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# Standardization of optimal seed rate for maximizing seed yield, quality and economic efficiency in chickpea (*Cicer arietinum* L.)

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## Abstract
A field experiment was conducted during the *rabi* season of 2022-23 to determine the optimal seed rate for medium-seeded chickpea variety Jaki 9218. Various seed rates ranging from 80 to 100 kg/ha were evaluated for their effects on crop establishment, growth parameters, yield attributes, and economic viability. Results indicated that while higher seed rates (100 kg/ha) promoted greater plant stand establishment, earlier flowering, and increased plant height, they adversely affected individual plant productivity. The lower seed rate of 80 kg/ha demonstrated superior performance, yielding 25.68 q/ha compared to 22.26 q/ha at 100 kg/ha, representing a 15.3% increase in seed yield. Similarly, graded seed yield was significantly higher at 80 kg/ha (23.95 q/ha) than at 100 kg/ha (20.19 q/ha). Economic analysis revealed that the 80 kg/ha seed rate generated the highest net monetary returns (Rs. 2,20,418/ha) with a benefit-cost ratio of 2.94, substantially outperforming the 100 kg/ha treatment (Rs. 1,75,958/ha; B:C ratio 2.55). These findings conclusively demonstrate that a reduced seed rate of 80 kg/ha optimizes both agronomic performance and economic returns in chickpea seed production. Based on these results, 80 kg/ha is recommended as the optimal seed rate for medium-seeded chickpea variety Jaki 9218 under similar agro-climatic conditions.


**Keywords:** Chickpea, seed rate optimization, Jaki 9218, seed yield, economic viability, *rabi* season

## Introduction
Chickpea (*Cicer arietinum* L.) belongs to family Leguminosae and originated from north-west India constitutes the third most important food legume globally and dominates pulse production in South Asia, where it provides critical protein nutrition (20-25% protein content) to predominantly vegetarian populations (FAO, 2021). India accounts for 65-90% of global chickpea production, with annual output reaching 13.75 million tonnes from 10.91 million hectares during 2021-22, representing nearly 50% of the country's total pulse production. However, national average productivity (12.6 q $ha^{-1}$) remains substantially below the achievable on-farm potential of 40-50 q $ha^{-1}$, indicating significant scope for yield enhancement through improved agronomic interventions (Singh *et al*., 2021) [25].

Among various agronomic practices, seed rate is a key factor influencing plant population density, canopy architecture, light interception, nutrient uptake, and ultimately seed yield and quality (Meena *et al*., 2020; Sharma *et al*., 2020) [15, 21]. Plant population density, regulated primarily through seed rate manipulation, represents one of the most flexible yet critical management parameters directly controllable by producers. Seed rates fundamentally determine canopy development, light interception efficiency, radiation use dynamics, moisture utilization patterns, and nutrient acquisition, thereby exerting profound influence on both quantitative yield and qualitative seed parameters (Rao and Yadav, 2019) [18]. Lower seed rates (<80 kg $ha^{-1}$) result in poor canopy closure, increased weed infestation, and inefficient resource utilization, whereas higher seed rates (>100 kg $ha^{-1}$) lead to overcrowding, intense interplant competition for water, nutrients and light, poor grain filling, and higher susceptibility to pests and diseases (Kumar *et al*., 2019; Reddy *et al*., 2021; Sharma *et al*., 2021) [11, 19, 22]. The optimization challenge is further compounded by interactions between seed rate and row spacing, which collectively modulate yield attributes including pods $plant^{-1}$, seeds $pod^{-1}$, 100-seed weight, biological yield, and harvest index (Patel *et al*., 2021) [17].

In seed multiplication systems, seed rate optimization assumes dual significance: maximizing multiplication ratios while maintaining stringent seed quality standards for physical purity, germination capacity, and genetic integrity (Hampton, 2002) [9]. Research demonstrates that reduced seed rates enhance multiplication efficiency indicating it as a critical factor for rapid dissemination of newly released varieties through formal and informal seed chains. However, optimal seed rates are not universally applicable; they vary substantially based on cultivar morphology (growth habit, branching architecture, seed size), soil characteristics, moisture regimes, climatic parameters, and production objectives—grain production versus seed multiplication (Gaur *et al*., 2012; Ali and Kumar, 2006) [8, 4].

Published recommendations exhibit considerable variation (60-150 kg ha⁻¹), reflecting this complexity. Singh and Sekhon (2006) [26] demonstrated yield improvements with increasing seed rates from 30 to 50 kg ha⁻¹ in desi genotypes, though varietal responses differed significantly. Loria *et al.* (2022) [14] identified 75 kg ha⁻¹ as optimal for both seed yield and benefit:cost ratio under 30 cm row spacing. Conversely, machine-planted systems showed optimal yields at 105 kg ha⁻¹, despite superior nodulation and seed quality parameters at 52 kg ha⁻¹ (Yadav *et al.*, 2017) [29]. Similarly, Choudhary *et al.* (2022) [5] reported maximum seed yield at 100 kg ha⁻¹ seed rate under semi-arid conditions, while Sharma *et al.* (2020) [21] advocated 80 kg ha⁻¹ for optimizing seed production efficiency. These contrasting findings underscore the necessity for location-specific, context-dependent standardization.

Despite recognized importance, location-specific research addressing seed rate × variety × agro-climatic interactions remain limited, particularly for seed production systems where quantitative multiplication and qualitative parameters require simultaneous optimization (Ahlawat and Sharma, 2016) [2]. Given escalating certified seed costs and urgent requirements for rapid variety dissemination, establishing seed rates that balance multiplication efficiency, seed quality, and economic viability become imperative (Kumar *et al*., 2020) [12].

Therefore, this investigation was undertaken to evaluate differential seed rate effects on: (i) crop establishment and plant population dynamics, (ii) phenological development and growth parameters, (iii) yield components and productivity, (iv) seed quality attributes, and (v) economic returns under the agro-ecological conditions of Vidarbha region. The research aims to develop scientifically robust, economically viable, location-specific seed rate recommendations for chickpea cultivar Jaki 9218 that address the critical bottleneck of quality seed availability while enhancing chickpea productivity through improved seed production systems.

## Material and Methods

The field and laboratory experiment was conducted at the Research Field and State Notified Seed Testing Laboratory of Seed Technology Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth (Dr. PDKV), Akola, Maharashtra, during the *rabi* season of 2022-23. The field experiment was laid out in a Randomized Block Design (RBD) with five treatments (Table 1) and four replications, comprising a total of 20 experimental plots. Each experimental plot measured 5.0 m × 2.0 m (10 m²), with a total experimental area of 200 m². The experiment utilized chickpea (*Cicer arietinum* L.) variety Jaki 9218 (Desi type) as the test cultivar. The variety is characterized by a 100-seed weight (test weight) ranging from 21-23 g, which served as the basis for calculating treatment-specific seed requirements.

**Table 1:** Treatment details for seed rate optimization in chickpea variety Jaki 9218

| Treatment | Seed Rate (kg ha⁻¹) | Description |
|---|---|---|
| $T_1$ | 100 | Control/Recommended seed rate |
| $T_2$ | 90 | 10% reduction from recommended |
| $T_3$ | 80 | 20% reduction from recommended |
| $T_4$ | 70 | 30% reduction from recommended |
| $T_5$ | 60 | 40% reduction from recommended |

**Note:** The recommended seed rate for medium-seeded chickpea variety Jaki 9218 is 100 kg ha⁻¹, which served as the control treatment ($T_1$).

Seeds were sown directly in the field on November 2, 2022, at a uniform depth of 6-8 cm to ensure optimal germination and seedling establishment. A fixed row-to-row spacing of 30 cm was maintained across all treatments, while plant-to-plant spacing within rows was adjusted proportionally according to the respective seed rate to achieve the desired plant population density for each treatment. Seed quantity for individual plots was calculated based on the plot area (10 m²) and the prescribed seed rate, accounting for the 100-seed weight of the variety. Standard agronomic practices recommended for chickpea cultivation in the region were uniformly followed across all experimental plots. These included pre-sowing land preparation, application of recommended doses of fertilizers, need-based irrigation, integrated pest and disease management and weed control measures to ensure optimal crop growth and development under uniform management conditions, except for the variable seed rate treatments.

Observations on seed yield and its attributing characters i.e., field emergence, plant population/m², plant height at 30 DAS and at harvest, days to first flower initiation, days to 50% flowering, seed yield/plant, seed yield, 1000 seed weight, graded seed yield, seed quality parameters such as seed germination and vigour indices and pure live seed were recorded. Economics were worked out on existing market price of inputs and outputs. The germination test was performed on a total of 400 seeds, divided into four replications of 100 seeds each. These seeds were placed on germination papers (BP) that were adequately moistened and kept in a seed germinator at a temperature of 20 °C with a relative humidity of 90-95%. The seedlings were evaluated on the 8th day (ISTA, 2019). The length of ten randomly selected seedlings was measured, and the average seedling length was expressed in centimetres. The calculation of vigour Index-I and II was carried out using the formula suggested by Abdul Baki and Anderson (1973) [1].

Vigour index I = Standard germination (%) x Average seedling length (cm)

Vigour index II = Standard germination (%) x Average seedling dry weight (mg)

The experiment was conducted in a Factorial Completely Randomized Design for laboratory parameters as per standard method suggested by Panse and Sukhatme (1985) [16] and data observed was analyzed by using the online statistical tool i.e. OPSTAT (Sheoran, 2010) [23].

## Results and Discussion

### Crop Establishment and Growth Parameters

The experimental findings revealed that plant population density exhibited a progressive decline with decreasing seed rates, ranging from the highest establishment at 100 kg ha⁻¹ to the lowest at 60 kg ha⁻¹ (Table 2).

**Table 2:** Effect of differential seed rates on plant growth and seed yield attributes

| Treatment | Field emergence (%) | Plant stand establishment/ m2 | Days to first flowering | Days to 50% flowering | Plant height | | Seed yield/ plant (g) | Seed yield (q/ha) | Seed recovery (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | At 30 days (cm) | At harvest (cm) | | | |
| T1 | 93 | 40 | 36.00 | 53.48 | 26.93 | 60.68 | 09.14 | 22.26 | 90.72 |
| T2 | 91 | 34 | 35.56 | 51.52 | 26.00 | 59.04 | 10.42 | 23.09 | 91.52 |
| T3 | 92 | 31 | 35.76 | 47.94 | 25.03 | 57.49 | 13.06 | 25.68 | 93.21 |
| T4 | 90 | 27 | 35.37 | 50.06 | 25.41 | 54.63 | 12.41 | 23.90 | 92.44 |
| T5 | 93 | 23 | 36.03 | 49.45 | 22.75 | 54.59 | 12.22 | 18.43 | 91.58 |
| CV | 3.31 | 5.76 | 1.63 | 3.98 | 3.83 | 2.13 | 4.46 | 5.63 | 1.19 |
| CD (p=0.05) | NS | 2.74 | NS | 1.40 | 1.50 | 1.90 | 0.79 | 1.98 | NS |

**Table 3:** Effect of differential seed rates on seed quality and economic indicators

| Treatments | Graded seed yield (q/ha) | Test weight 1000 seeds (g) | Seed quality | | | Pure live seed | Net monetary returns | Benefit-Cost ratio |
|---|---|---|---|---|---|---|---|---|
| | | | Germination (%) | Vigor Index I | Vigor Index II | | | |
| T1 | 20.19 | 241.97 | 90.75 | 2658.89 | 69.42 | 88.93 | 175958 | 2.55 |
| T2 | 21.15 | 242.15 | 90.50 | 2537.26 | 70.81 | 88.69 | 186748 | 2.65 |
| T3 | 23.95 | 243.32 | 94.08 | 2699.01 | 74.55 | 92.19 | 220418 | 2.94 |
| T4 | 22.09 | 245.78 | 91.00 | 2541.31 | 68.72 | 89.18 | 197278 | 2.74 |
| T5 | 16.88 | 245.99 | 92.75 | 2570.34 | 72.36 | 90.89 | 126168 | 2.11 |
| CV | 5.92 | 0.51 | 1.94 | 4.90 | 3.87 | 1.90 | | |
| CD (p=0.05) | 1.92 | NS | NS | NS | NS | NS | | |

This proportional relationship between seed rate and plant stand is consistent with the fundamental principle that higher seeding rates result in greater plant density, provided germination percentage and field emergence conditions remain uniform across treatments (Singh *et al.*, 2018) [27]. Phenological observations indicated that days to first flowering and days to 50% flowering decreased marginally with reduction in seed rate. This trend can be attributed to reduced interplant competition at lower plant densities, allowing individual plants to access adequate resources for earlier reproductive transition. Plant height also exhibited a declining trend with decreasing seed rates, likely due to reduced apical dominance and etiolation effects that typically occur under high-density planting conditions where plants compete for light (Yadav *et al.*, 2017; Kumar *et al.*, 2019) [19, 11].

### Yield and Yield Components

A critical observation was the inverse relationship between seed rate and seed yield per plant. As seed rate decreased, individual plant productivity increased substantially, which can be attributed to reduced intra-specific competition, improved resource partitioning, and enhanced availability of photosynthetically active radiation, soil moisture, and nutrients per plant (Meena *et al.*, 2020) [15]. Lower plant densities facilitated greater lateral branching, increased pod-bearing nodes and improved assimilate translocation to reproductive sinks, thereby augmenting per-plant seed yield (Reddy *et al.*, 2021) [19].

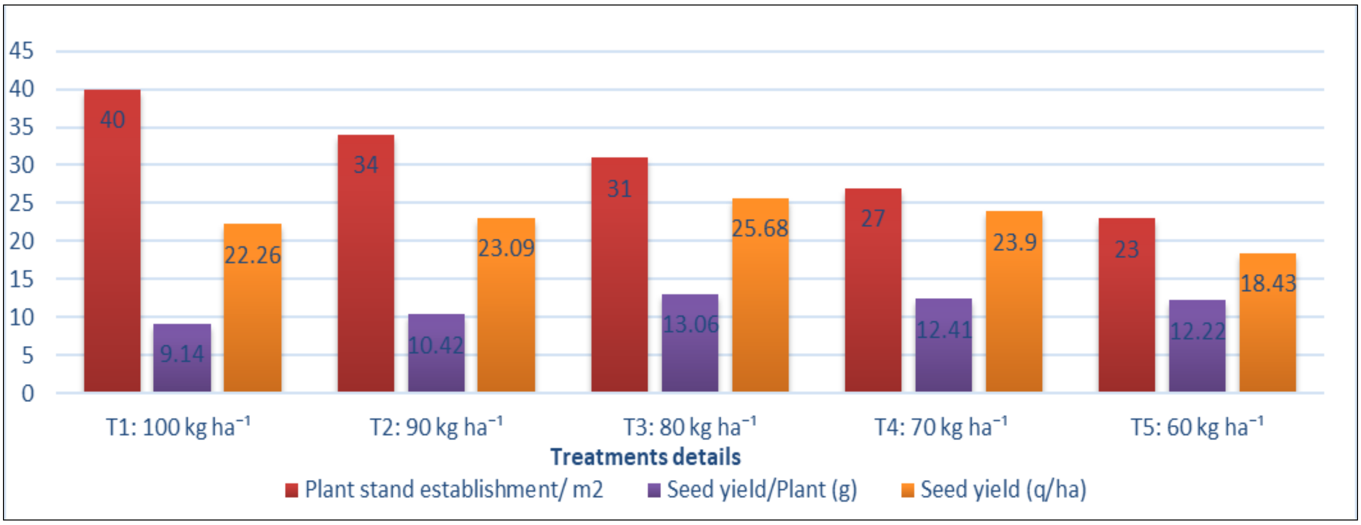


**Fig 1:** Seed yield attributes of chickpea as influenced by different seed rates.

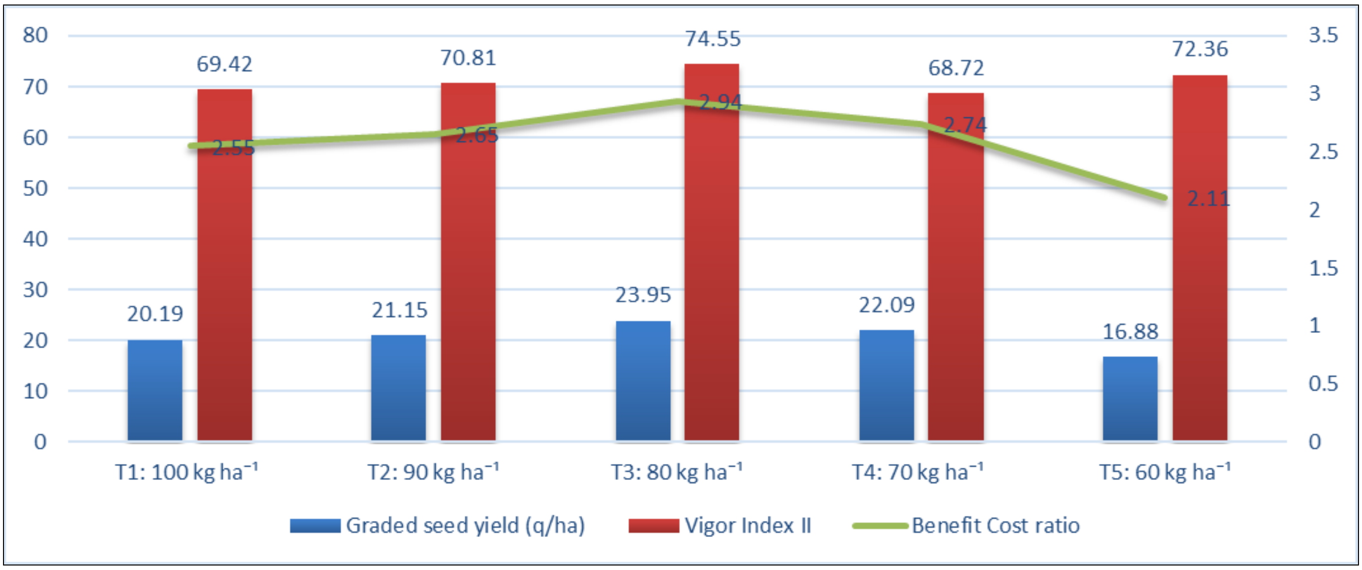


**Fig 2:** Seed quality and economic indicators by different seed rates

However, when translated to per-hectare basis, seed yield exhibited a curvilinear response to seed rate variation. The maximum seed yield (25.68 q ha$^{-1}$) was recorded at 80 kg ha$^{-1}$ seed rate, which was significantly superior to both higher (100 kg ha$^{-1}$) and lower (60 kg ha$^{-1}$) seed rates (Table 3). The yield declined to 18.43 q ha$^{-1}$ at the lowest seed rate of 60 kg ha$^{-1}$, indicating suboptimal plant population and underutilization of growth resources. On the contrary, the reduced seed yield at 100 kg ha$^{-1}$ can be attributed to excessive plant crowding, resulting in intensified competition for light, space, and nutrients, leading to increased barrenness, reduced pod set, poor grain filling, and diminished individual plant performance (Sharma *et al.*, 2021) [22]. These findings substantiate earlier reports by Khan *et al.* (2010) [3], who observed significant yield penalties with both excessively high (120 kg ha$^{-1}$) and low (60 kg ha$^{-1}$) seed rates in chickpea. Similarly, Lines *et al.* (2008) [13] reported that reducing seed rate by 20% (from 75 to 60 kg ha$^{-1}$) resulted in a 5% yield decline, while increasing it from 75 to 90 or 100 kg ha$^{-1}$ led to yield reductions of 9% and 15%, respectively. Chaudhary *et al.* (2022) [5] identified 80 kg ha$^{-1}$ as the optimal seed rate for chickpea cultivar GNG-1581, which aligns with the present findings for variety Jaki 9218.

Graded seed yield, representing the marketable quality seed fraction, followed a similar trend, with the highest value recorded at 80 kg ha$^{-1}$ (23.95 q ha$^{-1}$), which was substantially greater than that obtained at 100 kg ha$^{-1}$ (20.19 q ha$^{-1}$). This differential emphasizes the dual advantage of the intermediate seed rate in maximizing both total and marketable seed production.

**Seed Quality Parameters**

The 1000-seed weight exhibited a progressive increase from 241.96 g at 100 kg ha$^{-1}$ to 245.99 g at 60 kg ha$^{-1}$ seed rate (Table 3), although these differences were statistically non-significant. This trend reflects the principle of source-sink relationships, wherein lower plant densities allow greater assimilate availability per seed, resulting in marginally better seed filling and test weight (Gaur *et al.*, 2012) [8]. These results are in agreement with Khan *et al.* (2010) [3], who reported 100-seed weight ranging from 27.68 g to 30.15 g across different seed rates, with the highest value (30.15 g) observed at 75 kg ha$^{-1}$ and the lowest (27.55 g) at 120 kg ha$^{-1}$. Similarly, Sandhu *et al.* (2012) [20] demonstrated in kabuli chickpea that seed yield decreased with increasing seed size beyond 30 g per 100 seeds, suggesting an optimal seed size threshold for maximizing productivity.

Seed quality attributes including germination percentage, vigor index I, vigor index II and pure live seed percentage exhibited improvement with decreasing seed rates from 100 to 60 kg ha$^{-1}$ (Table 3). Enhanced seed quality at lower plant densities can be attributed to superior seed maturation, better nutrient accumulation in seeds, reduced disease and pest incidence and improved physiological seed quality resulting from optimal growing conditions (Hampton, 2002) [9]. Seeds produced under less competitive environments typically possess greater vigor, attributed to higher carbohydrate reserves, protein content and enzyme activity, which collectively enhance germination and seedling establishment potential (Copeland and McDonald, 2001) [6].

**Economic Efficiency**

Economic analysis revealed that net monetary returns were maximized at 80 kg ha$^{-1}$ seed rate (₹2,20,418 ha$^{-1}$), which was substantially higher than returns obtained at 100 kg ha$^{-1}$ (₹1,75,958 ha$^{-1}$) (Table 3). This superior economic performance at the intermediate seed rate resulted from the combined effect of higher graded seed yield and reduced seed cost investment. The benefit:cost ratio exhibited a similar trend, with the maximum value (2.94) recorded at 80 kg ha$^{-1}$ compared to 2.55 at 100 kg ha$^{-1}$. These findings demonstrate that the 80 kg ha$^{-1}$ seed rate offers the optimal balance between input costs and output returns, making it the most economically viable option for seed production enterprises (Loria *et al.*, 2022; Patel *et al.*, 2021) [17].

The economic superiority of 80 kg ha$^{-1}$ seed rate can be attributed to: (i) 20% reduction in seed cost compared to 100 kg ha$^{-1}$, (ii) 27% higher graded seed yield compared to 100 kg ha$^{-1}$, (iii) superior seed quality parameters enhancing market value, and (iv) improved seed multiplication ratio facilitating rapid variety dissemination. These factors collectively contribute to enhanced profitability and sustainability of seed production systems.

**Conclusion**

Based on the comprehensive evaluation of crop performance, seed yield, seed quality parameters and economic returns, it can be concluded that a seed rate of 80 kg ha$^{-1}$ is optimal for seed production of chickpea variety Jaki 9218 (with 100 seed weight of 21-23 g) under the agro-climatic conditions of Vidarbha region. This recommendation provides an effective balance between maximizing seed yield, ensuring superior seed quality and optimizing economic returns. The findings offer practical implications for seed production agencies and farmers engaged in certified seed multiplication programs, facilitating enhanced seed availability and accelerated varietal adoption in the region.

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