pod yield (2040 kg ha^{-1}) was recorded with treatment K_0 (00 kg K_2O ha^{-1}). Beneficial effect of potassium on pod production is attributed to its role in plant nutrition, physiological and metabolic processes, including photosynthesis, transport of nutrients, transport and storage of carbohydrates from which fat has synthesized, nitrogen absorption and synthesis of proteins and starch. The present result is in close agreement with the result obtained by Hadwani *et al.* (2005) [19], Chandra *et al.* (2006) [12] and Hemeid (2015) [20].

Application of 50 kg K_2O ha^{-1} recorded significantly higher haulm yield (3390 kg ha^{-1}) which was at par with treatment receiving 25 kg K_2O ha^{-1} (Table 1). The lowest haulm yield (3058 kg ha^{-1}) was recorded with 00 kg K_2O ha^{-1} application. Potassium also make a pronounced role in carbohydrates synthesis, photosynthesis cell elongation, stomatal activity and higher nutrient uptake under this level resulted in higher plant height and number of branches per plant and ultimately helped in realization of higher haulm yield. The similar result was obtained by Hadwani *et al.* (2005) [19] and Chandra *et al.* (2006) [12] in groundnut and Jadeja *et al.* (2016) in chickpea.

Significantly higher pod yield (2267 kg ha^{-1}) was noted with application 45 kg S ha^{-1} but it was at par with treatment receiving 30 kg S ha^{-1} (Table 1). However, pod yield of groundnut was recorded from 30 kg S ha^{-1} and 15 kg S ha^{-1} was at par with each other. 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 Vaghasia *et al.* (2007) [41], Yadav *et al.* (2017) [43] and Dudekula *et al.* (2021) [15].

Sulphur application @ 45 kg ha^{-1} produces significantly highest haulm yield (3399 kg ha^{-1}) as compared to 15 kg S ha^{-1}, but it was at par with 30 kg S ha^{-1} (Table 1). 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) [31], Noman *et al.* (2015) [24], Pawar *et al.* (2015) [28] and Aier and Nongmaithem (2020) [4].

Effect on quality parameter

Application of 50 kg K_2O ha^{-1} recorded significantly higher protein content (23.67 %), but it was remained at par with the treatment receiving 25 kg K_2O ha^{-1} (Table 1). Potassium promotes the conversion of plant metabolites into proteins and amino acids, thus providing a sink for the nitrogen fixed. Similar results were also reported by Salve and Gunjal (2011) [33], Borah *et al.* (2017) [5] and Sanadi *et al.* (2018) [34].

Significantly higher oil content (44.90 %) was observed under treatment receiving 50 kg K_2O ha^{-1} which was remained at par with treatment K_1 (25 kg K_2O ha^{-1}) (Table 1). The role of potassium in facilitating the uptake as well as assimilation of nitrogen into simple amino acids and amides which enhanced the peptide synthesis and led to oil synthesis. Similar results were also reported by Salve and Gunjal (2011) [33], Amolic *et al.* (2018) [33] and Sakarvadia *et al.* (2019) [35].

Treatment receiving 50 kg K_2O ha^{-1} recorded significantly higher oil yield (727 kg ha^{-1}) as compared other treatments. However, oil yield was recorded from 00 kg K_2O ha^{-1} and 25 kg K_2O ha^{-1} was at par with each other (Table 1). The increase in oil yield with increase in level of K was observed because of increase in oil content and pod yield of groundnut under higher levels of K. Similar results were also reported by Hadwani *et al*. (2005) [19] and Salve and Gunjal (2011) [33].

Application of 45 kg S ha^{-1} recorded significantly higher protein content (23.66%) as compared to 15 kg S ha^{-1} application but, it was statistically at par with application of 30 kg S ha^{-1} (Table 1). However, protein content was recorded from 15 kg S ha^{-1} and 30 kg S ha^{-1} was at par with each other. Sulphur, besides a structural component of protein, is also directly involved in protein bio-synthesis. The results are in conformity with the findings of Tathe *et al*. (2008) [40] and Pawar *et al.* (2015) [28] in groundnut and Jat *et al*. (2017) [21] in sesamum.

Significantly higher oil content (44.69 %) was observed under application of 45 kg S ha^{-1} which was remained at par with 30 kg S ha^{-1} (Table 1). This results 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. Similar results were also reported by Das *et al.* (2015) [13], Pawar *et al.* (2015) [28] and Elakiya *et al.* (2020) [16].

Application of 45 kg S ha^{-1} recorded significantly higher oil yield (729 kg ha^{-1}) as compared to 15 kg S ha^{-1} (S_1) and 30 kg S ha^{-1} (S_2). Significantly the lowest oil yield (589 kg ha^{-1}) was recorded under treatment receiving 15 kg S ha^{-1} (Table 1). Full utilization of carbohydrates for the synthesis of the oil with sulphur as well as increase in pod yield might be increase the oil yield. Similar results were also reported by Pawar *et al*., (2015) [28] and Jat *et al*., (2017) [21].

Table 1: Effect of potassium and sulphur on yield, protein content, oil content and oil yield of summer groundnut

Treatments	Pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Protein content (%)	Oil content (%)	Oil yield (kg ha^{-1})
Levels of Potassium (K)					
K_0: 00 kg K_2O ha^{-1}	2040	3058	22.91	43.33	603
K_1: 25 kg K_2O ha^{-1}	2104	3199	23.23	43.83	641
K_2: 50 kg K_2O ha^{-1}	2281	3390	23.67	44.90	727
S.Em. ±	59	86	0.20	0.40	18
C. D. at 5%	177	259	0.60	1.21	54
Levels of Sulphur (S)					
S_1: 15 kg S ha^{-1}	2023	3028	22.82	43.10	589
S_2: 30 kg S ha^{-1}	2136	3220	23.33	44.27	654
S_3: 45 kg S ha^{-1}	2267	3399	23.66	44.69	729
S.Em. ±	59	86	0.20	0.40	18
C. D. at 5%	177	259	0.60	1.21	54
Interaction: K × S					
S.Em. ±	102	150	0.35	0.67	31
C. D. at 5%	NS	NS	NS	NS	NS
C.V. %	8.27	8.07	2.59	2.74	8.18

Effect on nutrient uptake

Application of 50 kg K_2O ha^{-1} recorded significantly the highest total nitrogen uptake (129.7 kg ha^{-1}) by groundnut than other treatments. However, nitrogen uptake by groundnut recorded from 0 kg K_2O ha^{-1} and 25 kg K_2O ha^{-1} was at par with each other (Table 2). The increase in uptake of nitrogen by haulm could be attributed to favourable effect of potassium on growth and yield attributes which resulted into higher yield of pod and haulm. The findings are in close agreement with those obtained by Salve and Gunjal (2011) [33] and Nathiya and Sanjivkumar (2014) [26].

Application of 50 kg K_2O ha^{-1} recorded significantly the highest total phosphorus uptake (14.81 kg ha^{-1}) by groundnut than other treatments. However, total phosphorus uptake by groundnut recorded from 0 kg K_2O ha^{-1} and 25 kg K_2O ha^{-1} was at par with each other (Table 2). The increased root and plant growth might have increased higher total uptake of P. The results are in close conformity with the findings reported Rathore *et al.* (2013) [32] and Borah *et al.* (2018) [7].

Among different levels of potassium, the application of 50 kg K_2O ha^{-1} registered significantly the highest total potassium uptake (39.79 kg ha^{-1}) by groundnut crop over rest of the treatments (Table 2). The increased total uptake of potassium might be due to added potassium and profuse growth of root and plant as a result of added nutrients. Similar finding were reported by Salve and Gunjal (2011) [33] and Borah *et al.* (2018) [7].

Application of 50 kg K_2O ha^{-1} recorded significantly the highest total sulphur uptake (10.88 kg ha^{-1}) by groundnut than other treatments. The lowest total sulphur uptake by groundnut (9.203 kg ha^{-1}) was observed under 0 kg K_2O ha^{-1} (Table 2). The increase in potassium uptake may be due to increase in pod and haulm yield. The findings are in close agreement with those obtained by Rathore *et al.* (2013) [32] and Borah *et al.* (2018) [7].

The significantly highest N uptake (130.9 kg ha^{-1}) by groundnut crop was obtained under treatment receiving 45 kg S ha^{-1} while, the lowest total nitrogen uptake (106.7 kg ha^{-1}) was noted with treatment receiving 15 kg S ha^{-1} (Table 2). 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 Narseen and Imamulhuq (2002) [25], Kumar *et al.* (2008) [23] and Patel and Zinzala (2018) [30].

Significantly highest total uptake of phosphorus (14.63 kg ha^{-1}) by groundnut was obtained with application of 45 kg S ha^{-1} which was at par with treatment receiving 30 kg S ha^{-1} (Table 2). Sulphur might have shown the synergistic effect in increasing the total P uptake. The findings are in close agreement with those obtained by Kumar *et al.* (2008) [23] and Patel and Zinzala (2018) [30].

Application of 45 kg S ha^{-1} recorded significantly higher total potassium uptake (38.04 kg ha^{-1}) by groundnut crop as compared to 15 kg S ha^{-1} but it was at par with S_2 (30 kg S ha^{-1}) (Table 2). Sulphur might have shown the positive effect on increasing the K uptake by plant. The findings are in close agreement with those obtained by Kumar *et al.* (2008) [23] and Patel and Zinzala (2018) [30].

Among different levels of sulphur, significantly highest total uptake of sulphur (10.94 kg ha^{-1}) by groundnut was obtained with application of 45 kg S ha^{-1}, but it was at par with treatment S_2 (30 kg S ha^{-1}) (Table 2). This may be ascribed to increase in pod and haulm yield and concentrations of respective nutrients in kernel, shell and haulm of groundnut in present investigation. The findings are in close agreement with those obtained by Singh *et al.* (2003) [37] and Devi and Singh (2012) [14].

Table 2: Effect of potassium and sulphur on total uptake of N, P, K and S by summer groundnut

Treatments	Total nutrient uptake (kg ha^{-1})			
	N	P	K	S
Levels of Potassium (K)				
K_0: 00 kg K_2O ha^{-1}	109.4	12.98	32.03	9.203
K_1: 25 kg K_2O ha^{-1}	116.8	13.48	35.56	10.03
K_2: 50 kg K_2O ha^{-1}	129.7	14.81	39.79	10.88
S.Em. ±	3.53	0.39	1.12	0.27
C. D. at 5%	10.6	1.15	3.35	0.80
Levels of Sulphur (S)				
S_1: 15 kg S ha^{-1}	106.7	12.58	33.62	8.99
S_2: 30 kg S ha^{-1}	118.3	14.06	35.71	10.18
S_3: 45 kg S ha^{-1}	130.9	14.63	38.04	10.94
S.Em. ±	3.53	0.39	1.12	0.27
C. D. at 5%	10.6	1.15	3.35	0.80
Interaction: K × S				
S.Em. ±	6.11	0.67	1.94	0.46
C. D. at 5%	NS	NS	NS	NS
C.V. %	8.93	8.41	9.36	7.95

Effect on available nutrients content in soil

An appraisal of data given in Table 3 indicated that potassium levels did not exert its significant effect on available nitrogen, phosphorus and sulphur content in soil after harvest of crop.

The significantly higher available potash content in soil (258.7 kg ha^{-1}) was recorded with application of 50 kg K_2O ha^{-1} over 00 kg K_2O ha^{-1}; but it was at par with 25 kg K_2O ha^{-1}. The lowest available potash (245.4 kg ha^{-1}) was found with 00 kg K_2O ha^{-1} (Table 3). The significant increase in available potassium status of soil by application of potassium may be attributed to solubilization of native status of potassium and such increase in available potassium status of the soil at harvest of the crop may also be due to direct addition of potassium to available pool of the soil. Similar results were also reported by Gajghane *et al.* (2015) [17] in mustard crop and Patel *et al.* (2018) [30] in groundnut crop.

Tabulated data (Table 3) revealed that the differences in available nitrogen, phosphorus and potash status in soil after harvest of the groundnut crop due to different levels of sulphur were found to be non-significant.

Significantly the highest available sulphur (7.95 mg kg^{-1}) was recorded under 45 kg S ha^{-1} as compared to other treatments. The lowest available sulphur (6.91 mg kg^{-1}) was noted with treatment receiving 15 kg S ha^{-1} (Table 3). This increase 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 greengram. Similar results were also reported by Chattopaddhyay *et al.* (2012) [9], Jat *et al.* (2017) [21] and Chauhan *et al.* (2020) [10].

Table 3: Effect of levels of potassium and sulphur on available nutrients content in soil after harvest of groundnut crop

Treatments	Available nutrients in soil (kg ha^{-1})			Sulphur
	Nitrogen	Phosphorus	Potash	(mg kg^{-1})
Levels of Potassium (K)				
K_0: 00 kg K_2O ha^{-1}	134.9	50.93	245.4	7.29
K_1: 25 kg K_2O ha^{-1}	135.6	51.43	254.4	7.36
K_2: 50 kg K_2O ha^{-1}	140.3	51.61	258.7	7.67
S.Em. ±	1.94	0.69	3.28	0.13
C. D. at 5%	NS	NS	9.83	NS
Levels of Sulphur (S)				
S_1: 15 kg S ha^{-1}	135.2	50.92	252.8	6.91
S_2: 30 kg S ha^{-1}	135.8	51.49	252.9	7.41
S_3: 45 kg S ha^{-1}	139.8	51.56	253.9	7.95
S.Em. ±	1.94	0.69	3.28	0.13
C. D. at 5%	NS	NS	NS	0.39
Interaction: K × S				
S.Em. ±	3.36	1.19	5.68	0.23
C. D. at 5%	NS	NS	NS	NS
C.V. %	4.25	4.03	3.89	5.30
Initial	136.2	49.25	248.2	6.80

Conclusion

Based on present investigation, it can be concluded that for getting higher yield as well as for improving quality of summer groundnut the crop should be fertilized with 50 kg K_2O ha^{-1} and 45 kg S ha^{-1} besides the recommended dose of nitrogen and phosphorus (25:50 kg N:P_2O_5 ha^{-1}). In addition, potash and sulphur content in soil were also improved.

References

1. Anonymous. Crop wise area, production and productivity of Gujarat state, Directorate of Agriculture, Gandhinagar, 2019-20.
2. Aulakh MS, Pasricha NS, Dev G. Sulphur fertilization of oilseeds for yield and quality. Proc. TSI-FAI. Symposium on sulphur in Indian Agriculture, held at New Delhi. 1988;S-II/3:1-14.
3. Amolic U, Patil DS, Pawar RB. Enhancing the yield of *kharif* Groundnut (*Arachis hypogaea* L.) and quality in entisol through different levels of potassium. International Journal Current Microbiological and Applied Sciences. 2018;7(9):1398-1402.
4. Aier I, Nongmaithem D. Response of groundnut (*Arachis hypogeal* L.) to lime and different levels of sulphur. International Journal of Bio-resource and Stress Management. 2020;11(6):585-589.
5. Borah B, Patil DS, Pawar RB. Enhanching *kharif* groundnut (*Arachis hypogaea* L.) yield and quality in entisol through potassic fertilizer management. International Journal Current Microbiological and Applied Sciences. 2017;6(11):4068-4074.
6. Bhuija ZH, Chadhari SV. Effect of N, P,K and S on quality of groundnut. Asian Journal of Agricultural Science. 1974;44(1):751-754.
7. Borah B, Patil DS, Reddy BH. Response of *kharif* groundnut (*Arachis hypogaea* L.) to various levels and sources of potassium. International Journal of Chemical Studies. 2018;6(3):2162-2166.
8. Chaudhary IA, Cornfield AH. The determination of total

sulphur in soil and plant material. Analyst. 1966;91:528.
9. Chattopaddhyay S, Ghosh GS. Response of rapeseed to various source and levels of sulphur in red and lateratic soil of West Bengal. International Journal of Plant, Animal and Environmental Science, 2012, 2(4). ISSN-2231-4490
10. Chauhan ZY, Patel DK, Bhabhor K. Effect of nitrogen, phosphorus and sulphur on yield, nutrient uptake and soil fertility after harvest of mustard. International Journal Current Microbiological and Applied Sciences. 2020;9(6):3506-3512.
11. Cakmak. Effect of N, P and K levels on yield, nutrient content, uptake and quality of summer groundnut grown on typic haplustepts. Journal of the Indian Society of Soil Science. 2005;53(1):125-128.
12. Chandra, Pradyut, Samui RC, Bordolut Sanjoy Kumar. Growth, yield attributes and yield of different cultivars of groundnut as affected by potassium application. Journal of Crop and Weed. 2006;2(1):37-39.
13. Das S, Chowdhuri TK, Singh AK. Effect of calcium and sulphur based fertilizers on yield and quality of groundnut in red and lateritic belt of bankura district of West Bengal. Journal of Krishi Vigyan. 2015;3(2):35-38.
14. Devi KN, Singh MS. Influence of sulphur and boron fertilization on yield, quality, nutrient uptake and economics of soybean (*Glycine max*) under upland conditions. Journal of Agricultural Science, 2012, 4(4). ISSN-1916-9760.
15. Dudekula D, Singh V, Tiwari D, George SG, Padachala S. Effect of variety and sulphur on growth and yield of groundnut (*Arachis hypogaea* L.). Biological Forum- An International Journal. 2021;13(1):0975-1130.
16. Elakiya N, Meena S, Amirtham D. Effect of sulphur on yield and biochemical constituents in groundnut grown in vertic ustropept of Tamil Nadu. Madras Agricultural Journal. 2020;1(3):74-79.
17. Gajghane PG, Toncher SS, Raut MM. Effect of potassium and sulphur levels on soil fertility status after harvest of mustard. Plant Archives. 2015;15(1):347-351
18. Gangadhara GA, Manijunathaiah HM, Stayanarayana T. Effect of sulphur on yield, oil content of sunflower and uptake of micronutrient by plants. Journal of Indian Society of Soil Science. 1990;38:693-695.
19. Hadwani GJ, Gundalia JD. Effect of N, P and K Levels on Yield, Nutrient Content, Uptake and Quality of Summer Groundnut Grown in Typic Haplustepts. Journal of the Indian Society of Soil Science. 2005;53(1):125-128.
20. Hemeid NM. Effect of different sources and levels of potassium fertilization on productivity of peanut grown under sandy soil conditions. Journal of Soil Science and Agricultural Engineering. 2015;6(12):1441-1454.
21. Jat R, Naga SR, Choudhary, Rajsingh, Jat S, Mohammad I. Effect of potassium and sulphur fertilization on soil fertility of sesame (*Sesamum indicum* L.) International Journal of Chemical Studies. 2017;5(2):95-96.
22. Jackson ML. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 1973, 183-192.
23. Kumar A, Sharma M, Mehra RK. Effect of phosphorus and sulphur on yield and nutrient uptake by groundnut in inceptisols. An Asian Journal of Soil Science. 2008;3(1):139-141.
24. Noman, Heba Mohamed, Rana DS, Rana KS. Influence of sulphur and zinc levels and zinc solubilizer on productivity, economics and nutrient uptake in groundnut (*Arachis hypogaea* L.). Indian Journal of Agronomy. 2015;60(2);301-306.
25. Narseen S, Immulhuq SM. Effect of sulphur fertilization on yield and nutrient uptake of sunflower crop in albaquept soil. Pakistan Journal of Biological Sciences. 2002;5(5):533-536.
26. Nathiya KV, Sanjivkumar V. Combined effect of different plant nutrients of organic and inorganic sources on nutrient uptake and yield of groundnut crop. Journal of Applied and Natural Science. 2014;6(2):463-466.
27. Panse VC, Sukhatme PV. Statistical methods for agricultural workers. (4th Ed) ICAR, New Delhi, 1985, pp. 97-164.
28. Pawar RG, Naiknaware MD, Murumkar SB. Effect of varying levels of boron and sulphur on growth, yield and quality of summer groundnut (*Arachis hypogaea* L.). National Academy of Agricultural Science (NAAS). 2015;33(2):471-474.
29. Patel AR, Zinzala VJ. Effect of sulphur and boron on nutrient content and uptake by summer groundnut (*Arachis hypogeal* L.) The Pharma Innovation Journal. 2018;7(4):47-50.
30. Patel PK, Viradiya MB, Patel VS, Kadivala VH. Effect of potassium and sulphur on nutrient content, uptake and soil fertility of summer groundnut (*Arachis hypogaea* L.) under middle Gujarat condition. International Journal of Chemical Studies. 2018;7(1):797-800.
31. Rao KT, Rao AU, Sekhar D. Effect of sources and levels of sulphur on groundnut. Journal of Academia and Industrial Research. 2013;2(5):2278-5213.
32. Rathore S, Chaudhary DR, Bhatt BP. Scheonite and Potassium Sulphate: Indigenous Potassic Fertilizer for Rainfed Groundnut. International Journal of Traditional Knowledge. 2013;13(1):222-226.
33. Salve YV, Gunjal BS. Effect of different levels of phosphorus and potassium on summer groundnut (*Arachis hypogaea* L.). International Journal of Agricultural Science. 2011;7(2):352-355.
34. Sanadi S, Math KK, Bidari BI, Yenagi BS. Effect of potassium nutrition on yield, quality and economics in groundnut (*Arachis hypogaea* L.) in a vertisol. Journal of Pharmacognosy and Phytochemistry. 2018;7(2):220-222.
35. Sakarvadia HL, Vekaria LC, Ponkiya HP, Vaghasia PM, Polara KB. Potassium fertilization to kharif groundnut in medium black calcareous soils of Saurashtra region of Gujarat. International Journal of Chemical Studies. 2019;7(4):1752-1755.
36. Singh AL. Mineral nutrition of groundnut. In: Advances in plant physiology Scientific Publisher, India. 1999;2:161-200
37. Singh S, Kumar Y, Gill Singh, Kumar Y. Growth characteristics of summer groundnut (*Arachis hypogaea* L.) as influenced by sulphur levels, irrigation schedules and organic manures. Annals Biology. 200319(2)135-139.
Scientific publisher, India, 2:161-200.
38. Tiwari PN, Grambler PN, Rajan TS. Rapid and non destructive determination of oil in oilseed. Journal of Oilseed Chemical Science. 1974;51:1049.
39. Tasso NM, Chaudhary VN. Schoenite and potassium sulphate: Indigenous potassic fertilizer for rainfed

groundnut. Indian Journal of Traditional Knowledge. 2004;13(1):222-226.

40. Tathe AS, Patil GD, Khilari JM. Effects of sulphur and zinc on groundnut in vertisols. An Asian Journal of Soil Science. 2008;3(1):178-180.
41. Vaghasia PM, Khanpara VD, Mathukia RK. Impact of in-situ moisture conservation and sulphur nutrition on yield, quality and nutrient uptake by groundnut. International Journal of agricultural Sciences. 2007;3(1):151-153.
42. Yadav IS, Kumar MN, Bhuiyan MS. Role of Potassium and Sulphur on the Growth, Yield and Oil Content of Soybean (*Glycine max* L.). Academic Journal of Plant Sciences. 2003;3(2):99-103.
43. Yadav Nagesh, Yadav SS, Yadav Neelam, Yadav MR, Kumar Rakesh, Yadav LR, *et al*. Growth and productivity of groundnut (*Arachis hypogaea* L.) under varying levels and sources of sulphur in semi-arid conditions of Rajasthan. Legume Research, 2017. DOI: 10.18805/LR-3853.