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Effect of Crop Geometry and Phosphorus Levels on Growth, Yield and Economics of Kabuli Chickpea (*Cicer arietinum* L.)

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Abstract
A field experiment was conducted during the Rabi season of 2025–26 at the Crop Research Farm, Department of Agronomy, Prof. Rajendra Singh (Rajju Bhaiya) University, Prayagraj, to study the effect of crop geometry and phosphorus levels on the growth, yield and economics of Kabuli chickpea (variety PKV-2). The experiment was laid out in a Factorial Randomized Block Design with nine treatment combinations replicated thrice, comprising three crop geometries (30×15, 40×15 and 50×15 cm) and three phosphorus levels (40, 50 and 60 kg ha^{-1}). The soil was sandy loam in texture, neutral in reaction (pH 7.0), low in organic carbon and medium in available phosphorus. Results revealed that the wider spacing of 50×15 cm recorded the highest plant dry weight, number of branches, pods per plant, seeds per pod, seed yield (1.96 t ha^{-1}) and straw yield, whereas phosphorus applied at 60 kg ha^{-1} produced the maximum values of most yield attributes and the highest seed yield (1.79 t ha^{-1}). Among the interactions, the treatment 50×15 cm with phosphorus at 60 kg ha^{-1} (T9) recorded the maximum seed yield (2.14 t ha^{-1}) and straw yield (4.68 t ha^{-1}). However, the highest net return (₹ 86,815 ha^{-1}) and benefit–cost ratio (2.54) were obtained under 50×15 cm with phosphorus at 50 kg ha^{-1} (T8), making it the most economically remunerative treatment. It is concluded that sowing Kabuli chickpea at 50×15 cm spacing with 50–60 kg P_2O_5 ha^{-1} is desirable for higher productivity and profitability under the agro-climatic conditions of Prayagraj.

Keywords: Kabuli chickpea, crop geometry, plant spacing, phosphorus levels, growth, yield attributes, seed yield, economics, benefit–cost ratio

1. Introduction
Chickpea (*Cicer arietinum* L.), commonly known as gram or Bengal gram, is the most important protein-rich Rabi pulse crop of India. It is grown in two main types, the small-seeded desi (red) type and the bold-seeded Kabuli (white) type, the latter commanding a premium price in domestic and export markets. Chickpea grains are a rich and affordable source of protein, carbohydrates, fats, minerals and vitamins, and serve as an important vegetarian substitute for animal protein. Globally, India is the largest producer of chickpea, contributing more than two-thirds of the world area and production, with Madhya Pradesh, Rajasthan, Maharashtra, Karnataka and Uttar Pradesh being the leading producing states.

Being a legume, chickpea meets a large part of its nitrogen requirement through symbiotic fixation and is therefore a heavy feeder of phosphorus rather than nitrogen. Phosphorus is a key nutrient governing root proliferation, nodulation, energy transfer through ATP synthesis, cell division and the translocation of photosynthates. Adequate phosphorus nutrition enhances nodule development, plant height, branching, pod formation, grain yield and harvest index, while its deficiency is a major constraint limiting the productivity of grain legumes. In most Indian soils the available phosphorus status ranges from low to medium, so a positive and profitable crop response to phosphorus application is widely reported.

Crop geometry, through its influence on plant population and the spatial arrangement of plants, regulates the availability of light, moisture, nutrients and space. Plants grown under optimum or wider spacing generally exhibit superior individual growth on account of reduced inter-plant competition, whereas closer spacing favours higher plant density per unit area. The interaction between crop geometry and phosphorus is therefore important, since efficient plant arrangement can improve nutrient-use efficiency and maximise productivity. Determining the most suitable combination of spacing and phosphorus level is essential for achieving higher yields and economic returns in Kabuli chickpea.

Keeping these facts in view, the present investigation was undertaken with the objectives of studying the effect of crop geometry on the growth and yield of Kabuli chickpea, evaluating the effect of phosphorus levels on its growth and yield, and working out the economics of the different treatment combinations.

2. Materials and Methods

2.1 Experimental site and soil

The field experiment was conducted during the Rabi season of 2025–26 at the Crop Research Farm, Department of Agronomy, Prof. Rajendra Singh (Rajju Bhaiya) University, Naini, Prayagraj, Uttar Pradesh (25.36° N latitude, 81.86° E longitude, 98 m above mean sea level). The region has a sub-tropical, semi-arid climate with extremes of temperature in both summer and winter. The soil of the experimental field, forming a part of the central Gangetic alluvium, was sandy loam in texture, neutral in reaction (pH 7.0) with an electrical conductivity of 0.56 dS m^{-1}, low in organic carbon (0.62%), medium in available nitrogen (255 kg ha^{-1}) and available phosphorus (18.2 kg ha^{-1}), and medium in available potassium (240.7 kg ha^{-1}).

2.2 Experimental design and treatments

The experiment was laid out in a Factorial Randomized Block Design (FRBD) with nine treatment combinations replicated three times, giving a total of 27 plots of 3 m × 3 m (9 m^2) each. The treatments comprised two factors: three crop geometries (30×15, 40×15 and 50×15 cm) and three phosphorus levels (40, 50 and 60 kg ha^{-1}). A uniform recommended basal dose of 20–40–20 kg NPK ha^{-1} was applied through urea, single super phosphate and muriate of potash, the phosphorus being adjusted according to the treatments. The nine treatment combinations are presented in Table 1.

Table 1: Treatment combinations of crop geometry and phosphorus levels.

Symbol	Crop geometry (cm)	Phosphorus level (kg ha^{-1})
T1	30 × 15	40
T2	30 × 15	50
T3	30 × 15	60
T4	40 × 15	40
T5	40 × 15	50
T6	40 × 15	60
T7	50 × 15	40
T8	50 × 15	50
T9	50 × 15	60

2.3 Crop management

The field was ploughed, harrowed and levelled to a fine tilth and laid out as per the design. Kabuli chickpea variety PKV-2 was sown by line sowing at a depth of about 3 cm using a seed rate of 80 kg ha^{-1}, maintaining the row-to-row and plant-to-plant spacing as per the treatments. Gap filling and thinning were carried out to maintain the desired plant population, and two manual weedings were done at about 25 and 45 days after sowing (DAS). Nipping was performed at 30 and 45 DAS, and irrigation was applied as required. The crop was harvested at maturity, sun-dried, threshed, winnowed and the produce recorded plot-wise.

2.4 Observations recorded

Growth parameters, namely plant height (cm), number of branches per plant and plant dry weight (g), were recorded at 30, 60 and 90 DAS from five randomly tagged plants per plot. Yield attributes, viz. number of pods per plant, number of seeds per pod and seed index (1000-seed weight, g), were recorded at harvest. Seed yield, straw yield and biological yield were recorded on a net-plot basis and expressed in t ha^{-1}, and the harvest index (%) was computed as the ratio of economic yield to biological yield.

2.5 Economics and statistical analysis

The cost of cultivation, gross return, net return and benefit–cost (B:C) ratio of each treatment were worked out on the basis of prevailing market prices of inputs and produce. The data were subjected to analysis of variance for a factorial randomized block design as described by Gomez and Gomez (1984). The significance of treatment effects was tested using the F-test, and critical differences (CD) were computed at the 5% level of significance to compare treatment means.

3. Results and Discussion

3.1 Plant height

Plant height increased progressively with crop age and was significantly influenced by crop geometry and phosphorus levels at 60 and 90 DAS, while differences at 30 DAS were non-significant (Table 2). Among the crop geometries, the widest spacing of 50×15 cm recorded the tallest plants at 60 DAS (59.86 cm), and 40×15 cm gave the maximum height at 90 DAS (78.79 cm), both being significantly superior to the closer spacing of 30×15 cm. The greater height under wider spacing may be attributed to reduced inter-plant competition for light, moisture and nutrients, which favoured better stem elongation and vegetative growth.

Increasing phosphorus levels significantly increased plant height at 60 DAS, with the highest value (60.31 cm) recorded at 60 kg ha^{-1}, whereas the effect at 90 DAS was non-significant. The improvement in height with phosphorus may be ascribed to its role in root proliferation, cell division, energy transfer and improved nodulation, which together enhanced nutrient acquisition and vegetative growth. The interaction effect was significant at 60 and 90 DAS; the maximum height at 90 DAS (81.90 cm) was recorded under 40×15 cm with phosphorus at 40 kg ha^{-1} (T4). These findings are in agreement with Ali *et al*. (2018) [1] and Singh *et al*. (2019) [14].

Table 2: Effect of crop geometry and phosphorus levels on plant height (cm) of Kabuli chickpea.

Treatment	30 DAS	60 DAS	90 DAS
Crop geometry (cm)			
30 × 15	26.54	57.15	74.05
40 × 15	27.68	58.75	78.79
50 × 15	26.63	59.86	77.10
SEm ±	1.59	0.22	1.06
CD (p=0.05)	NS	0.66	3.19
Phosphorus (kg ha⁻¹)			
40	27.73	55.83	77.75
50	27.23	59.62	75.32
60	25.90	60.31	76.87
SEm ±	1.59	0.22	1.06
CD (p=0.05)	NS	0.66	NS
Interaction (G × P)			
T1	23.97	54.28	71.87
T2	29.53	58.23	77.16
T3	26.11	58.95	73.13
T4	30.31	56.15	81.90
T5	27.51	59.72	75.89
T6	25.23	60.38	78.58
T7	28.90	57.07	79.48
T8	24.64	60.90	72.90
T9	26.36	61.60	78.90
SEm ±	2.74	0.38	1.84
CD (p=0.05)	NS	1.45	5.52

DAS = days after sowing; NS = non-significant; G × P = crop geometry × phosphorus interaction.

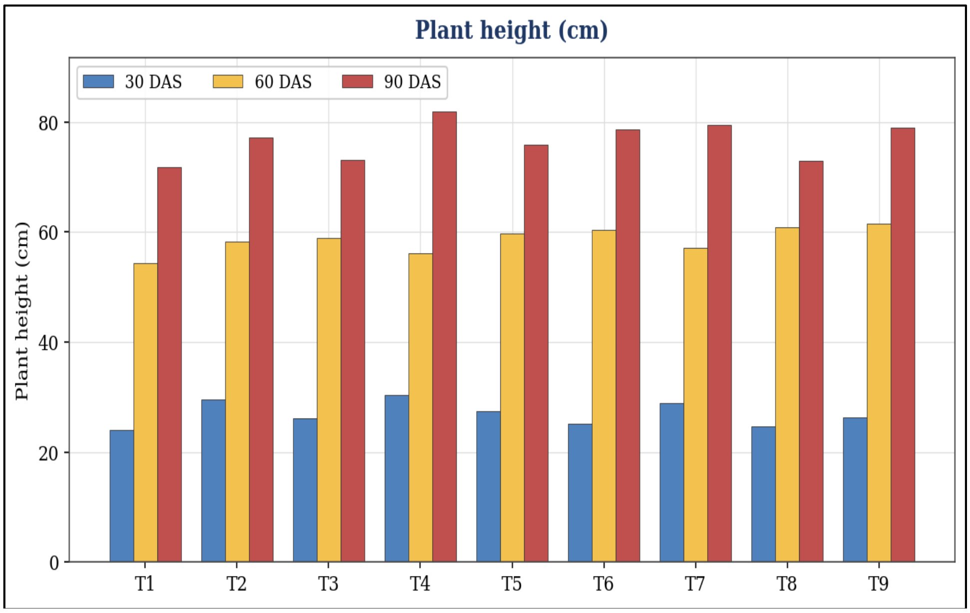

Fig 1: Effect of crop geometry and phosphorus levels on plant height (cm) of Kabuli chickpea.

3.2 Plant dry weight

Plant dry weight was significantly affected by both factors at 60 and 90 DAS (Table 3). The widest spacing of 50×15 cm produced the maximum dry matter at all stages, recording 9.30 g and 17.61 g per plant at 60 and 90 DAS, respectively, which indicates efficient utilisation of light, moisture and nutrients under reduced competition. Phosphorus applied at 60 kg ha^{-1} recorded the highest dry weight (8.51 g at 60 DAS and 17.94 g at 90 DAS), the increase being attributable to enhanced root development, improved nodulation and greater translocation of photosynthates. The interaction was significant; the treatment 50×15 cm with phosphorus at 60 kg ha^{-1} (T9) recorded the maximum dry weight (9.69 g and 18.40 g at 60 and 90 DAS). Similar responses of dry-matter accumulation to phosphorus have been reported by Singh *et al*. (2020).

Table 3: Effect of crop geometry and phosphorus levels on plant dry weight (g) of Kabuli chickpea.

Treatment	30 DAS	60 DAS	90 DAS
Crop geometry (cm)			
30 × 15	1.51	7.50	16.91
40 × 15	1.74	8.02	17.60
50 × 15	1.78	9.30	17.61
SEm ±	0.08	0.28	0.13
CD (p=0.05)	NS	0.83	0.38
Phosphorus (kg ha⁻¹)			
40	1.55	8.00	16.72
50	1.70	8.32	17.45
60	1.79	8.51	17.94
SEm ±	0.08	0.28	0.13
CD (p=0.05)	NS	0.83	0.38
Interaction (G × P)			
T1	1.36	7.34	16.44
T2	1.60	7.56	16.75
T3	1.59	7.61	17.52
T4	1.78	7.74	17.34
T5	1.67	8.07	17.56
T6	1.77	8.24	17.90
T7	1.51	8.91	16.37
T8	1.82	9.31	18.05
T9	2.01	9.69	18.40
SEm ±	0.13	0.47	0.21
CD (p=0.05)	NS	1.43	0.65

DAS = days after sowing; NS = non-significant.

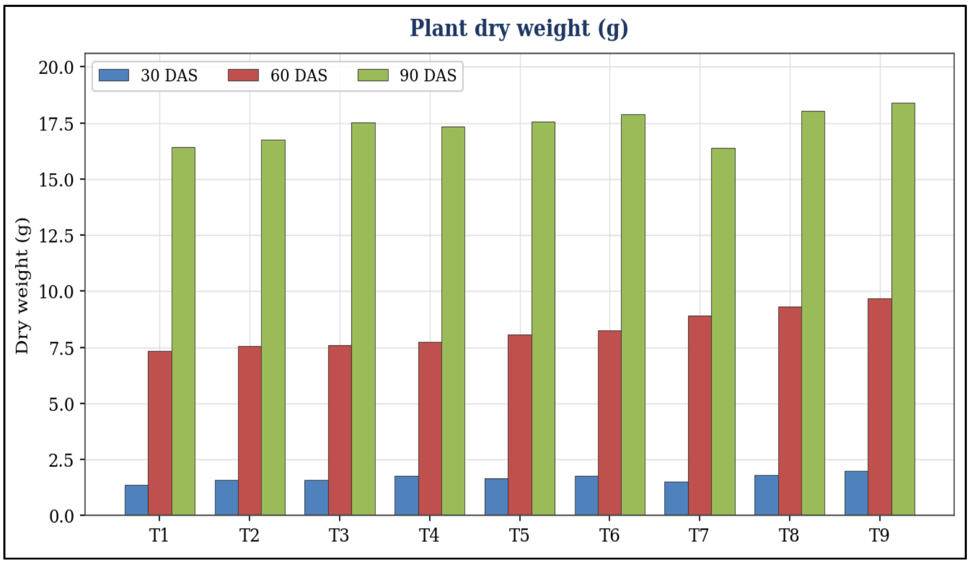

Fig 2: Effect of crop geometry and phosphorus levels on plant dry weight (g) of Kabuli chickpea.

3.3 Number of branches per plant

The number of branches per plant increased with crop age and responded significantly to crop geometry and phosphorus at 60 DAS, the differences at 30 DAS being non-significant (Table 4). Wider spacing of 50×15 cm produced the maximum number of branches (3.52 at 30 DAS and 14.88 at 60 DAS), reflecting the better availability of growing space, light and nutrients to individual plants. Among phosphorus levels, the highest dose of 60 kg ha⁻¹ recorded the greatest branching (14.82 at 60 DAS). The treatment combination 50×15 cm with phosphorus at 60 kg ha⁻¹ (T9) recorded the maximum branches (15.24 at 60 DAS). The favourable effect of phosphorus on branching is consistent with the observations of Kumar *et al.* (2022) [7].

Table 4: Effect of crop geometry and phosphorus levels on number of branches per plant of Kabuli chickpea.

Treatment	30 DAS	60 DAS
Crop geometry (cm)		
30 × 15	3.25	14.37
40 × 15	3.32	14.56
50 × 15	3.52	14.88
SEm ±	0.29	0.13
CD (p=0.05)	NS	0.40
Phosphorus (kg ha⁻¹)		
40	3.14	14.26
50	3.44	14.73
60	3.52	14.82
SEm ±	0.29	0.13
CD (p=0.05)	NS	0.40
Interaction (G × P)		
T1	3.08	14.07
T2	3.33	14.66
T3	3.33	14.39
T4	3.09	14.13
T5	3.38	14.70
T6	3.49	14.84
T7	3.23	14.58
T8	3.61	14.83
T9	3.73	15.24
SEm ±	0.05	0.23
CD (p=0.05)	NS	0.69

DAS = days after sowing; NS = non-significant.

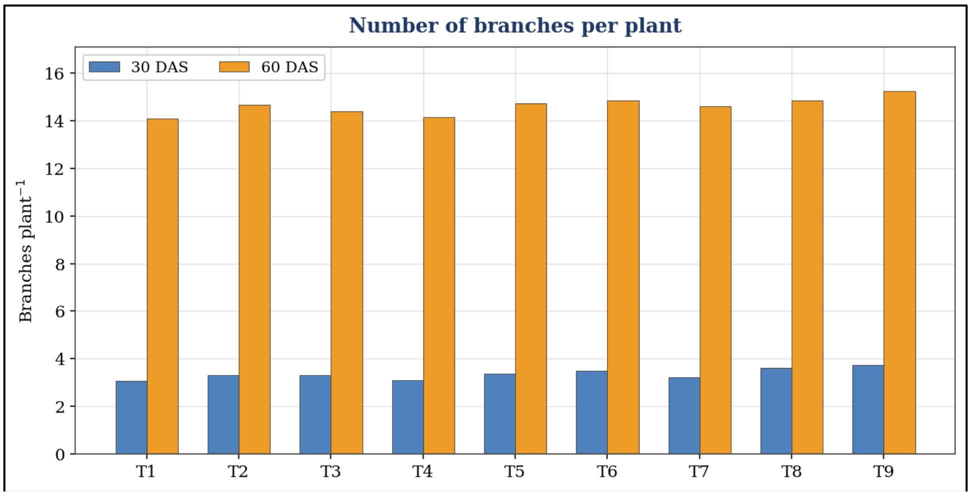

Fig 3: Effect of crop geometry and phosphorus levels on number of branches per plant of Kabuli chickpea.

3.4 Yield attributes and yield

Crop geometry and phosphorus levels exerted a marked influence on the yield attributes and yield of Kabuli chickpea (Table 5). Among the crop geometries, the widest spacing of 50×15 cm recorded the highest number of pods per plant (59.30), seeds per pod (3.56), seed yield (1.96 t ha⁻¹), straw yield (4.58 t ha⁻¹) and biological yield (13.81 t ha⁻¹). The superior performance under wider spacing may be attributed to reduced competition for light, moisture, nutrients and space, which improved photosynthetic activity, flowering and pod development and favoured greater translocation of assimilates to the reproductive structures.

Increasing phosphorus levels up to 60 kg ha⁻¹ significantly improved pods per plant (59.87), seed yield (1.79 t ha⁻¹) and straw yield (4.22 t ha⁻¹), confirming the important role of phosphorus in tissue differentiation, carbohydrate metabolism, sugar translocation and the development of a well-spread root system. The seed index, however, was not significantly affected by either factor. Among the interactions, the treatment 50×15 cm with phosphorus at 60 kg ha⁻¹ (T9) recorded the maximum seed yield (2.14 t ha⁻¹), straw yield (4.68 t ha⁻¹), seeds per pod (3.80) and seed index (42.23 g), whereas 50×15 cm with phosphorus at 50 kg ha⁻¹ (T8) recorded the highest number of pods per plant (60.90), biological yield (14.52 t ha⁻¹) and harvest index (40.45%). These results corroborate the findings of Yadav and Meena (2020) [16], Rathi *et al*. (2020) [12] and Balai *et al*. (2020) [2].

Table 5: Effect of crop geometry and phosphorus levels on yield attributes and yield of Kabuli chickpea.

Treatment	Pods plant⁻¹	Seeds pod⁻¹	Seed index (g)	Seed yield (t ha⁻¹)	Straw yield (t ha⁻¹)	Biol. yield (t ha⁻¹)	HI (%)
Crop geometry (cm)							
30 × 15	57.82	2.51	40.22	1.31	3.54	11.92	37.98
40 × 15	58.75	2.85	40.89	1.64	4.07	12.59	39.10
50 × 15	59.30	3.56	41.24	1.96	4.58	13.81	38.17
SEm ±	0.37	0.15	1.06	0.07	0.16	0.25	0.81
CD (p=0.05)	1.10	0.46	NS	0.20	0.48	0.75	NS
Phosphorus (kg ha⁻¹)							
40	56.39	2.85	39.49	1.49	3.93	12.76	39.77
50	59.62	2.93	41.31	1.63	4.03	12.68	38.70
60	59.87	3.15	41.55	1.79	4.22	12.89	36.78
SEm ±	0.37	0.15	1.06	0.07	0.16	0.25	0.81
CD (p=0.05)	1.10	NS	NS	0.20	NS	NS	NS
Interaction (G × P)							
T1	55.94	2.46	39.17	1.16	3.13	11.28	39.63
T2	58.23	2.55	40.63	1.34	3.67	11.78	36.72
T3	59.29	2.52	40.86	1.45	3.83	12.70	37.59
T4	56.15	2.60	39.58	1.52	4.18	13.51	40.05
T5	59.72	2.83	41.53	1.62	3.87	11.73	38.92
T6	60.38	3.13	41.57	1.79	4.16	12.52	38.32
T7	57.07	3.48	39.72	1.80	4.49	13.48	39.62
T8	60.90	3.40	41.77	1.93	4.56	14.52	40.45
T9	59.93	3.80	42.23	2.14	4.68	13.44	34.45
SEm ±	0.63	0.26	1.21	0.11	0.27	0.43	1.39
CD (p=0.05)	1.90	0.97	NS	0.34	0.82	1.29	NS

HI = harvest index; Biol. = biological; NS = non-significant. Crop geometry in cm; phosphorus in kg ha⁻¹.

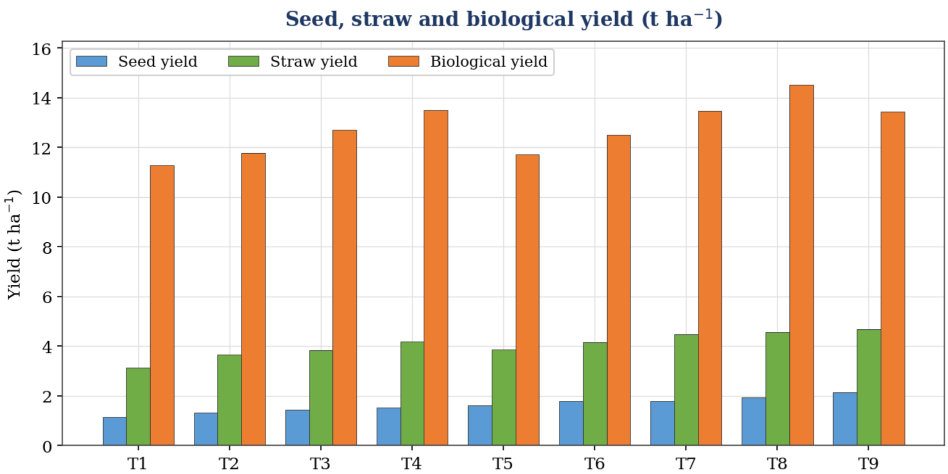

Fig 4: Effect of crop geometry and phosphorus levels on seed, straw and biological yield (t ha⁻¹) of Kabuli chickpea.

3.5 Economics

The economics of the different treatment combinations are presented in Table 6. The cost of cultivation varied marginally from ₹ 34,145 to ₹ 34,345 ha⁻¹ owing to the differing quantities of phosphatic fertiliser. Gross return, net return and the benefit–cost ratio increased appreciably with wider spacing and higher phosphorus levels, mainly through their positive effect on seed and straw yields. The maximum net return (₹ 86,815 ha⁻¹) and the highest benefit–cost ratio (2.54) were recorded under the treatment 50×15 cm with phosphorus at 50 kg ha⁻¹ (T8), closely followed by 50×15 cm with phosphorus at 60 kg ha⁻¹ (T9) with a net return of ₹ 86,302 ha⁻¹ and a B:C ratio of 2.51.

Although T9 produced the highest seed yield, T8 emerged as the most remunerative treatment because of its favourable balance between produce value and cost of cultivation, indicating that the moderate phosphorus level of 50 kg ha⁻¹ combined with wider spacing optimised profitability. The lowest net return and B:C ratio were obtained under the closest spacing with the lowest phosphorus level (T1). These findings are in conformity with the economic responses reported by Kumawat *et al*. (2020) [9] and Kumar *et al*. (2023).

Table 6: Effect of crop geometry and phosphorus levels on the economics of Kabuli chickpea.

Treatment	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio
T1 (30×15 + P40)	34,145	73,340	39,195	1.15
T2 (30×15 + P50)	34,245	84,860	50,615	1.48
T3 (30×15 + P60)	34,345	91,567	57,222	1.67
T4 (40×15 + P40)	34,145	96,520	62,375	1.83
T5 (40×15 + P50)	34,245	1,01,693	67,448	1.97
T6 (40×15 + P60)	34,345	1,12,133	77,788	2.26
T7 (50×15 + P40)	34,145	1,13,380	79,235	2.32
T8 (50×15 + P50)	**34,245**	**1,21,060**	**86,815**	**2.54**
T9 (50×15 + P60)	34,345	1,20,647	86,302	2.51

Selling price: seed ₹ 58,000 t^{-1} (T9 ₹ 52,000 t^{-1}), straw ₹ 2,000 t^{-1}. B:C ratio = net return ÷ cost of cultivation.

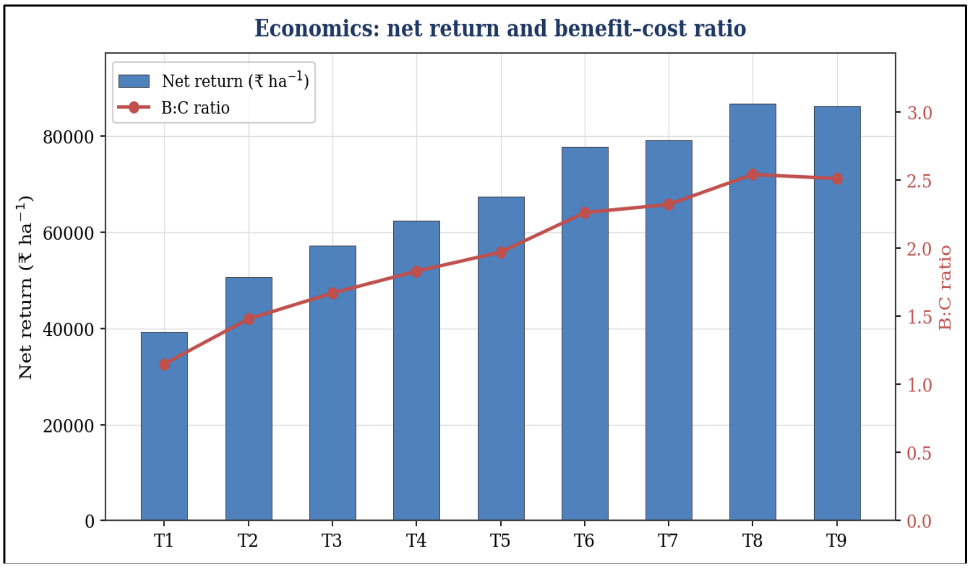

Fig 5: Effect of crop geometry and phosphorus levels on net return and benefit–cost ratio of Kabuli chickpea.

4. Conclusion

On the basis of one season of experimentation, it may be concluded that crop geometry and phosphorus levels significantly influenced the growth, yield attributes, yield and economics of Kabuli chickpea under the agro-climatic conditions of Prayagraj. Wider spacing of 50×15 cm and phosphorus application at 60 kg ha^{-1} were the most favourable for growth and productivity, the treatment 50×15 cm with 60 kg P_2O_5 ha^{-1} (T9) recording the maximum seed yield of 2.14 t ha^{-1}. However, from the economic standpoint, sowing at 50×15 cm with phosphorus at 50 kg ha^{-1} (T8) proved most remunerative, giving the highest net return (₹ 86,815 ha^{-1}) and benefit–cost ratio (2.54). Therefore, for higher productivity coupled with profitability, Kabuli chickpea may be sown at 50×15 cm spacing with 50–60 kg P_2O_5 ha^{-1}. As these conclusions are based on a single season, confirmation over additional seasons and locations is suggested before formulating a firm recommendation.

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