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Effect of Phosphorus Levels on Growth, Yield, and Yield Attributes of Chickpea (*Cicer arietinum* L.) Under Field Conditions in Central India

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Authors' contributions

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

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Short Research Article

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ABSTRACT

Phosphorus application is essential for energy transfer in living cells enhancing root growth besides increasing the mobility of symbiotic bacteria in the root zone which ultimately results in more nitrogen fixation. It also plays a key role in pod filling and ultimately enhances the grain yield. Different planting dates subject the vegetative and reproductive stages of the plant to various temperature, solar radiation and day length. The investigation was conducted the winter seasons of

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2024-25 at the Research Farm of the School of Agriculture, Sanjeev Agrawal Global Education (SAGE) University, Bhopal (M.P.). The experiment followed a randomized block design (RBD) with 7 treatments replicated thrice. The treatments consisted of seven phosphorus levels T_1(20 kg N, 65 kg P, 20 kg K), T_2(20 kg N, 54 kg P, 20 kg K), T_3(20 kg N, 43 kg P, 20 kg K), T_4(20 kg N, 32 kg P, 20 kg K), T_5(20 kg N, 21 kg P, 20 kg K), T_6(20 kg N, 10 kg P, 20 kg K) and T_7(20 kg N, 0 kg P, 20 kg K). The results showed that application of 65kg P_2O_5 ha^{-1} was recorded significantly plant population (35 m^2), Number of seeds plant^{-1} at harvest (45.66), Number of seedspod^{-1} at harvest (2.10), whereas significantly highest Pods plant^{-1}(45.66), Seed Pod^{-1}(2.10), Seed yield (2166 kg ha^{-1}), straw yield (3396 kg ha^{-1}) and Harvest index (38.95 %) was recorded with the treatment 65 kg P_2O_5 ha^{-1}. A notable and increased stover yield was seen with phosphorus application, which enhanced photosynthesis production and its movement from source to sink, resulting in a greater stover value.

Keywords: Plant population; number of seeds (per plant); number of seeds/pod; pods/plant;seed yield; straw yield; harvest index.

1. INTRODUCTION

"Chickpea (*Cicer arietinum* L.), a member of the family Leguminaceae or Fabaceae and subfamily Papilionaceae, *Cicer* L." (Nathawat, *et. al.,* 2024), is a self-pollinated true diploid (2n = 2x = 16) with a genome size of 738 Mbp (Madurapperumage, *et. al.,* 2021), an important *Rabi* season pulse crop having a predominant position and considered the 'King of pulses' (Dhakad and Kushwaha, 2018). "The crop originated in an area of southeastern Turkey adjoining Syria" (Toker, 2009). "The Latin words *cicer* and *arietinum* were taken from the Greek words Kikus, meaning 'force of strength,' and Krios, referring to 'ram,' respectively" (Mohsenzadeh, 2024, Van Der Maesen, 1972). "The English word "chickpea" was derived from "chickpea," referring to Cicer-pea" (Sajja, *et. al.,* 2017). Chickpeas are high in protein and one of the earliest cultivated vegetable crops (Bhausaheb,2021), and chickpea husks and bits of dal are used as nutritious feed for animals, and chickpeas can also be used as green fodder for animals (Hari and Dawson, 2022). "Globally, chickpea ranks as the fourth most important legume crop after soybean, peanut, and beans" (Kapoor, *et. al.,* 2010; Cokkizgin, 2012).

"Chickpea is the third most important grain legume after common bean and pea" (Anwar, *et. al.,* 2009). "Asia covers 89.7 percent of the area in chickpea cultivation, followed by 4.3 percent in Africa, 2.6 percent in Oceania, 2.9 percent in America, and 0.4 percent in Europe" (Gaur, *et. al.,* 2010). "India ranks first in terms of chickpea production and consumption in the world. About 65 percent of the global area, with 68 percent of global production, is contributed by India" (Reddy and Mishra, 2006). The country harvested a record production of more than 117 lakh tonnes (LT) at the productivity level of 1164 kg/ha. "Maharashtra has contributed 23% of the total gram area (23.27 L ha), whereas in production as usual, Madhya Pradesh is the contributing state with 27% of total gram production (31.93 LT) in the country, thereby ranking Maharashtra first in area and Madhya Pradesh in production. Madhya Pradesh (22%) and Rajasthan (21%) were the next in terms of area. The total area under chickpea cultivation in India is about 10.1 million hectares with an annual production of 11.7 million tons. The average productivity of chickpeas is 1164 kg/ha." (Anonymous, 2023-24).

"Phosphorus (P) is one of the most crucial components of plant nutrition. It promoted the growth of roots, enhanced flowering and more uniform seed production" (Ali, *et. al.,* 2010), early crop maturity, enhanced legumes' ability to fix nitrogen, enhanced crop quality, and heightened resistance to plant diseases (Kardile, *et. al.,* 2024). It is a constituent of certain nucleic acids, i.e., phospholipids, chromosomes, and the coenzymes nicotinamide adenine dinucleotide (NAD), adenosine triphosphate (ATP), and nicotinamide adenine dinucleotide phosphate (NADP) Gulpadiya, *et. al.,* (2010).

2. METHODS AND MATERIALS

The study using chickpea as a test crop was conducted during the winter (*Rabi*) season of 2024-25 at the SAGE experimental farm of the School of Agriculture, Sanjeev Global Educational University, Bhopal, Madhya Pradesh. It comes under the agro-climate region classified as the Vindhya F Chartau Hills Zone. The experimental site is located in the east direction, with an average elevation of 405.07 meters above mean sea level. The climate of the region is characterized as subtropical, with hot and sub-humid weather in summer and cool weather in winter. The temperature varies significantly across seasons, and the average winter rainfall is recorded as 1000 - 1500 mm. The experiment was laid out in a randomized block design (RBD) comprising 7 treatments: T1 (20 kg N, 65 kg P, 20 kg K), T2 (20 kg N, 54 kg P, 20 kg K), T3 (20 kg N, 43 kg P, 20 kg K), T4 (20 kg N, 32 kg P, 20 kg K), T5 (20 kg N, 21 kg P, 20 kg K), T6 (20 kg N, 10 kg P, 20 kg K), and T7 (20 kg N, 0 kg P, 20 kg K), replicated thrice. The soil at the experimental site was identified as clay loam with pH (7.9), organic carbon (0.42%), available N (172 kg ha^{-1}), available P (18.5 kg ha^{-1}), and available K (164 kg ha^{-1}). The chickpea variety Samrat (JG 315), with duration of 125 days, was sown in line at the experimental site. The healthy and bold chickpea seeds were dibbled into the soil with a plot size of 3 x 3 meters and spacing of 30 × 10 cm. The crop was harvested at physiological maturity, approximately 110 days after sowing. The statistical analysis of the experimental design was conducted following the methodology of Panse and Sukhatme (1967).

3. RESULTS AND DISCUSSION

Plant population is directly involved in yield of crop, both more and less plant population than optimum is harmful for production point of view. The data presented in Table 1, revealed that significant variation was found due to application of different levels of phosphorus on plant population of chickpea at 30 DAS and at harvesting stage it affects significantly. “At harvest maximum plant population T_2(29.50 m^{-2}) was recorded with application T_1 of 65 kg P_2O_5 ha^{-1} gave the maximum plant population (35.33 m^{-2}). At harvest stage the plant population increased significantly with the increase in phosphorus levels,itmay due to the pronounced effect of higher levelsof phosphorus on root growth and energy metabolism during early development dynamics observed in chickpea when phosphorus is available in stabilized form, such as biochar-based fertilizers” (Wali, *et. al.,* 2020), which, in turn, enhanced the extraction of nutrients and moisture from the soil, which lowered mortality rates and ultimately resulted in a better plant population at the time of harvest.

3.1 Yield Attributes and Yield

3.1.1 Number of seeds plant^{-1}and seed pods^{-1}

Phosphorus application exerted a significant influence on both the number of seeds plant^{-1}and pod^{-1}. Number of seeds plant^{-1}and seed pods^{-1} significantly maximum number of seeds plant^{-1}and seed pods^{-1}(45.66 and 2.10) was recorded with the treatment of application of (T_1) 65 Kg P_2O_5 ha^{-1} over all the treatments. However, the treatment (T_2) 54 Kg P_2O_5 ha^{-1}(41.00 and 1.91) which were found to be statistically at par with 65 Kg P_2O_5 ha^{-1}, because phosphorus critical role in facilitating flowering, pollination effectiveness and pod filling. The superior yield attributes of chickpea due to more availability of P and its active involvement in shoot and root growth in general and use of 40 kg P_2O_5 ha^{-1} along with PSB-II in particular. Thus it improved translocation of photosynthesis from source to sink. This finding is in agreement with the findings of Mishra, *et. al.,* (2010), Patel, *et. al.,* (2015) and Sarvjeet, *et. al.,* (2018).

3.2 Grain Yield

Grain yield markedly increased with phosphorus (P_2O_5) application, with T_1 yielding the highest (45.66 and 2.10), which was recorded with the treatment of application of (T_1) 65 kg P_2O_5 ha^{-1} over all the treatments. However, the treatment (T_2) 54 kg P_2O_5 ha^{-1}(41.00 and 1.91) was found to be statistically at par with 65 kg P_2O_5 ha^{-1}. The higher yield was due to the combined role of phosphorus doses and PSB inoculation supported by yield attributes and root nodulation. The result also showed a 20 kg saving of P_2O_5 ha^{-1}. These results are in agreement with those reported by Bhuiyan, *et. al.* (2008), Mishra, *et. al.* (2010), Singh, *et. al.* (2015) and Sarvjeet, *et. al.* (2018).

3.3 Straw Yield

Straw yield also increased with higher phosphorus application, with T1 producing the highest straw yield (45.66 and 2.10), which was recorded with the treatment of application of (T_1) 65 kg P_2O_5 ha^{-1} over all the treatments. However, the treatment (T_2) 54 kg P_2O_5 ha^{-1}(41.00 and 1.91) was found to be statistically at par with 65 kg P_2O_5 ha^{-1}. Adequate phosphorus promotes root expansion and vegetative vigor, resulting in greater aboveground biomass. Significant and higher stover yield was observed with the application of phosphorus, which accelerated the production of photosynthesis and their translocation from source to sink, which ultimately gave the higher value of stover. Similar results were also observed by Lalrinzuali, *et. al.*(2023).

Table 1. Response of Phosphorus on Growth and Yield attributes of Chickpea (*Cicer arietinum* L.)

S.N.	Treatments	Plant population (M^2)	Number of seeds plant^{-1}	Number of seed pods^{-1}	Grain yield (Kg ha^{-1})	Straw Yield (Kg ha^{-1})	Harvest Index
1.	20 kg N, 65 kg P, 20 kg K	35.33	45.66	2.10	2,166	3,396	38.95
2.	20 kg N, 54 kg P, 20 kg K	33.33	41.00	1.91	2,048	3,307	38.24
3.	20 kg N, 43 kg P, 20 kg K	30.66	38.00	1.86	1,926	3,185	37.67
4.	20 kg N, 32 kg P, 20 kg K	29.66	34.33	1.73	1,844	3,025	37.87
5.	20 kg N, 21 kg P, 20 kg K	26.66	33.33	1.56	1,803	2,959	37.87
6.	20 kg N, 10 kg P, 20 kg K	22.66	32.33	1.51	1,752	2,907	37.60
7.	20 kg N, 0 kg P, 20 kg K	20.0	28.33	1.42	1,681	2,852	37.09
SEm±		0.60	1.21	0.05	18.57	15.11	0.22
CD(P=0.05)		1.89	3.78	0.17	57.56	47.08	0.70

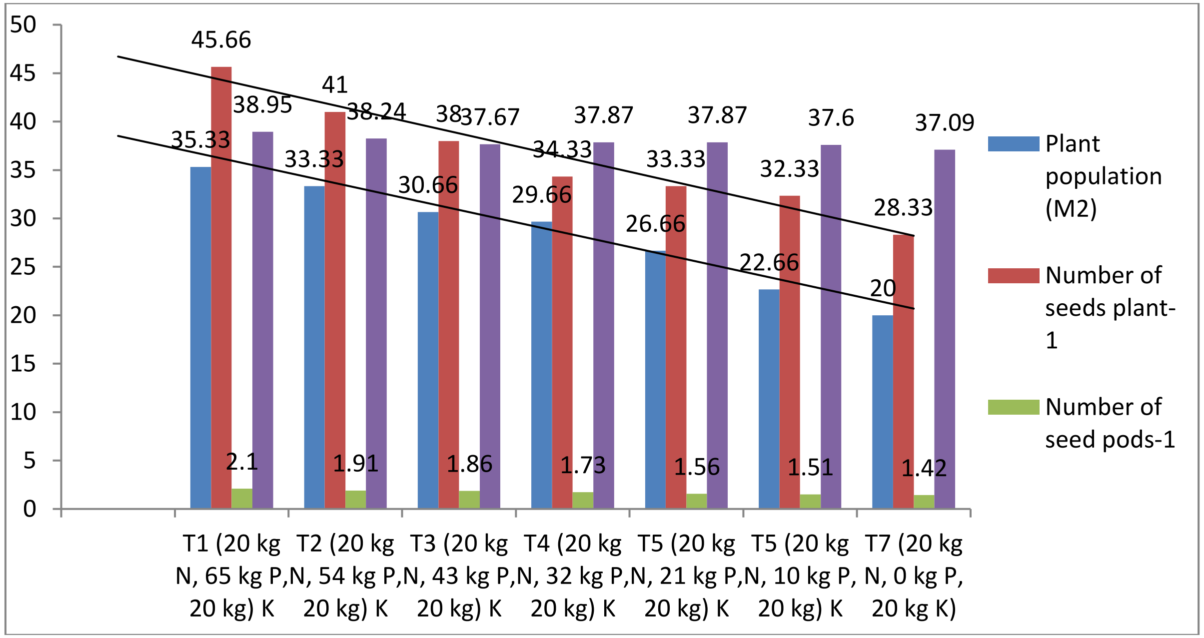

Fig. 1. Response of phosphorus on growth and yield attributes of Chickpea (*Cicer arietinum* L.)

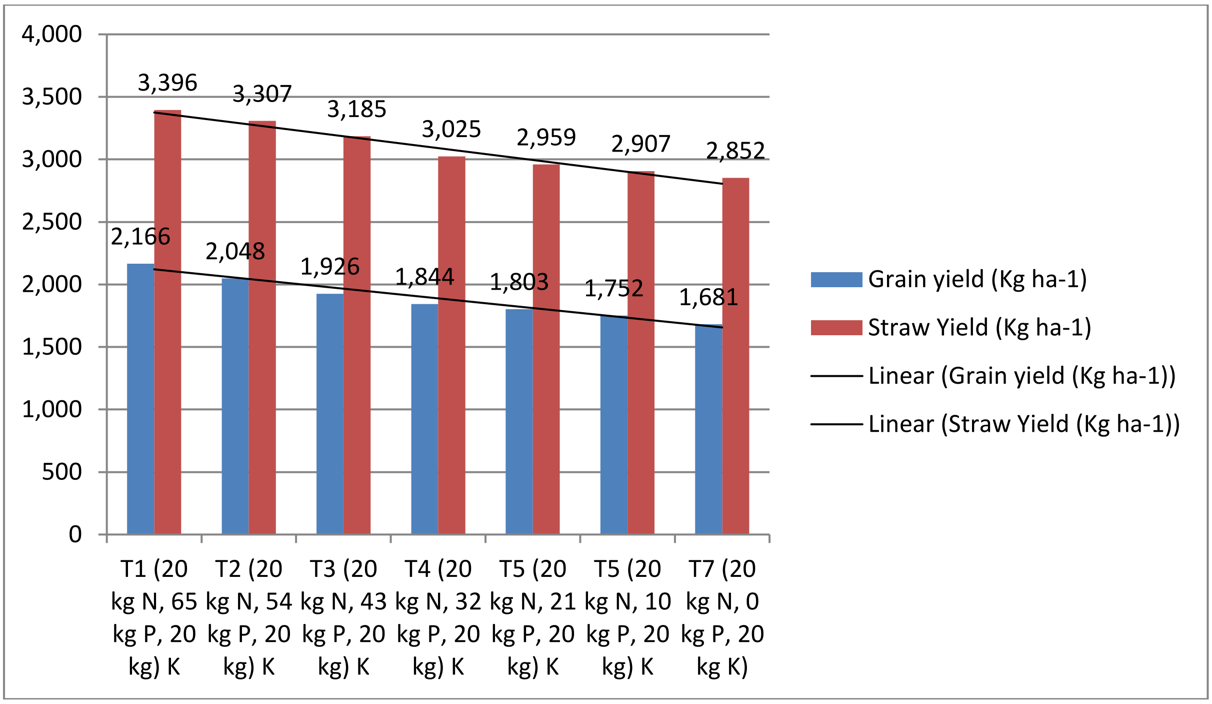

Fig. 2. Response of Phosphorus on grain and straw yield of Chickpea (*Cicer arietinum* L.)

3.4 Harvest Index

The harvest index showed a modest increase in phosphorus-enriched treatments, with the highest value (45.66 and 2.10) recorded with the treatment of application of (T_1) 65 kg P_2O_5 ha^{-1} over all the treatments. However, the treatment (T_2) 54 kg P_2O_5 ha^{-1}(41.00 and 1.91) was found to be statistically at par with 65 kg P_2O_5 ha^{-1}. Although differences were small, the trend suggests better assimilate partitioning toward grain yield under sufficient phosphorus nutrition. Phosphorus contributes to improved flowering, pod development, and grain filling, enhancing the conversion efficiency of photosynthates into economic yield. In a recent study, Tetteh, *et. al.*(2022) demonstrated that phosphorus application improved both yield components and harvest index in legumes under smallholder conditions, affirming its key role in reproductive efficiency. Khan, *et. al.*(2007) and Singh, *et. al.*(2018) also reported.

4. CONCLUSION

Phosphorus (P) is one of the most crucial components of plant nutrition. It promoted the growth of roots, enhanced flowering and more uniform seed production. Adequate phosphorus promotes root expansion and vegetative vigor, resulting in greater aboveground biomass. A notable and increased stover yield was noted with phosphorus application, which enhanced photosynthesis production and their movement from source to sink, ultimately resulting in a higher stover value.

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 the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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