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Effect of planting techniques and growth hormones on growth, yield and economics of quinoa (*Chenopodium quinoa* Willd.) under Prayagraj conditions

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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, Uttar Pradesh, to evaluate the effect of planting techniques and foliar-applied growth hormones on the growth, yield and economics of quinoa. The experiment was laid out in a Factorial Randomized Block Design with three replications and twelve treatment combinations comprising four planting techniques (broadcasting, line sowing, ridge sowing and bed method) and three foliar treatments (gibberellic acid, GA₃ @ 100 ppm; ascorbic acid @ 50 ppm; and Panchgavya @ 5%). Among the planting techniques, ridge sowing recorded superior dry matter accumulation, crop growth rate and seed yield, while line and bed methods produced taller plants and higher harvest index. Among the foliar treatments, Panchgavya promoted early vegetative growth and branching, whereas GA₃ @ 100 ppm enhanced reproductive growth and seed yield. The treatment combination of ridge sowing with GA₃ @ 100 ppm (T₇) recorded the highest seed yield (3.55 q ha⁻¹), straw yield (8.02 t ha⁻¹), gross return (₹ 1,93,528 ha⁻¹), net return (₹ 1,25,728 ha⁻¹) and benefit-cost ratio (1.85). It is concluded that ridge sowing coupled with foliar application of GA₃ @ 100 ppm is the most productive and profitable practice for quinoa cultivation under Prayagraj conditions.

Keywords: Quinoa, planting techniques, ridge sowing, gibberellic acid, foliar application, growth, yield, economics

Introduction

Quinoa (*Chenopodium quinoa* Willd.), a pseudo-cereal of the family Amaranthaceae native to the Andean region of South America, has gained worldwide attention as a climate-resilient and highly nutritious crop. Its grains contain 12-18% protein with a balanced essential amino-acid profile, together with dietary fibre, minerals and antioxidants, and are naturally gluten-free, making the crop valuable for nutritional security. Quinoa tolerates drought, salinity, frost and poor soil fertility, allowing cultivation on marginal lands where conventional cereals often fail.

In India, quinoa was introduced in the early 2010s and is gradually expanding across Rajasthan, Gujarat, Uttar Pradesh and parts of southern India, with average productivity of about 1.2-1.5 t ha⁻¹. The Prayagraj region of the Indo-Gangetic plains, with its alluvial soils, subtropical climate and assured irrigation, offers good potential for quinoa cultivation during the Rabi season. However, productivity is often constrained by inappropriate planting techniques and limited use of growth-promoting inputs.

Planting technique governs plant stand, canopy architecture, root development and resource-use efficiency. Methods such as broadcasting, line sowing, ridge sowing and bed planting differ in aeration, drainage and moisture distribution, and thereby influence growth and yield. Likewise, plant growth regulators play a decisive role in crop development: gibberellic acid (GA₃) promotes cell elongation, stem growth and flowering; ascorbic acid acts as an antioxidant improving physiological efficiency; and Panchgavya, an organic bio-enhancer, supplies nutrients, beneficial microbes and natural hormones. As very little work integrating both factors has been carried out for quinoa in the Prayagraj region, the present study was undertaken to evaluate their effect on growth, yield and economics.

The specific objectives were: (i) to study the effect of planting techniques and growth hormones on the growth of quinoa; (ii) to study their effect on yield; and (iii) to work out the economics of the different treatment combinations.

2. Materials and Methods

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 (25.35° N, 81.89° E; 98 m above mean sea level). The region is subtropical with hot dry summers and cool winters and a mean annual rainfall of about 1042 mm. The experimental soil was sandy clay loam, neutral in reaction (pH 7.3), with electrical conductivity 0.37 dS m⁻¹, medium organic carbon (0.57%), low available nitrogen (212 kg ha⁻¹) and medium available phosphorus (12.5 kg ha⁻¹) and potassium (267 kg ha⁻¹).

The experiment was laid out in a Factorial Randomized Block Design with three replications and twelve treatment combinations (Table 1), comprising four planting techniques and three foliar-

applied growth hormones. Quinoa variety EC507740 (AICRP, UAS Bangalore) was sown at 30 × 10 cm spacing in plots of 9 m² (3 × 1.75 m). Recommended fertilizer doses were applied uniformly through urea, DAP and MOP. Three irrigations were given as per crop need, and weeds were controlled by hand weeding at 35 and 60 DAS.

Foliar sprays were applied with a knapsack sprayer: GA₃ @ 100 ppm (100 mg L⁻¹), ascorbic acid @ 50 ppm and Panchgavya @ 5% (50 mL L⁻¹). Growth observations (plant height, dry matter accumulation, crop growth rate, relative growth rate and number of branches) were recorded at 20, 40, 60, 80 DAS and at harvest on five tagged plants per plot. Yield attributes (panicles plant⁻¹, test weight, seed, straw and biological yield, and harvest index) were recorded at harvest, and economics (cost of cultivation, gross return, net return and benefit-cost ratio) were computed from prevailing market prices. Data were analysed by analysis of variance for the Factorial Randomized Block Design, and treatment differences were tested at the 5% level of significance.

Table 1: Treatment combinations

Code	Treatment combination	Code	Treatment combination
T ₁	Broadcasting + GA ₃ @ 100 ppm	T ₇	Ridge sowing + GA ₃ @ 100 ppm
T ₂	Broadcasting + Ascorbic acid @ 50 ppm	T ₈	Ridge sowing + Ascorbic acid @ 50 ppm
T ₃	Broadcasting + Panchgavya @ 5%	T ₉	Ridge sowing + Panchgavya @ 5%
T ₄	Line sowing + GA ₃ @ 100 ppm	T ₁₀	Bed method + GA ₃ @ 100 ppm
T ₅	Line sowing + Ascorbic acid @ 50 ppm	T ₁₁	Bed method + Ascorbic acid @ 50 ppm
T ₆	Line sowing + Panchgavya @ 5%	T ₁₂	Bed method + Panchgavya @ 5%

3. Results and Discussion

3.1 Growth parameters

Plant height increased progressively with crop age and reached a maximum at harvest (Fig. 1). At early stages (20 DAS) planting techniques had no significant effect, reflecting uniform germination. From 40 DAS onward, organized planting methods were significantly superior to broadcasting. At 100 DAS, ridge

sowing and bed method recorded the tallest plants (106.93 cm each), significantly exceeding line sowing (104.62 cm) and broadcasting (101.80 cm). Among foliar treatments, Panchgavya @ 5% generally promoted greater height at early and final stages, while GA₃ @ 100 ppm was most effective during the active vegetative phase (80 DAS), consistent with its role in cell elongation.

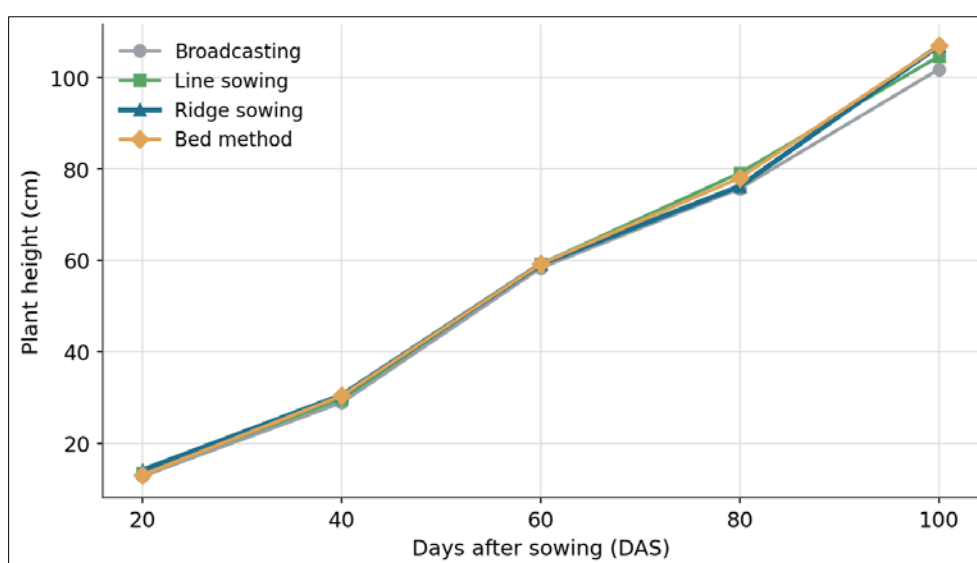


Fig 1: Plant height of quinoa under different planting methods.

Dry matter accumulation followed a similar increasing trend (Fig. 2). At harvest, ridge sowing recorded the maximum dry weight (85.62 g plant⁻¹), statistically at par with bed method (85.28 g plant⁻¹) and significantly superior to line sowing (83.83 g plant⁻¹) and broadcasting (80.41 g plant⁻¹). The superior biomass under

ridge and bed planting is attributed to improved soil aeration, better drainage and efficient nutrient uptake. Among growth hormones, Panchgavya @ 5% recorded the highest dry matter at most stages, while GA₃ improved biomass during intermediate stages.

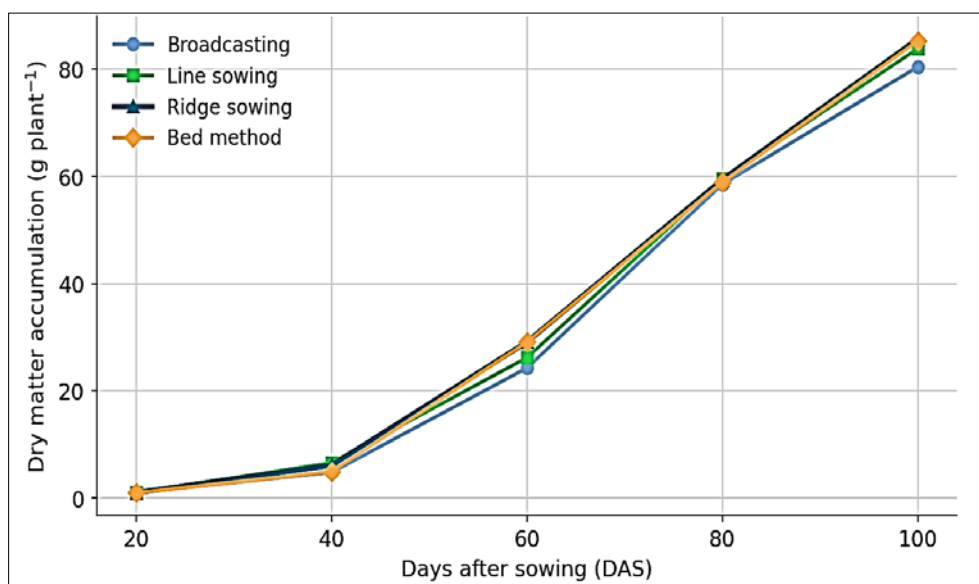


Fig 2: Dry matter accumulation of quinoa under different planting methods.

Crop growth rate (CGR) increased from early stages, peaked during 60-80 DAS and declined towards maturity (Fig. 3). Ridge sowing recorded the highest CGR during 40-60 DAS ($23.01 \text{ g m}^{-2} \text{ day}^{-1}$) and 80-100 DAS ($23.82 \text{ g m}^{-2} \text{ day}^{-1}$), while line sowing was superior during peak growth (60-80 DAS). GA_3 @ 100 ppm enhanced CGR during early and late stages, whereas Panchgavya

recorded the maximum CGR during peak vegetative growth. Relative growth rate (RGR) declined steadily with crop age and showed no significant treatment differences, indicating that although treatments altered absolute growth, they did not change the proportional efficiency of biomass production.

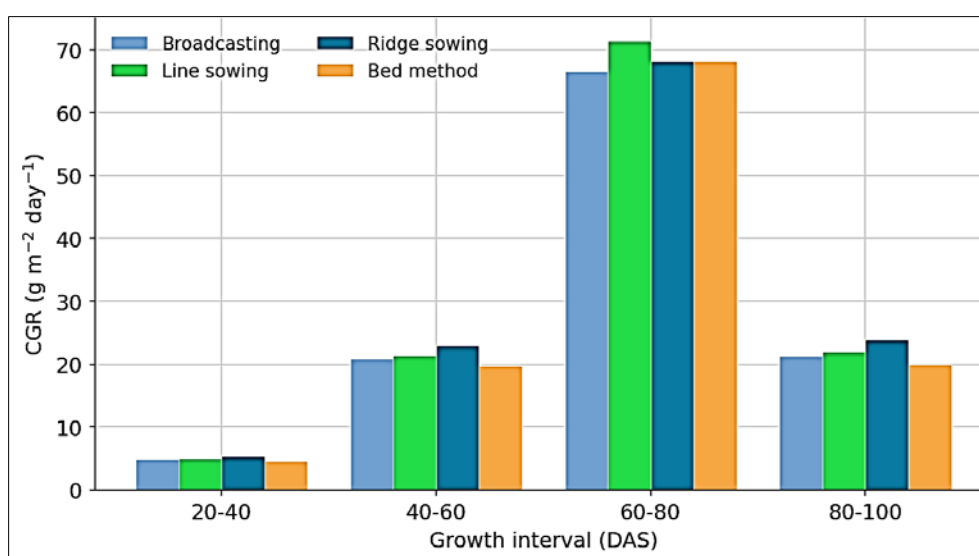


Fig 3: Crop growth rate of quinoa under different planting methods.

Number of branches per plant increased with crop age. Ridge sowing maintained superiority through the active vegetative phase (21.25 branches plant^{-1} at 80 DAS), but at harvest line sowing recorded the highest branching (27.03 plant^{-1}) owing to

uniform plant distribution. Among foliar treatments, Panchgavya @ 5% produced the most branches at early and mid-stages, while ascorbic acid was most effective at harvest.

Table 2: Growth parameters of quinoa as influenced by planting methods (main plot)

Planting method	Plant height at harvest (cm)	Dry matter at harvest (g plant^{-1})	CGR 60-80 DAS ($\text{g m}^{-2} \text{ day}^{-1}$)	Branches at harvest (plant^{-1})
Broadcasting	101.80	80.41	66.66	24.74
Line sowing	104.62	83.83	71.44	27.03
Ridge sowing	106.93	85.62	68.22	24.53
Bed method	106.93	85.28	68.22	26.25
SEm ($\pm$)	0.36	0.58	2.32	-
CD ($p=0.05$)	1.05	1.70	6.81	-

3.2 Yield attributes and yield

Yield attributes were appreciably influenced by planting technique and foliar treatment (Fig. 4). The bed method produced the highest number of panicles per plant (18.35), followed by ridge (17.20) and line sowing (17.12). Test weight was greatest

under line sowing (3.40 g) and ridge sowing (3.35 g). Seed yield, however, was highest under ridge sowing (3.23 q ha⁻¹), followed by line sowing (3.01 q ha⁻¹), broadcasting (2.93 q ha⁻¹) and bed method (2.77 q ha⁻¹), reflecting the better dry-matter accumulation and assimilate translocation under ridge planting.

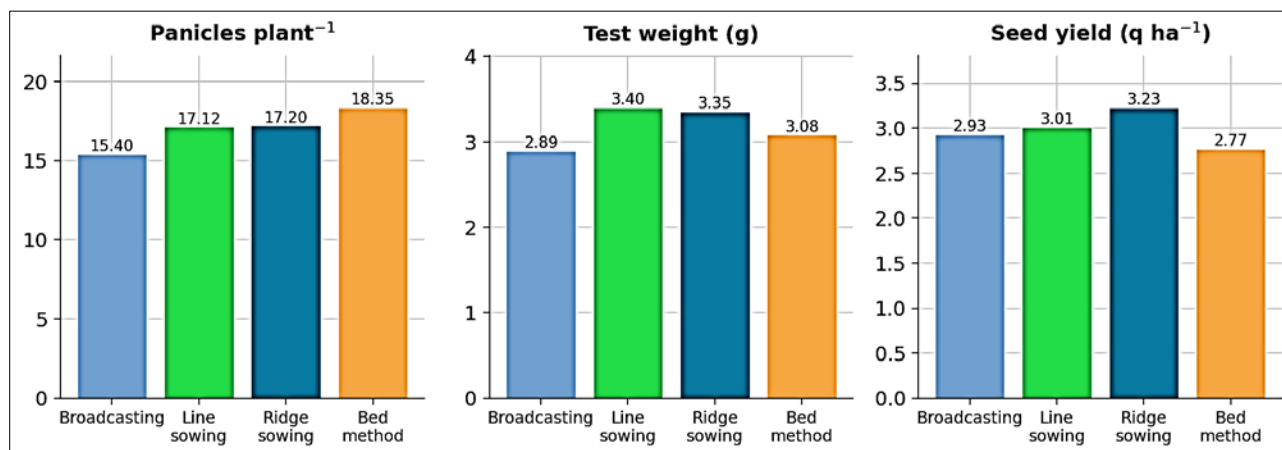


Fig 4: Yield attributes and seed yield of quinoa under different planting methods.

Straw yield was likewise maximum under ridge sowing (7.79 t ha⁻¹) and minimum under bed method (6.28 t ha⁻¹) (Fig. 5). Considering treatment combinations, ridge sowing with GA₃ @ 100 ppm (T₇) recorded the highest seed yield (3.55 q ha⁻¹) and straw yield (8.02 t ha⁻¹), whereas bed method with Panchgavya

(T₁₂) recorded the lowest. Harvest index was highest under line and bed methods combined with ascorbic acid (31.25%), indicating better partitioning of assimilates towards reproductive structures under these treatments.

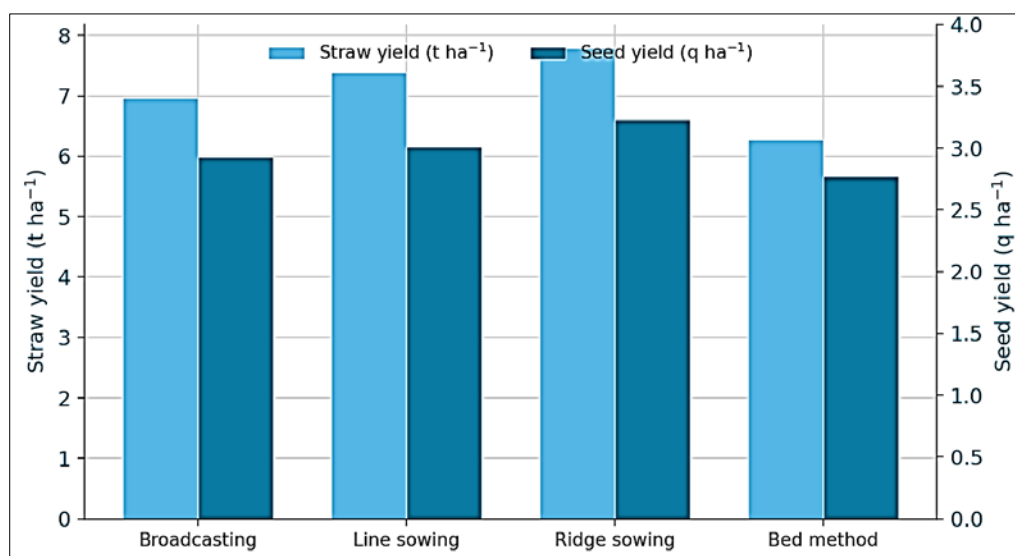


Fig 5: Seed and straw yield of quinoa under different planting methods.

Table 3: Yield attributes and yield of quinoa as influenced by planting methods (main plot)

Planting method	Panicles plant ⁻¹	Test weight (g)	Seed yield (q ha ⁻¹)	Straw yield (t ha ⁻¹)	Harvest index (%)
Broadcasting	15.40	2.89	2.93	6.96	29.68
Line sowing	17.12	3.40	3.01	7.39	28.96
Ridge sowing	17.20	3.35	3.23	7.79	29.30
Bed method	18.35	3.08	2.77	6.28	30.64
SEm (±)	0.43	0.11	0.009	0.14	1.00
CD (p=0.05)	1.27	0.32	0.025	1.27	2.94

3.3 Economics: Economic analysis (Table 4) showed that the cost of cultivation ranged from ₹ 62,800 to ₹ 68,200 ha⁻¹, being higher under ridge and bed methods owing to greater field-preparation and management costs. The maximum gross return (₹ 1,93,528

ha⁻¹) and net return (₹ 1,25,728 ha⁻¹) were obtained under ridge sowing with GA₃ @ 100 ppm (T₇), driven by its superior seed and straw yields (Fig. 6). The lowest returns were recorded under bed method with Panchgavya (T₁₂).

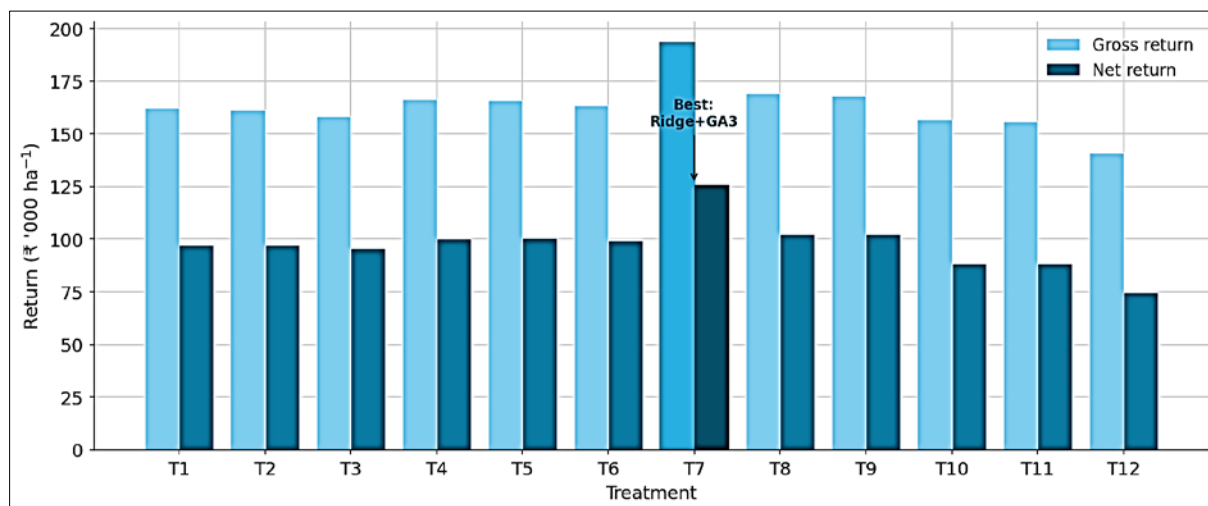


Fig 6: Gross and net return of quinoa as influenced by treatments.

The benefit-cost ratio reinforced this advantage (Fig. 7). The highest B:C ratio (1.85) was recorded under ridge sowing with GA₃ @ 100 ppm (T₇), clearly superior to all other combinations, followed by line sowing with Panchgavya (T₆) and ridge sowing with Panchgavya (T₉), each at 1.55. The lowest B:C ratio (1.13)

occurred under bed method with Panchgavya (T₁₂). The superior profitability of T₇ resulted from its ability to generate the maximum yield and gross return at a moderate increase in cultivation cost.

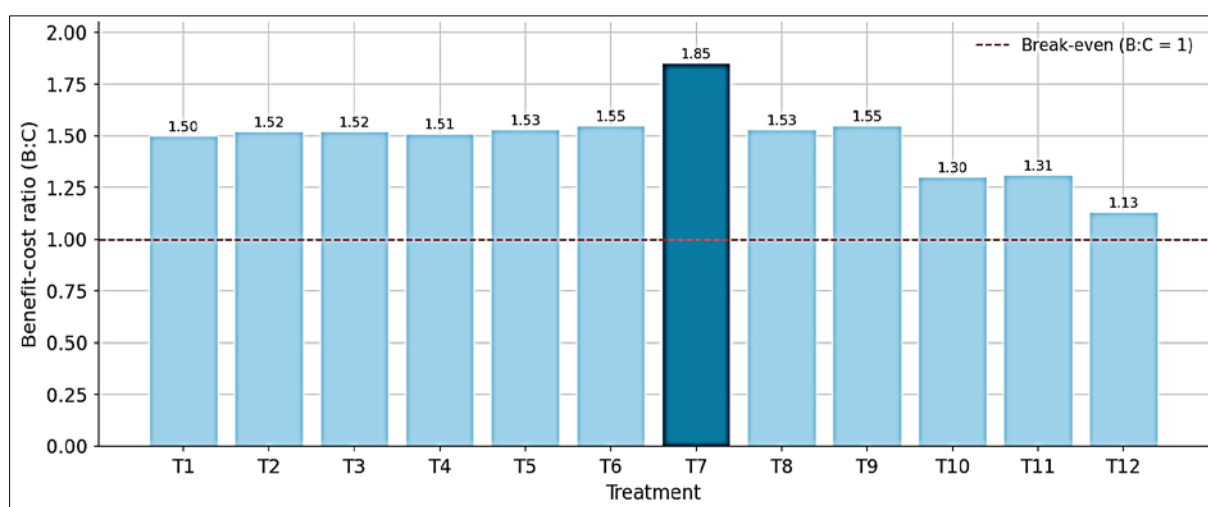


Fig 7: Benefit-cost ratio of quinoa as influenced by treatments.

Table 4: Economics of quinoa cultivation as influenced by treatment combinations

Treatment	Cost of cultivation (₹ ha ⁻¹)	Gross return (₹ ha ⁻¹)	Net return (₹ ha ⁻¹)	B:C ratio
T ₁ Broadcasting + GA ₃	64,850	1,62,192	97,342	1.50
T ₂ Broadcasting + Ascorbic acid	63,900	1,61,234	97,334	1.52
T ₃ Broadcasting + Panchgavya	62,800	1,58,313	95,513	1.52
T ₄ Line sowing + GA ₃	66,300	1,66,422	1,00,122	1.51
T ₅ Line sowing + Ascorbic acid	65,450	1,65,846	1,00,396	1.53
T ₆ Line sowing + Panchgavya	64,200	1,63,495	99,295	1.55
T ₇ Ridge sowing + GA ₃	67,800	1,93,528	1,25,728	1.85
T ₈ Ridge sowing + Ascorbic acid	66,900	1,69,252	1,02,352	1.53
T ₉ Ridge sowing + Panchgavya	65,700	1,68,104	1,02,404	1.55
T ₁₀ Bed method + GA ₃	68,200	1,56,712	88,512	1.30
T ₁₁ Bed method + Ascorbic acid	67,300	1,55,795	88,495	1.31
T ₁₂ Bed method + Panchgavya	66,100	1,40,870	74,770	1.13

4. Conclusion

The study demonstrated that planting technique and foliar-applied growth hormones significantly influenced the growth, yield and profitability of quinoa under Prayagraj conditions. Ridge sowing improved dry matter accumulation, crop growth rate and seed

yield, while GA₃ @ 100 ppm enhanced reproductive growth and grain filling. The combination of ridge sowing with foliar application of gibberellic acid @ 100 ppm (T₇) produced the highest seed yield (3.55 q ha⁻¹), net return (₹ 1,25,728 ha⁻¹) and benefit-cost ratio (1.85), and is therefore recommended as the

most productive and economically feasible practice for quinoa cultivation in the Prayagraj district. Being based on a single season, the findings may be confirmed through further multi-location and multi-season testing.

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