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Effect of phosphorus and boron on growth, yield, nutrient uptake by chickpea (*Cicer arietinum* L.) and soil chemical characteristics

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Abstract

A field experiment was conducted during Rabi 2025-26 at the Agricultural Research Farm to evaluate the effects of phosphorus and boron on growth, yield, nutrient uptake, soil fertility and economics of chickpea (*Cicer arietinum* L.). The experiment was laid out in a Factorial Randomized Block Design with three replications, comprising four phosphorus levels (0, 20, 40 and 60 kg P₂O₅ ha⁻¹) and four boron treatments. Phosphorus application at 60 kg P₂O₅ ha⁻¹ significantly enhanced plant growth, nodulation, yield attributes, grain yield, nutrient content and uptake, and post-harvest available soil N, P and K. Among boron treatments, combined soil application of borax @ 5 kg ha⁻¹ and foliar spray @ 0.3% at 30 and 60 DAS was superior for most parameters. The interaction between phosphorus and boron was significant for pods plant⁻¹ and grain yield, with P₃B₃ producing the highest pods (36.85 plant⁻¹) and grain yield (1720 kg ha⁻¹). The highest economic returns were also recorded with higher phosphorus and combined boron application. Thus, application of 60 kg P₂O₅ ha⁻¹ along with soil and foliar boron application proved most effective for improving productivity, nutrient uptake, soil fertility and profitability of chickpea under the conditions of the study.

Keywords: Phosphorus, nodulation, soil properties, sustainable agriculture

1. Introduction

Chickpea (*Cicer arietinum* L.), commonly known as Bengal gram or chana, is one of the most important Rabi pulse crops and is considered the “king of pulses.” It is an important source of dietary protein, carbohydrates, minerals and dietary fibre and contributes substantially to food and nutritional security. In addition to its nutritional importance, chickpea improves soil fertility through biological nitrogen fixation, making it an important component of sustainable cropping systems.

However, chickpea productivity is frequently limited by inadequate availability of essential nutrients, particularly phosphorus (P) and boron (B). Phosphorus plays a vital role in energy transfer, root development, nodulation and reproductive growth, while boron is essential for pollen germination, fertilization, pod formation and seed development. Adequate phosphorus promotes root proliferation and effective nodulation, whereas boron helps in reducing flower abortion and improving pod and seed formation (Tomar and Singh, 2022; Koul *et al.*, 2022) ^[8]. Phosphorus and boron nutrition can also improve nutrient uptake and grain productivity of chickpea, particularly under nutrient-deficient soil conditions (Sultonov *et al.*, 2025) ^[15].

Balanced application of P and B is therefore important for improving growth, yield attributes, grain yield and nutrient-use efficiency of chickpea while maintaining soil fertility. Hence, the present study was undertaken to evaluate the effect of phosphorus and boron application on growth, yield, nutrient uptake and soil chemical properties of chickpea under the agro-climatic conditions of Rajasthan.

2. Materials and methods

A field experiment was conducted during the Rabi season of 2025-26 at the Agricultural Research Farm, Department of Soil Science, School of Agriculture, Suresh Gyan Vihar University, Jaipur,

Rajasthan, to assess the effects of phosphorus and boron on growth, yield, nutrient uptake, soil fertility and economics of chickpea (*Cicer arietinum* L.). The experimental site is located in a semi-arid, subtropical climate characterized by extreme temperature variations, with hot and dry summers (maximum temperature up to 45°C) and cold winters (minimum temperature as low as 2.8°C). The area receives an average annual rainfall of 500-800 mm, mostly concentrated during the monsoon season. The soil of the experimental field was sandy loam in texture, saline in reaction, with the following initial characteristics: Soil of the experimental field was sandy loam in texture, saline in reaction with a pH value of 7.62, EC (0.48 dSm⁻¹), poor in organic carbon (0.34%), low in available nitrogen (134.25 kg/ha), phosphorus (13.25 kg/ha) and (178.15 kg/ha) but medium in available potassium (320 kg/ha). The factorial randomized block design with three replications. The collected data were statistically analysed using analysis of variance (ANOVA) appropriate for the RBD design to determine the significance of treatment effects.

3. Results and Discussion

3.1 Growth and nodulation: Phosphorus application significantly improved plant height and nodulation in chickpea. The maximum plant height at 30 and 60 DAS (22.60 and 47.90 cm, respectively) was recorded with 60 kg P₂O₅ ha⁻¹ (P₃) compared with 18.69 and 39.62 cm under the control. Similarly, P₃ produced the highest number of nodules (39.65 plant⁻¹), whereas the control recorded 27.32 nodules plant⁻¹.

The improvement in growth and nodulation may be attributed to the role of phosphorus in root development, energy transfer, cell division and biological nitrogen fixation. Adequate phosphorus promotes root proliferation and provides energy for the establishment and functioning of Rhizobium nodules. Similar enhancement of chickpea growth and nodulation with phosphorus application has been reported by Badini (2015), Jaiswal and Tomar (2022), Kumar *et al.* (2022), Lalrinzuali *et al.* (2023) and Garg and Lilhare (2024) [5, 8, 10, 12]. Recent research also confirms that phosphorus availability is closely associated with improved nodulation and nutrient acquisition in chickpea.

Boron also significantly improved plant height and nodulation. The highest plant height (20.99 and 44.85 cm at 30 and 60 DAS) and nodules (35.45 plant⁻¹) were obtained with B₃, i.e., soil application of borax @ 5 kg ha⁻¹ + foliar spray of borax @ 0.3% at 30 and 60 DAS. The beneficial effect of boron may be related to its involvement in cell-wall formation, membrane stability, carbohydrate translocation, root growth and reproductive development. Boron is an essential micronutrient and its deficiency can restrict normal plant growth and productivity. Singh *et al.* (2019) emphasized the importance of adequate boron availability for crop production in Indian soils, while Embadwar *et al.* (2023), Kumar *et al.* (2022) and Reddy and Umesha (2022) [4, 10, 13] reported beneficial effects of boron on chickpea growth and yield.

3.2 Yield attributes and grain yield

Phosphorus and boron significantly enhanced the yield attributes of chickpea. The highest values were generally obtained with higher phosphorus application and combined soil and foliar boron application. The interaction between phosphorus and boron was also important, with P₃B₃ recording the maximum grain yield of 1720 kg ha⁻¹, whereas P₀B₀ produced only 1220 kg ha⁻¹.

The increased grain yield under phosphorus application may be explained by better root development, enhanced nodulation, greater nutrient uptake and efficient translocation of assimilates

towards reproductive organs. Phosphorus is particularly important during flowering, pod formation and seed development. Similar increases in yield and yield attributes of chickpea with phosphorus fertilization were reported by Badini (2015), Jaiswal and Tomar (2022), Kumar *et al.* (2022) and Lalrinzuali *et al.* (2023) [8, 10, 12].

The positive effect of boron on yield may be attributed to its role in pollen germination, pollen-tube growth, fertilization, seed formation and carbohydrate movement. Embadwar *et al.* (2023) and Kumar *et al.* (2022) reported significant improvement in growth and yield of chickpea following boron application. The present results are particularly consistent with Garg and Lilhare (2024) [4, 5, 10], who reported that combined phosphorus and boron application improved chickpea growth, yield attributes, grain yield and quality.

3.3 Nutrient content and uptake: Phosphorus and boron significantly increased nutrient concentration and uptake by chickpea grain. Grain nitrogen content increased from 3.12% under control to 3.40% with P₃, while nitrogen uptake increased from 38.22 to 54.47 kg ha⁻¹. Under boron, B₃ recorded 3.30% nitrogen and 50.73 kg ha⁻¹ nitrogen uptake compared with 3.19% and 43.32 kg ha⁻¹ under B₀. The greater nitrogen uptake under phosphorus may be associated with enhanced nodulation and biological nitrogen fixation. Increased biomass and grain production also contributed to greater nutrient removal from the soil. Similar improvement in nutrient uptake following phosphorus application has been reported by Das *et al.* (2016) and Lalrinzuali *et al.* (2023) [12]. Phosphorus-microbial interactions have also been shown to improve chickpea growth and nutrient acquisition under P-deficient conditions.

Grain phosphorus content increased from 0.32% in P₀ to 0.41% in P₃, while B₃ recorded 0.38% compared with 0.34% under B₀. The increase indicates improved phosphorus availability and uptake under fertilized conditions. Similar improvement in grain nutrient concentration and quality with balanced phosphorus and boron nutrition has been reported in chickpea.

3.4 Soil chemical properties: Phosphorus and boron application did not significantly influence soil pH, EC and organic carbon, indicating that these properties remained relatively stable during the experimental season. In contrast, available nitrogen was significantly increased, with the highest value of 178.85 kg ha⁻¹ under P₃ and 176.45 kg ha⁻¹ under B₃.

The increase in available nutrients may be due to enhanced root activity, improved nutrient cycling and greater biological activity in the rhizosphere. Phosphorus fertilization directly increases the soil P pool, while improved root growth facilitates nutrient acquisition. Similar effects of phosphorus fertilization on soil fertility and chickpea productivity have been reported by Kumar *et al.* (2019) and Lalrinzuali *et al.* (2023) [11, 12].

Conclusion: The overall results indicate that P₃ (60 kg P₂O₅ ha⁻¹) and B₃ (soil borax @ 5 kg ha⁻¹ + foliar borax @ 0.3%) were the most effective treatments. Their combined application (P₃B₃) produced the highest grain yield of 1720 kg ha⁻¹. The synergistic response of P and B can be explained by their complementary physiological functions. Phosphorus mainly promotes root development, energy metabolism, nodulation and nutrient uptake, whereas boron supports cell development, reproductive growth, pollen fertility and assimilate translocation. Therefore, balanced application of both nutrients can improve chickpea productivity and nutrient-use efficiency. This conclusion is strongly supported by recent field research on combined P and B nutrition in chickpea.

Table 1: Effect of phosphorus and boron on plant population of chickpea

Sr. no.	Treatments	Plant population/m row length		Plant height (cm)		Number of nodules per plant
		30 DAS	At harvest	30 DAS	60 DAS	
A.	Phosphorus levels					
1.	P0	8.52	8.10	18.69	39.62	27.32
2.	P1	8.85	8.43	19.75	41.88	30.36
3.	P2	9.25	8.83	20.83	44.15	34.85
4.	P3	9.52	9.10	22.60	47.90	39.65
	S.Em.±	0.30	0.28	0.38	1.23	0.81
	CD	NS	NS	1.15	3.68	2.43
B.	Boron levels					
1.	B0	8.75	8.33	19.94	42.27	30.32
2.	B1	9.24	8.82	20.59	43.60	34.62
3.	B2	9.15	8.73	20.35	43.25	32.85
4.	B3-	9.32	8.90	20.99	44.85	35.45
	S.Em.±	0.30	0.28	0.29	0.74	0.81
	CD	NS	NS	0.87	2.22	2.43
A × B	Phosphorus × Boron levels					
	S.Em.±	0.60	0.56	0.58	1.48	1.62
	CD	NS	NS	NS	NS	NS

Table 2: Effect of phosphorus and boron on yield attributes and yield of chickpea

Sr. no.	Treatments	Number of pods per plant	Number of seeds per pod	Seed index (g)	Seed yield (kg/ha)
A.	Phosphorus levels				
1.	P0-Control	25.32	1.66	19.32	1225
2.	P1-20 kg P2O5	28.45	1.75	19.85	1374
3.	P2-40 kg P2O5	30.96	1.95	20.15	1485
4.	P3-60 kg P2O5	34.85	2.10	20.85	1602
	S.Em.±	1.08	0.07	0.10	49.25
	CD	3.25	0.21	0.31	147.72
B.	Boron levels				
1.	B0-Control	27.65	1.70	19.55	1358
2.	B1-Soil application of Borax @5 kg/ha	29.85	1.85	19.74	1478
3.	B2-Foliar spray of Borax @0.3% at 30, 60 DAS	28.45	1.75	19.62	1395
4.	B3-Soil application of Borax @5 kg/ha + Foliar spray of Borax @0.3% at 30, 60 DAS	31.63	1.95	19.92	1528
	S.Em.±	1.08	0.07	0.10	49.25
	CD	3.25	0.21	0.31	147.72
A × B	Phosphorus × Boron levels				
	S.Em.±	2.16	0.14	0.20	98.50
	CD	6.49	NS	NS	295.52

Table 3: Effect of phosphorus and boron on nutrient content in seed of chickpea

Sr. no.	Treatments	Nitrogen content (%)	Phosphorus content (%)	Potassium content (%)
A.	Phosphorus levels			
1.	P0-Control	3.12	0.32	0.61
2.	P1-20 kg P2O5	3.2	0.34	0.64
3.	P2-40 kg P2O5	3.28	0.37	0.67
4.	P3-60 kg P2O5	3.4	0.41	0.7
	S.Em.±	0.01	0.01	0.01
	CD	0.03	0.02	0.03
B.	Boron levels			
1.	B0-Control	3.19	0.34	0.63
2.	B1-Soil application of Borax @5 kg/ha	3.28	0.36	0.66
3.	B2-Foliar spray of Borax @0.3% at 30, 60 DAS	3.25	0.35	0.64
4.	B3-Soil application of Borax @5 kg/ha + Foliar spray of Borax @0.3% at 30, 60 DAS	3.3	0.38	0.68
	S.Em.±	0.01	0.01	0.01
	CD	0.03	0.02	0.03
A × B	Phosphorus × Boron levels			
	S.Em.±	0.02	0.02	0.02
	CD	NS	NS	NS

Table 4: Effect of phosphorus and boron on nutrient uptake by seed of chickpea

Sr. no.	Treatments	Nitrogen uptake (kg/ha)	Nitrogen uptake (kg/ha)	Potassium uptake (kg/ha)
A.	Phosphorus levels			
1.	P0-Control	38.22	3.92	7.47
2.	P1-20 kg P ₂ O ₅	43.97	4.67	8.79
3.	P2-40 kg P ₂ O ₅	48.71	5.49	9.95
4.	P3-60 kg P ₂ O ₅	54.47	6.57	11.21
	S.Em.±	2.02	0.32	0.52
	CD	6.07	0.95	1.55
B.	Boron levels			
1.	B0-Control	43.32	4.62	8.56
2.	B1-Soil application of Borax @5 kg/ha	48.48	5.32	9.75
3.	B2-Foliar spray of Borax @0.3% at 30, 60 DAS	45.34	4.88	8.93
4.	B3-Soil application of Borax @5 kg/ha + Foliar spray of Borax @0.3% at 30, 60 DAS	50.73	5.81	10.39
	S.Em.±	2.02	0.32	0.52
	CD	6.07	0.95	1.55
A × B	Phosphorus × Boron levels			
	S.Em.±	4.04	0.64	1.04
	CD	NS	NS	NS

Table 5: Effect of phosphorus and boron on pH, EC and organic carbon in soil after harvest of chickpea

Sr. no.	Treatments	Soil pH	Electrical conductivity (dSm-1)	Organic carbon (%)
A.	Phosphorus levels			
1.	P0-Control	7.75	0.50	0.35
2.	P1-20 kg P ₂ O ₅	7.70	0.48	0.37
3.	P2-40 kg P ₂ O ₅	7.67	0.46	0.38
4.	P3-60 kg P ₂ O ₅	7.65	0.44	0.40
	S.Em.±	0.05	0.03	0.02
	CD	NS	NS	NS
B.	Boron levels			
1.	B0-Control	7.74	0.49	0.36
2.	B1-Soil application of Borax @5 kg/ha	7.72	0.47	0.38
3.	B2-Foliar spray of Borax @0.3% at 30, 60 DAS	7.71	0.48	0.37
4.	B3-Soil application of Borax @5 kg/ha + Foliar spray of Borax @0.3% at 30, 60 DAS	7.70	0.45	0.39
	S.Em.±	0.05	0.03	0.02
	CD	NS	NS	NS
A × B	Phosphorus × Boron levels			
	S.Em.±	0.10	0.06	0.04
	CD	NS	NS	NS

Table 6: Effect of phosphorus and boron on available nitrogen, phosphorus and potassium in soil after harvest of chickpea

Sr. no.	Treatments	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
A.	Phosphorus levels			
1.	P0-Control	168.25	12.32	180.32
2.	P1-20 kg P ₂ O ₅	171.32	14.52	183.25
3.	P2-40 kg P ₂ O ₅	174.56	16.45	185.45
4.	P3-60 kg P ₂ O ₅	178.85	18.32	189.65
	S.Em.±	1.28	0.22	1.15
	CD	3.85	0.66	3.46
B.	Boron levels			
1.	B0-Control	170.32	13.65	182.58
2.	B1-Soil application of Borax @5 kg/ha	174.25	14.25	186.45
3.	B2-Foliar spray of Borax @0.3% at 30, 60 DAS	172.65	13.85	184.20
4.	B3-Soil application of Borax @5 kg/ha + Foliar spray of Borax @0.3% at 30, 60 DAS	176.45	14.78	188.78
	S.Em.±	1.28	0.22	1.15
	CD	3.85	0.66	3.46
A × B	Phosphorus × Boron levels			
	S.Em.±	1.56	0.44	1.30
	CD	NS	NS	NS

Table 7: Effect of phosphorus and boron on economics

Sr. no.	Treatments	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
A.	Phosphorus levels				
1.	P0-Control	34000	73500	39500	2.16
2.	P1-20 kg P ₂ O ₅	34600	82440	47840	2.38
3.	P2-40 kg P ₂ O ₅	35200	89100	53900	2.53
4.	P3-60 kg P ₂ O ₅	35800	96120	60320	2.68
B.	Boron levels				
1.	B0-Control	34000	81480	47480	2.40
2.	B1-Soil application of Borax @5 kg/ha	34400	88680	54280	2.58
3.	B2-Foliar spray of Borax @0.3% at 30, 60 DAS	34800	83700	48900	2.41
4.	B3-Soil application of Borax @5 kg/ha + Foliar spray of Borax @0.3% at 30, 60 DAS	35200	91680	56480	2.60

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