International Journal of Plant & Soil Science

Volume 37, Issue 9, Page 427-434, 2025; Article no.IJPSS.143878
ISSN: 2320-7035

Influence of Phosphorus and Sulphur on Growth and Yield of Chickpea (*Cicer arietinum* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2025/v37i95720

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/143878

Original Research Article

Received: 16/07/2025
Accepted: 06/09/2025
Published: 08/09/2025

ABSTRACT

The present field experiment was conducted during *Rabi* season 2024–2025 at the Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj (U.P.), using a Randomized Block Design (RBD) with ten treatments and three replications. The treatments comprised different combinations of Phosphorus (20, 40 and 60 kg/ha) and Sulphur (10, 20 and 30 kg/ha) along with a control (NPK 20-60-20 kg/ha). The results revealed that the application of Phosphorus at 60 kg/ha with Sulphur at 30 kg/ha (T9) recorded significant improvement in growth parameters, viz., plant height (52.02 cm), number of branches per plant (26.33), number of nodules per plant (32.96), plant dry weight (24.20 g) and crop growth rate (24.09 g/m²/day). The same treatment also produced the maximum yield

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Cite as: *Mohd Arish, Vikram Singh, Amit Kumar, Amit Raj, and Ekta Singh. 2025. "Influence of Phosphorus and Sulphur on Growth and Yield of Chickpea (Cicer Arietinum L.)". International Journal of Plant & Soil Science 37 (9):427–434. https://doi.org/10.9734/ijpss/2025/v37i95720.*

attributes such as number of pods per plant (33.49), seeds per pod (1.33), test weight (5.93 g), which ultimately resulted in the highest grain yield (2.44 t/ha) and straw yield (4.93 t/ha). Economic analysis indicated that treatment T9 also fetched the maximum gross return (₹1,51,430/ha), net return (₹1,03,816.02/ha) and benefit cost ratio (2.18).

Keywords: Chickpea; phosphorus; Sulphur; growth; yield and economic.

1. INTRODUCTION

"Chickpea (*Cicer arietinum* L.), a member of the Fabaceae family, is one of the most important pulse crops cultivated worldwide. The Fabaceae family, also known as the legume, pea, or bean family, includes other major crops such as peas, beans, lentils, soybeans, peanuts, and clover, and Plant nutrient, suitable cultivars and correct fertilizer have significant effect on yield and yield component" (Upadhayaya & Chapai, 2024) "Chickpea is cultivated primarily for its edible seeds, commonly known as chickpeas or garbanzo beans, which form a vital part of human diets in many countries. Multi-location trials had indicated that inoculation of seed with phospho-bacterial increased the yield of rice by 10-20 per cent, wheat by 10-40 per cent, bengal gram by 10-30 per cent, and potato by 30-35 per cent over control" (Gaur, 1985). "In India, it is referred to as *chana* (Hindi) or Bengal gram. During 2021, INDIA'S share in global Export of chickpea wa 5.87% (Rank 5, Export Volume 94.08 MKGs) and share in import was 12.51% (Rank 2, Import Volume 240.97 MKGs). Share of India in global chickpea production was 73.46% during 2020" (Tridge, 2023).

"Two distinct types of chickpeas are recognized: Kabuli and Desi. Kabuli types are characterized by tall plants, large cream-colored seeds, and white flowers, while Desi types are relatively shorter with smaller leaflets, pods, and seeds, and exhibit variability in color and seed morphology Some important strains are mentioned as plant growth promoting rhizobacteria (PGPR) and that can be used as biofertilizers" (Kennedy et al., 2004). "P fertilizer use is very inefficient in agriculture and its recovery is estimated to be between 10-15% of the P applied (Syers and Curtis, 2008). Nutritionally, chickpeas are rich in protein (around 23%), carbohydrates (64%), dietary fiber, minerals such as phosphorus, calcium, magnesium, iron, and zinc, and vitamins such as folate" (Deppe, 2010; Jukanti *et al.,* 2012). They are also valued as a healthy carbohydrate source for diabetic and insulin-sensitive individuals, and their consumption has been linked to reduced risks of cardiovascular diseases, diabetes, digestive disorders, and certain cancers. With the increasing popularity of plant-based protein products, chickpea's significance in the food processing industry has grown considerably.

"India is the world's largest producer of chickpeas, contributing nearly 50% of global pulse production. In 2021–2022, chickpea production was estimated at 13.75 million tonnes, covering 10.91 million hectares, with a productivity of 12.6 q/ha" (DES, 2023; MoAF & W, GoI, 2022). The major chickpea producing states in India include Maharashtra, Madhya Pradesh, Rajasthan, Gujarat, and Uttar Pradesh. Understanding sulphur's role in growth and development of pulses is very much important from the viewpoint that the deficiency of sulphur in soils is increasing (Kodavali and Khurana, 2022).

"Among the essential nutrients for chickpea production, phosphorus and sulphur play a crucial role. Phosphorus, often termed the "Master Key of Agriculture," is vital for plant physiological processes, being a component of ADP, nucleic acids, proteins, and co-enzymes, and is directly involved in energy transformation, root development, and biological nitrogen fixation" (Nawange *et al.,* 2011). "On the other hand, sulphur is increasingly recognized as the fourth major nutrient, after nitrogen, phosphorus, and potassium. Sulphur fertilizer is recognized to augment the crop produce and macronutrients uptake especially most of them nitrogen" (Yadav *et al.,* 2016). "It is essential for protein synthesis, enzymatic activity, and chlorophyll formation, and is absorbed by plants primarily as sulphate ions (SO_4^{2-}).). the utilization of P as a foliar application becomes increasingly important. The mechanistic processes by foliar applied indicate that nutrients are taken up through leaf stomata" (Eicher, 2012) Application of fertilizer to alkaline soils has been reported to reduce the pH of soil (Liu *et al*. 2013; Phogat et al., 2020).

"Generally, the legumes have need of almost equal quantity of sulphur and phosphorus" (Singh *et al.,* 2018). Considering the nutritional importance of chickpea and the critical role of phosphorus and sulphur in enhancing its growth and yield, the present investigation was undertaken to evaluate the combined effect of phosphorus and sulphur application on the performance and profitability of chickpea under the agro-climatic conditions of Prayagraj, Uttar Pradesh.

2. MATERIALS AND METHODS

The experiment was carried out during *Rabi* season of 2024-2025 at crop research farm of Naini agricultural institute, Sam Higginbottom university of agriculture, technology and sciences, Prayagraj, which is located at 25^0 24' 42" n latitude, 81^0 50' 56" e longitude and 98 m altitude above the mean sea level. This area is situated on the right side of the river Yamuna by the side of Prayagraj Rewa road about 5 km away from Prayagraj city. The experiment was conducted in randomized block design with 10 treatment each replicated thrice. The plot size of each treatment was 3m x 3m. The factors are Phosphorus (20, 40 and 60 kg/ha) and Sulphur (10, 20 and 30 kg/ha) along with a control (NPK 20-60-20 kg/ha). The treatment combinations are T1. Phosphorus at 20 kg/ha + Sulphur at 10 kg/ha, T2. Phosphorus at 20 kg/ha + Sulphur at 20 kg/ha, T3. Phosphorus at 20 kg/ha + Sulphur at 30 kg/ha, T4. Phosphorus at 40 kg/ha + Sulphur at 10 kg/ha, T5. Phosphorus at 40 kg/ha + Sulphur at 20 kg/ha, T6. Phosphorus at 40 kg/ha + Sulphur at 30 kg/ha, T7. Phosphorus at 60 kg/ha + Sulphur at 10 kg/ha, T8. Phosphorus at 60 kg/ha + Sulphur at 20 kg/ha, T9.Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha, T10. N-P-K – 20-60-20 kg/ha (Control). Chickpea Seeds were sown in line manually. Seeds were covered with soil immediately after sowing. The Chickpea crop was sown on 28 November 2024. Harvesting was done by taking 1 m^2 area from each. And from it five plants were randomly selected for recording growth and yield parameters. The observations were recorded for plant height, number of branches per plant, number of nodules per plant, plant dry weight, crop growth rate, relative growth rate, pods per plant, seeds per pod, test weight, grain yield and straw yield. The data was subjected to statistical analysis by Analysis of variance method. Economics was calculated viz., cost of cultivation, gross return, net return, benefit cost ratio were calculated.

3. RESULTS AND DISCUSSION

3.1 Plant Height (cm)

The Plant height of Chickpea was observed from 20 DAS to 100 DAS and highest plant height was observed at 100 DAS. Effect of Phosphorus and Sulphur on increasing plant height was observed among all the treatments. The significantly highest plant height (52.02 cm) was recorded in treatment T9 (Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha) However, the treatments T_3 and T_4 were found to be statistically at par with T_9. Where as the minimum plant height (40.82) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control). However, The present findings are in conformity with the reports of earlier researchers. Phosphorus fertilization promoted vegetative growth and resulted in significantly taller plants in pulses due to its role in root development and nutrient uptake (Nosheen & Shafique, 2006). observed that combined application of phosphorus and sulphur enhanced plant height and biomass production in chickpea by improving photosynthetic efficiency and dry matter accumulation. More recently, Digvijay *et al.* (2024) reported that phosphorus and sulphur application, either individually or in combination, significantly influenced plant height, nodulation, and yield attributes of chickpea, with higher levels of both nutrients producing the best results. These studies corroborate the present investigation, highlighting the synergistic role of phosphorus and sulphur in improving chickpea growth and productivity.

3.2 Number of Nodules Per Plant

The Number of nodules per plant of Chickpea was observed from 20 DAS to 100 DAS and highest Number of nodules per plant as observed at 100 DAS. Effect of Phosphorus and Sulphur on Number of nodules per plant was observed among the all treatments. The significantly higher number of nodules per plant (11.17) was recorded with the treatment T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha. However, the treatments T2, T3, T4, T5, T6 and T7 were found to be statistically at par with T_9. Where as the minimum number of nodules per plant (9.23) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

However the present results are in close agreement with earlier findings. Application of phosphorus significantly increased nodulation and nitrogen fixation in chickpea, attributing this to the role of phosphorus in root proliferation and energy transfer processes that support symbiotic activity. Similarly, observed that the combined application of phosphorus and sulphur markedly enhanced the number of nodules, nodule dry weight, and nitrogenase activity in legumes.

3.3 Number of Branches Per Plant

The Number of branches per plant of Chickpea was observed from 20 DAS to 100 DAS and highest Number of branches per plant as observed at 100 DAS. Effect of Phosphorus and Sulphur on Number of branches per plant was observed among the all treatments. significantly higher number of branches per plant (26.33) was recorded with the treatment T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha. However, the treatments T7 were found to be statistically at par with T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha. Where as the minimum number of branches per plant (9.27) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

3.4 Plant Dry Weight (g/plant)

The Plant dry weight of Chickpea was observed from 20 DAS to 100 DAS and highest plant dry weight was observed at 100 DAS. Effect of Phosphorus and Sulphur on increasing plant dry weight was observed among all the treatments. The significantly higher dry weight (g) per plant (24.20) was recorded with the treatment T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha (Nosheen & Shafique, 2006). However, the treatments T1 were found to be statistically at par with T_9. Where as the minimum dry weight (g) per plant (18.27) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

The observed increase in dry weight per plant is in agreement with earlier findings reported by Nosheen & Shafique (2006), who observed that phosphorus application significantly enhanced vegetative growth and biomass accumulation in chickpea. Similarly, reported that combined application of phosphorus and sulfur improved dry matter production at all growth stages due to enhanced nutrient uptake and photosynthetic efficiency. More recently, Digvijay et al. (2024) also reported that chickpea plants receiving balanced phosphorus and sulfur nutrition produced significantly higher plant biomass compared to control and other nutrient combinations.

3.5 Crop Growth Rate (g/m^2/ Day)

The data pertaining to crop growth rate (g/m^2/ day) of Chickpea was recorded at intervals 20-40 DAS, 40-60 DAS, 60-80 DAS and 80-100 DAS. At 80-100 DAS, non-significantly higher crop growth rate (g/m^2/ day) (18.01) was recorded with the treatment T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha. Where as the minimum crop growth rate (g/m2/ day) (11.84) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

3.6 Relative Growth Rate (g/g/day)

The data pertaining to relatives growth rate (g/g/day) of Chickpea was recorded at intervals 20-40 DAS, 40-60 DAS, 60-80 DAS and 80-100 DAS. At 80-100 DAS, the data was found to be non-significantly higher relatives growth rate (g/g/day) (0.032) was recorded with the treatment T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha. However, the treatments Phosphorus at 40 kg/ha + Sulphur at 20 kg/ha and Phosphorus at 20 kg/ha + Sulphur at 20 kg/ha. Where as the minimum relatives growth rate (g/g/day) (0.017) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

3.7 Yield Attributes and Yield

3.7.1 Number of pod per plant

Significantly higher number of pod per plant was observed (33.49) with the treatment T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha. However, the treatments T6 and T7 were found to be statistically at par with T_9.. Where as the minimum number of pod per plant (28.63) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

The present findings are in line with the earlier reports of who observed that phosphorus application at higher levels significantly increased the number of pods per plant in chickpea. Similarly, reported that the integrated application of phosphorus and sulphur enhanced reproductive efficiency and pod formation in legumes. Further, also noted that phosphorus and sulphur, either individually or in combination, had a significant impact on number of pods per plant, attributing it to improved nutrient availability, photosynthetic efficiency, and better translocation of assimilates to the sink

3.7.2 No. of seed/pod

Significantly higher number of seed per pod (1.33) was observed with the treatment T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha. However, the treatments T6 and T7 were found to be statistically at par with T_9. Where as the minimum number of seed per pod (1.03) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

Table 1. Influence of Phosphorus and Sulphur on growth and growth attributes of Chickpea

S. No.	Treatments	Plant Height	Number of nodules per plant	Number of branches per plant	Dry weight (g) per plant	Crop growth rate (g/m^2/ day)	Relative growth rate (g/g/day)
1.	Phosphorus at 20 kg/ha + Sulphur at 10 kg/ha	44.13	9.80	10.73	18.30	12.62	0.025
2.	Phosphorus at 20 Kg/ha +Sulphur at 20 kg/ha	44.53	10.13	13.07	19.31	14.50	0.028
3.	Phosphorus at 20 Kg/ha +Sulphur at 30 kg/ha	47.05	10.17	15.10	19.45	14.11	0.026
4.	Phosphorus at 40 Kg/ha +Sulphur at 10 kg/ha	47.48	10.40	17.13	21.46	12.36	0.018
5.	Phosphorus at 40 Kg/ha +Sulphur at 20 kg/ha	48.50	10.60	18.70	22.37	16.89	0.028
6.	Phosphorus at 40 Kg/ha +Sulphur at 30 kg/ha	50.01	10.70	19.80	22.36	15.07	0.024
7.	Phosphorus at 60 Kg/ha +Sulphur at 10 kg/ha	49.53	10.90	20.97	22.92	14.10	0.022
8.	Phosphorus at 60 Kg/ha +Sulphur at 20 kg/ha	49.86	11.03	21.00	23.77	13.61	0.027
9.	Phosphorus at 60 Kg/ha +Sulphur at 30 kg/ha	52.02	11.17	26.33	24.20	18.01	0.032
10.	NPK -20-60-20 Kg/ha (Control)	40.82	9.23	9.27	18.27	11.81	0.017
	F – Test	**S**	**S**	**S**	**S**	**NS**	**NS**
	SE m (±)	**1.37**	**0.31**	**1.91**	**1.94**	**1.48**	**0.0023**
	CD (p=0.05)	**4.07**	**0.94**	**5.68**	**5.77**	**-**	**-**

Table 2. Influence of Phosphorus and Sulphur on yield and yield attributes of Chickpea

S. No	Treatments	Number of pod per plant	No. of seed/pod	Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1.	Phosphorus at 20 kg/ha + Sulphur at 10 kg/ha	29.28	1.07	3.68	1.71	3.72	31.63
2.	Phosphorus at 20 Kg/ha +Sulphur at 20 kg/ha	29.44	1.10	4.23	1.72	3.85	30.92
3.	Phosphorus at 20 Kg/ha +Sulphur at 30 kg/ha	29.70	1.10	4.32	1.75	3.99	30.51
4.	Phosphorus at 40 Kg/ha +Sulphur at 10 kg/ha	30.15	1.13	4.36	1.80	4.10	30.44
5.	Phosphorus at 40 Kg/ha +Sulphur at 20 kg/ha	30.51	1.13	4.79	1.86	4.29	29.73
6.	Phosphorus at 40 Kg/ha +Sulphur at 30 kg/ha	31.88	1.17	4.98	2.02	4.37	31.62
7.	Phosphorus at 60 Kg/ha +Sulphur at 10 kg/ha	32.07	1.20	5.15	2.18	4.46	32.77
8.	Phosphorus at 60 Kg/ha +Sulphur at 20 kg/ha	32.51	1.33	5.57	2.32	4.58	33.54
9.	Phosphorus at 60 Kg/ha +Sulphur at 30 kg/ha	33.49	1.33	5.93	2.44	4.93	33.11
10.	NPK -20-60-20 Kg/ha (Control)	28.63	1.03	3.65	1.62	3.32	32.82
	F – Test	**S**	**S**	**S**	**S**	**S**	**NS**
	SE m (±)	**0.89**	**0.04**	**0.16**	**0.13**	**0.15**	**1.52**
	CD (p=0.05)	**2.65**	**0.13**	**0.49**	**0.40**	**0.47**	**-**

Table 3. Influence of Phosphorus and Sulphur on Economic of Chickpea

S No	Treatments	Cost of Cultivation (INR/ha)	Gross return (INR/ha)	Net return (INR/ha)	Benefit: Cost Ratio (B:C)
1.	Phosphorus at 20 kg/ha + Sulphur at 10 kg/ha	44951.48	106920	61968.52	1.37
2.	Phosphorus at 20 Kg/ha +Sulphur at 20 kg/ha	45513.98	107870	62356.02	1.37
3.	Phosphorus at 20 Kg/ha +Sulphur at 30 kg/ha	46076.48	109970	63893.52	1.38
4.	Phosphorus at 40 Kg/ha +Sulphur at 10 kg/ha	46001.48	113100	67098.52	1.45
5.	Phosphorus at 40 Kg/ha +Sulphur at 20 kg/ha	46563.98	117030	70466.02	1.51
6.	Phosphorus at 40 Kg/ha +Sulphur at 30 kg/ha	47126.48	126230	79103.02	1.67
7.	Phosphorus at 60 Kg/ha +Sulphur at 10 kg/ha	47051.48	135460	88408.52	1.87
8.	Phosphorus at 60 Kg/ha +Sulphur at 20 kg/ha	47613.98	143660	96533.52	2.04
9.	Phosphorus at 60 Kg/ha +Sulphur at 30 kg/ha	48176.48	151430	103816.02	2.18
10.	NPK -20-60-20 Kg/ha (Control)	43338.98	100680	57341.02	1.32

The present findings are in conformity with earlier reports. noted that phosphorus application improved seed setting and enhanced number of seeds per pod in chickpea. Similarly, reported that phosphorus in combination with sulphur significantly influenced reproductive growth and increased seed number per pod in pulses. also confirmed that adequate phosphorus and sulphur application improved the efficiency of flowering and pod filling, thereby leading to higher seed count per pod in chickpea.

3.7.3 Test Weight (g)

Significantly higher test weight (g) was (5.93 g) observed with the treatment T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha. However, the treatments T6 and T7 were found to be statistically at par with T_9. Where as the minimum test weight (g) (3.65) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

These findings are in agreement with earlier studies by Singh (2017), Singh et al. (2018), and Kumawat et al. (2020), which reported that phosphorus and sulfur nutrition play a critical role in enhancing seed weight and overall yield in chickpea by promoting better nutrient uptake, pod filling, and assimilate translocation to seeds.

3.7.4 Seed yield (t/ha)

Significantly higher seed yield (t/ha) was observed (2.44 t/ha) with the treatment T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha. However, the treatments T7 and T8 were found to be statistically at par with T_9. Where as the minimum seed yield (t/ha) (1.62) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

The results are in close agreement with those reported by earlier researchers. observed that phosphorus application improved test weight by enhancing seed filling efficiency. also reported that phosphorus in combination with sulphur significantly increased 100-seed weight in chickpea by improving assimilate translocation to developing seeds. Similarly, confirmed that phosphorus and sulphur nutrition had a positive effect on seed size and test weight, attributing it to improved metabolic activity and grain development

3.7.5 Straw yield (kg/ha)

Significantly higher stover yield (t/ha) was observed (4.93 t/ha) with the treatment T_9 Phosphorus at 60 kg/ha + Sulphur at 30 kg/ha. However, the treatments T7 and T8 were found to be statistically at par with T_9. Where as the minimum stover yield (t/ha (3.32) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

The present results are in conformity with earlier reports. observed that phosphorus fertilization significantly increased stover yield in chickpea by enhancing growth and biomass production. Similarly, reported that the combined application of phosphorus and sulphur improved total dry matter accumulation and stover yield in pulses also confirmed that higher levels of phosphorus and sulphur led to increased stover yield due to better nutrient availability and improved photosynthetic efficiency.

3.7.6 Harvest index (%)

Non-Significantly higher harvest index (%) was observed with the Phosphorus at 60 Kg/ha +Sulphur at 30 kg/ha (33.54). Where as the minimum harvest index (%) (29.73) was found in treatment T_{10} NPK – 20-60-20 kg/ha (Control).

Economic analysis: The Highest benefit cost ratio (2.18) was recorded in T9 (Phosphorus at 60 Kg/ha +Sulphur at 30 kg/ha) as compared to other treatments.

4. CONCLUSION

It is concluded that application of Phosphorus at 60 Kg/ha +Sulphur at 30 kg/ha has performed better in growth parameters, yield attributes, and benefit cost ratio of chickpea

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

ACKNOWLEDGEMENT

The authors are thankful to Department of Agronomy, Naini Agricultural Institute, Prayagraj, Sam Higginbottom University of Agriculture Technology and sciences, (U.P), India for providing necessary facilities to undertake the studies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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