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RESEARCH ARTICLE

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Effect of Phosphorus and Sulphur Levels on Yield Attributes, Yield and Quality of Groundnut (*Arachis hypogaea* L.)

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ABSTRACT

Background: Groundnut is one of the best known oilseed crops and belongs to the family Leguminosae. However, the productivity of groundnut in India is less as compared to average productivity of world due to *uncertainty* in monsoon rainfall and incidences of diseases, insect pests and weeds. The main cause of low groundnut production is an unbalanced and insufficient usage of nutrients. Because groundnut is a legume-oilseed crop, it has a high phosphorus, calcium and sulphur demand.

Methods: A field experiment consisting of four phosphorus levels (Control, 40, 50, 60 kg P_2O_5 ha^{-1}) and four sulphur levels (Control, 25, 50, 75 kg S ha^{-1}) was laid out in split plot design to analyze their effect on pod yield, yield components, physiological and quality parameters of groundnut.

Result: The results indicated the application of 60 kg P_2O_5 ha^{-1} and 75 kg S ha^{-1} significantly improved the pod yield and yield components except number of kernels per pod and harvest index, physiological parameters except leaf area index and all the quality parameters. However, the difference between 50 and 60 kg P_2O_5 ha^{-1} and 50 and 75 kg S ha^{-1} was found non-significant for most of the studied parameters.

Key words: Groundnut, Phosphorus, Pod yield, Quality, Sulphur.

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the best known oilseed crops which belongs to the family Leguminosae and sub-family Papilionaceae (Deivasigamani *et al*., 2022). It is believed that it has been originated in South America (Hussainy *et al.,* 2023). The global area, production and productivity of groundnut is 29.7 million ha, 50.8 million tonnes and 17.1 quintal ha^{-1}, respectively. China is the world's largest producer of groundnut followed by India (Anonymous, 2021). In India, it is cultivated in 4.8 million ha area with production of 9.9 million tonnes and productivity of 20.6 quintal ha^{-1}. In Haryana, groundnut is grown on 3500 ha with production and productivity of 4000 tonnes and 11.4 quintal ha^{-1}, respectively (Anonymous, 2021). However, the productivity of groundnut in Haryana is 46% less as compared to average productivity of India. The main cause of low groundnut production is an unbalanced and insufficient usage of nutrients. As groundnut is a legume-oilseed crop, it has a high amount of phosphorus, calcium and sulphur demand.

Phosphorus is considered a crucial mineral fertilizer for the flourishing production of the crop. The phosphorus is an essential part of membrane system of the cell, chloroplast and the mitochondria. Plants use it for energy transfer in metabolic processes such as photosynthesis (in the form of ATP and ADP), starch and sugar transformation and nutrient movement (Kamal *et al*., 2023b). The groundnut crop calls for sensible supply of phosphorus for its regular growth. Phosphorus has been found to improve the crop's effective use of soil nutrients and increase biological N fixation by increasing nitrogenase activity (Kesh and Yadav, 2016). Furthermore, for high yield and superior product quality, oilseed crops need about the same dose of sulphur as phosphorus, if not more. Sulphur, which makes up succinyl Co-A, is a crucial component in the production of chlorophyll. Through general improvement and their activation at the cellular level by encouraging increased photosynthesis and meristematic activity, it engages in the activation of a number of enzymes involved in the dark-reaction of photosynthesis (Solaimalai *et al.,* 2020). Sulphur is a component of proteins and plays a critical role in oil production, as well as improving chlorophyll production and decreasing chlorosis. It is essential in the process of synthesis of amino acids that contain sulphur, such as methionine and cysteine in plant (Kamal *et al*., 2023a). Keeping in mind the above said points, the present investigation was conducted to analyse the impact of phosphorus and sulphur levels on pod yield, yield components, physiological and quality parameters of groundnut.

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MATERIALS AND METHODS

The experiment was conducted during the *kharif* season in 2021 at the Agronomy Research Farm, CCS Haryana Agricultural University, Hisar (India). Geographically, Hisar is situated at 29°10′N latitude and 75°46′E longitude at an elevation of 215 m above mean sea level. The experiment was laid in split plot design with sixteen treatment combinations and three replications. *viz.*, four levels of phosphorus (Control, 40, 50, 60 kg P_2O_5 ha^{-1}) in main plots and four levels of sulphur (Control, 25, 50, 75 kg S ha^{-1}) in sub plots. The soil at the research site has a sandy texture, slightly alkaline in pH (8.1), low in organic carbon (0.12%), low in available N (131.4 kg ha^{-1}), medium in available P (15.8 kg ha^{-1}), medium in available K (137.6 kg ha^{-1}) and low in available S (19.4 kg ha^{-1}). At proper moisture condition, the field was ploughed twice with hand plough followed by planking. Layout was performed and fertilizers were applied before sowing as per treatments in all the plots. Nitrogen (15 kg ha^{-1}) and Potash (25 kg ha^{-1}) were applied before sowing in all the plots according to package and practices of the crop. The crop was sown in the middle of June 2021. The groundnut variety GNH 804 was sown manually with the help of hand plough with a spacing of 30 × 15 cm. The seeds of the variety were treated with Bavistin @ 2.5 g kg^{-1} seed before sowing. Weeding was done manually at 25-30 and 45-50 days after sowing (DAS) in all the plots. Three irrigations were applied to the crop during the crop season depending on the need of the crop. Last irrigation was given a few days before harvesting to facilitate the easy recovery of pods from the soil. Harvesting and separation of pods was done manually and harvested crop was left for sun drying in the field for 4-5 days. After that, the pods were separated from the plants manually and the pod yield data was recorded. The data were recorded for pod yield, yield components *i.e.,* number of pods per plant, number of kernels per pod, seed index (g), pod yield (kg ha^{-1}), kernel yield (kg ha^{-1}), biological yield (kg ha^{-1}), haulm yield (kg ha^{-1}), shelling (%), harvest index (%), quality parameters *i.e.,* protein content (%), protein yield (kg ha^{-1}), oil content (%), oil yield (kg ha^{-1}), physiological parameters *i.e.,* chlorophyll content at flowering stage with the help of SPAD chlorophyll meter, canopy temperature and ambient temperature were measured at flowering stage with the help of infrared thermometer (Telatemp AG-42) and expressed in °C, whereas canopy temperature depression is calculated as the difference between plant canopy temperature and air temperature and expressed in -°C and leaf area was measured by leaf area meter (LI 3000, LICOR Ltd. Nebraska U.S.A.) at flowering stage. Average leaf area per unit area was used for computation of LAI, which is the ratio between the surface area of green leaves and the ground area covered by single plant. All the data recorded were analyzed with the help of analysis of variance (ANOVA) technique (Gomez and Gomez, 1984) for split plot design. The least significance test was used to decipher the effect of treatments at 5% level of significance.

RESULTS AND DISCUSSION

Effect of phosphorus levels on

Pod yield and component parameters

The data on pod yield and its component traits as influenced by various phosphorus levels were presented in Table 1. The number of pods per plant were significantly affected by phosphorus levels. Increasing phosphorus dose from 40 to 60 kg ha^{-1} progressively increased the number of pods per plant but non-significant differences were recorded between 50 and 60 kg P_2O_5 ha^{-1}. Phosphorus level at 40, 50 and 60 kg ha^{-1} recorded 35.09, 50.05 and 55.72 per cent higher number of pods per plant over the control, respectively. Similarly, phosphorus levels from 40 to 60 kg ha^{-1} significantly improved the seed index value but, a non-significant

Table 1: Effect of phosphorus and sulphur levels on yield attributes and yield of groundnut.

Treatments	NPP	NKP	SI	PY	KY	BY	HY	SP	HI
Phosphorus levels									
Control	19.38	1.75	39.00	2115	1322	6060	3945	62.50	35.16
40 kg P_2O_5 ha^{-1}	26.18	1.93	42.00	2728	1850	7413	4684	67.50	38.08
50 kg P_2O_5 ha^{-1}	29.08	2.16	44.08	3001	2093	8433	5432	69.66	36.83
60 kg P_2O_5 ha^{-1}	30.18	2.30	44.40	3023	2143	8514	5490	70.58	36.91
SEm ±	0.74	0.10	0.53	43	55	235	205	1.36	1.83
CD at 5%	2.55	0.34	1.88	154	196	830	723	4.79	NS
Sulphur levels									
Control	23.68	1.84	41.25	2329	1513	6694	4364	64.50	37.50
25 kg S ha^{-1}	26.18	1.91	42.41	2678	1812	7426	4747	67.25	37.75
50 kg S ha^{-1}	27.28	2.18	42.75	2884	1986	8016	5131	68.58	36.08
75 kg S ha^{-1}	27.68	2.20	43.41	2975	2096	8285	5309	69.91	35.66
SEm ±	0.81	0.17	0.3	33	35	172	157	1.27	1.09
CD at 5%	2.36	NS	0.88	98	105	507	461	3.73	NS

NPP-number of pods per plant, NKP-number of kernels per pod, SI- Seed index (g), PY- Pod yield (kg ha^{-1}), KY- Kernel yield (kg ha^{-1}), BY- Biological yield (kg ha^{-1}), HY- Haulm yield (kg ha^{-1}), SP- Shelling (%), HI- Harvest index (%), NS- Non significant.

difference were observed between 50 and 60 kg ha^{-1}. A 7.69, 13.02 and 13.85 per cent increase in seed index value were seen at 40, 50 and 60 kg P_2O_5 ha^{-1} compared to control, respectively. Increased levels of phosphorus from 40 to 60 kg ha^{-1} significantly improved the pod yield, kernel yield, biological yield and haulm yield however, the differences were found non-significant between 50 and 60 kg P_2O_5 ha^{-1}. In comparison to control, the per cent increment was 28.98, 41.89 and 42.93 per cent for pod yield; 39.94, 58.32 and 62.10 per cent for kernel yield; 22.33, 39.16 and 40.50 per cent for biological yield; and 18.73, 37.69 and 39.16 per cent for haulm yield at 40, 50 and 60 kg P_2O_5 ha^{-1}, respectively. Likewise, the phosphorus levels from 40 to 60 kg ha^{-1} significantly increased the shelling (%), but non-significant differences were recorded between 40-50 kg ha^{-1} and 50-60 kg P_2O_5 ha^{-1}. The shelling % increased to the tune off 8.00, 11.46 and 12.93 per cent at 40, 50 and 60 kg P_2O_5 ha^{-1}, respectively. The differences for number of kernels per pod and harvest index were seen non-significant at different levels of phosphorus application. Phosphorus is an important nutrient for all crops in general, but for legumes in particular; where it is a key component of ATP and plays an important role in plant energy transformation as well as seed formation (Ikenganyia *et al.*, 2017). Phosphorus application increased nutrient availability to the crop during the growing season resulting in a greater utilization of assimilate during the pods development, leading to rise in number of filled pods and shelling percentage (Choudhary and Yadav, 2017). The higher pod and kernel yield recorded with 60 kg P_2O_5 ha^{-1} was due to increased yield component traits like number of pods per plant, number of kernels per pod and seed index. The application of 60 kg P_2O_5 ha^{-1} enhanced biological yield significantly due to its direct effect in improved dry matter accumulation at various growth stages of the crop (Kabir *et al.,* 2013). Furthermore, biological yield is the total of haulm and pod production, which measures a crop's vegetative and reproductive growth. The dramatic effect of phosphorus application on each of these characteristics was mediated by greater photosynthetic activity and nutrient buildup (Kesh *et al*., 2017a,b).

Physiological parameters

The data on different physiological parameters *viz*., chlorophyll content, canopy temperature depression and leaf area index as influenced by various phosphorus levels are presented in Table 2. Chlorophyll content and canopy temperature depression were significantly affected by phosphorus levels at flowering stage. Increasing phosphorus levels from 40 to 50 kg ha^{-1} progressively increased chlorophyll content but non-significant differences were recorded between level 50 and 60 kg ha^{-1}. Chlorophyll content at phosphorus level 40, 50 and 60 kg ha^{-1} was significantly higher than control, with a relative advantage of 19.99, 28.43 and 30.56 percent, respectively. The differences for canopy temperature depression were observed highly significant at all phosphorus levels starting from 40 to 60 kg ha^{-1} indicating the importance of phosphorus in groundnut canopy development. The increasing phosphorus levels from 40 to 60 kg ha^{-1} significantly increased LAI, however, the differences were non-significant between 40 and 50 kg P_2O_5 ha^{-1} as well as 50 and 60 kg P_2O_5 ha^{-1}. The increase in LAI was 8.14, 13.02 and 14.40 per cent at 40, 50 and 60 kg P_2O_5 ha^{-1} in comparison to control, respectively. Plant development in terms of growth was influenced by the rise in photosynthetic activity. As a result, adding phosphorus to the soil improved the plant ability to synthesise oxygen from carbon dioxide and other metabolic processes, which in turn improved the plant ability to develop the amount of chlorophyll. These results are in close conformity with the findings of Jat *et al.* (2023). The increase in leaf area index could be attributed due to

Table 2: Effect of phosphorus and sulphur levels on physiological and quality parameters of groundnut.

Treatments	CC	CTD	LAI	PC	PY	OC	OY
Phosphorus levels							
Control	15.51	2.54	3.61	20.5	271.9	39.2	524.3
40 kg P_2O_5 ha^{-1}	18.61	3.38	3.93	22.2	414.2	42.0	781.7
50 kg P_2O_5 ha^{-1}	19.92	4.01	4.08	23.6	495.8	43.1	886.4
60 kg P_2O_5 ha^{-1}	20.25	4.32	4.13	24.0	518.2	43.7	920.5
SEm ±	0.13	0.04	0.07	0.24	10.3	0.25	22.6
CD at 5%	0.46	0.13	0.25	0.87	36.4	0.88	79.8
Sulphur levels							
Control	17.05	3.26	3.82	21.3	327.3	39.3	592.7
25 kg S ha^{-1}	18.56	3.57	3.94	22.6	414.4	41.8	755.0
50 kg S ha^{-1}	19.22	3.65	3.99	23.1	464.6	43.1	852.0
75 kg S ha^{-1}	19.47	3.75	4.01	23.2	493.8	43.8	913.2
SEm ±	0.18	0.09	0.12	0.26	9.10	0.31	16.10
CD at 5%	0.53	0.27	NS	0.76	26.90	0.91	47.40

CC-chlorophyll content, CTD- Canopy temperature depression (-°C), LAI- Leaf area index, PC- Protein content (%), PY- Protein yield (kg ha^{-1}), OC- Oil content (%), OY- Oil yield (kg ha^{-1}), NS- Non significant.

increase in cell division and leaf expansion. The increased interception, absorption and utilization of radiant energy results in an increased overall growth, photosynthesis and leaf area index which could be explained by the increased canopy development and plant height under the additional application of phosphorus (Kabir *et al.,* 2013 and Khaswan *et al.*, 2016).

Quality parameters

The data on various quality parameters *viz*. protein content, protein yield, oil content and oil yield as influenced by various phosphorus levels are presented in Table 2. Increasing phosphorus levels from 40 to 60 kg ha^{-1} significantly enhanced the protein content, protein yield, oil content and oil yield. The differences between 50 and 60 kg S ha^{-1} however, were observed non-significant. Phosphorus levels increased protein content, protein yield, oil content and oil yield to the extent of 8.29, 52.33, 7.14 and 49.09 per cent at level 40 kg ha^{-1}, 15.12, 82.35, 9.95 and 69.06 per cent at level 50 kg ha^{-1} and 17.07, 90.58, 11.48 and 75.51 per cent at level 60 kg ha^{-1}, respectively over the control. Phosphorus plays crucial role for increasing seed yield and quality of oilseed crops. It enhances the symbiotic nitrogen fixation in legume crops which ultimately lead to increased nitrogen content. Nitrogen is a key component of amino acids, which are the building blocks of all proteins (Sukirtee *et al*., 2022). Therefore, increase in phosphorus level favours increased protein content in groundnut. The increasing levels of phosphorus progressively increased oil content, which might be due to the phosphorus, which is a primary component of fatty acids. The higher phosphorus buildup could have resulted in higher oil content in the seeds as reported earlier by Lepcha *et al*., (2022).

Effect of sulphur levels on

Pod yield and component parameters

The data on pod yield and its component traits as influenced by various sulphur levels were presented in Table 1. The number of pods per plant (27.68) recorded with a sulphur level of 75 kg ha^{-1} was significantly higher with a relative advantage of 16.89 per cent, over the control however, the differences were non-significant remaining sulphur levels. Similarly, seed index showed a significant difference between control and different sulphur levels with a relative increment of 2.81, 6.64 and 5.23 per cent at 25, 50 and 75 kg S ha^{-1}, but the differences were non-significant between 25 and 50 kg ha^{-1} and 50 and 75 kg ha^{-1}. Increased sulphur dose from 25 to 75 kg ha^{-1} significantly increased the pod yield, kernel yield and biological yield however, with a relative advantage of 14.98, 23.93 and 27.74 per cent for pod yield; 19.76, 31.26 and 38.53 per cent for kernel yield; 10.94, 19.75 and 23.77 per cent for biological yield, respectively, compared to control. Haulm yield was significantly higher at 50 and 75 kg S ha^{-1} with a relative advantage of 17.58 and 21.65 per cent over control, but non-significant differences observed among the different levels of sulphur applied. Likewise, shelling (%) was also significantly higher over control at 50 and 75 kg S ha^{-1} with a 6.33 and 8.39 per cent increment. Like the results of phosphorus, number of kernels per pod and harvest index showed non-significant differences at different level of sulphur. Higher photosynthesis and greater mobilization of photosynthates towards reproductive structures may have contributed to a large rise in groundnut yield and its parameters. Further, sink strength and sufficient supply of sulphur also aids in the development of floral primordial or reproductive parts, which might have resulted in the development of pods and kernels in plants (Kamal *et al.,* 2024). Higher pod and kernel yields recorded with higher level of sulphur were due to increased yield attributes *i.e.* number of pods per plant, number of kernel per pod and seed index. The application of 75 kg S ha^{-1} enhanced biological yield significantly due to the higher plant growth and biomass production. Moreover, increased nutrient uptake and better utilization of radiant energy resulted in increased vegetative growth and reproductive development, thereby increasing the biological yield in the presence of sulphur (Yadav *et al.*, 2018 and Noman *et al.,* 2015).

Physiological parameters

The data on different physiological parameters *viz*., chlorophyll content, canopy temperature depression and leaf area index as influenced by various sulphur levels are presented in Table 2. Likewise, chlorophyll content significantly increased with the increase in sulphur levels from 25 to 75 kg ha^{-1} but non-significant differences were recorded between 50 and 75 kg ha^{-1}. The per cent increase in chlorophyll content was 8.86, 12.72 and 14.19 per cent at 25, 50 and 75 kg S ha^{-1}, respectively. Canopy temperature depression significantly increased with the increase in sulphur levels from 25 to 75 kg ha^{-1}. However, a non-significant variation was observed between 25 to 50 kg S ha^{-1} and 50 to 75 kg S ha^{-1}. Canopy temperature depression at sulphur level 75 kg ha^{-1} was showed a 15 per cent increase over the control conditions. Moreover, the LAI depicted a numerical increase at 25, 50 and 75 kg S ha^{-1}, but the difference between control and three sulphur levels were non-significant. The photosynthetic rate appears to have improved due to better nourishing nutritional content at the cell level (Kumar and Yadav, 2007). The higher sulphur content in crop plants leads to better enlargement of the xylem and collenchyma tissues. In contrast to low levels, increasing sulphur levels resulted in higher crop growth and better development (Kamal *et al.,* 2024).

Quality parameters

The data on various quality parameters *viz*. protein content, protein yield, oil content and oil yield as influenced by various sulphur levels are presented in Table 2. Likewise, the increase in sulphur levels from 25 to 75 kg ha^{-1} significantly improved the protein content, protein yield, oil content and oil yield as compared to control. However, the variation among the different levels were found non-significant for protein content. Protein yield shows a 26.61, 41.95 and 50.87 per cent increment over control at 25, 50 and 75 kg ha^{-1} of sulphur level, respectively. Similalry, the per cent increment in oil content and oil yield were recorded 6.36 and 27.38; 9.67 and 43.75 and 11.45 and 54.07 per cent at 25, 50 and 75 kg ha^{-1} of levels of sulphur, respectively in comparison to control. Sulphur is best known in plants for its function in protein, oil, vitamins and flavor component synthesis. It is a component of three amino acids found in plants, namely cystine, cysteine and methionine, all of which are essential components of proteins. Sulphur increases the oil content and adds pungency to oil by forming disulphide linkages (Kamal *et al*., 2023a). The oilseeds require more sulphur than cereals because their oil-storing organs are mostly sulphur containing proteins. Sulphur deficiency is known to impair N metabolism in plants as well as the production of S-containing amino acids and thus has a negative impact on both seed yield and oil yield (Yadav *et al.*, 2019).

CONCLUSION

Based on the results of present study, it could be concluded that the application of 50 kg P_2O_5 ha^{-1} and 50 kg S ha^{-1} was most suitable for obtaining higher yield and better quality of groundnut produce.

Conflict of interest

There is no conflict of interest.

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